2021

U.PORTO

FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

ADAPTIVE PLANNING FOR COASTAL CLIMATE ADAPTATION IN PORT-CITIES: INTEGRATING ADAPTATION PATHWAYS INTO PLANNING INSTRUMENTS

SOFIA VALENTE VARANDAS DA ROCHA PAULA

TESE DE DOUTORAMENTO APRESENTADA À FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

ADAPTIVE PLANNING FOR COASTAL CLIMATE ADAPTATION IN PORT-CITIES

Integrating Adaptation Pathways into planning instruments

SOFIA VALENTE VARANDAS DA ROCHA PAULA

PhD Thesis

Doctoral Program in Spatial Planning

Supervisor: Professor Doutor Paulo Manuel Neto da Costa Pinho

Co-supervisor: Professor Doutor Fernando Francisco Machado Veloso Gomes

APRIL | 2021

PROGRAMA DOUTORAL EM PLANEAMENTO DO TERRITÓRIO | PDPT

PROGRAMA DOUTORAL EM PLANEAMENTO DO TERRITÓRIO – 2016/2017

DEPARTAMENTO DE ENGENHARIA CIVIL

SECÇÃO DE PLANEAMENTO TO TERRITÓRIO E AMBIENTE

Tel. +351-22-508 1903

Fax +351-22-508 1486

✉ pdpt@fe.up.pt

Editado por

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Rua Dr. Roberto Frias

4200-465 PORTO

Portugal

Tel. +351-22-508 1400

Fax +351-22-508 1440

✉ feup@fe.up.pt

http://www.fe.up.pt

Bolsa de Investigação PD/BD/128185/2016 financiada pela Fundação para a Ciência e a Tecnologia.

Acknowledgements

I would like to thank to:

My supervisor, Professor Paulo Pinho, for the guidance and assistance given, and for all for all teachings and knowledge transmitted throughout this research. His advice and suggestions were essential to improve my research. Professor Paulo Pinho has provided crucial inputs that helped to keep the whole research in the right course.

My co-supervisor, Professor Fernando Veloso Gomes, for his knowledge and experience, which were crucial to define the object of analysis of this research. For his support and for all ideas and suggestions given. During these years, I had the opportunity to learn a lot with Professor Veloso Gomes. I would also like to thank for supporting me in the publication of a scientific article.

CITTA - Research Centre for Territory, Transports and Environment, which welcomed me at its facilities and gave me the opportunity to learn about different topics in the field of spatial and urban planning during the 1st year of the PhD course.

Key-actors who participated in interviews, namely the spatial planning staff of the municipalities of Matosinhos, Gaia, Espinho, Cascais, Lisboa, Barreiro, and Sesimbra, and to the planning team of the Administration of the Leixões Port (APDL).

FCT- Portuguese Foundation for Science and Technology, FCT - Fundação para a Ciência e a Tecnologia. This research could not have been carried without the financial support of FCT, under research grant PD/BD/128185/2016.

My parents and sister for all their support and patience.

Abstract

The coastal zones of port-cities are particularly vulnerable to emerging coastal risks associated with the effects of climate change, namely sea-level rise (SLR), and anthropic pressures on coastal environments. As *risk-focci*, coastal port-cities are increasingly faced with the need to adapt to (manage) changing risks. In last decades, coastal climate adaptation – i.e. adaptation aimed at reducing emerging coastal risks (related with the effects of climate change), namely the risks of erosion, flooding and submersion – has evolved as a scientific field with an increasing body of knowledge and experience. Despite that, adaptation deficits are recognized in several coastal port-cities worldwide. The emerging coastal risks pose more complex challenges to the spatial planning and management of coastal zones: planning for coastal climate adaptation is marked by deep uncertainties about climate change, its effects (e.g. SLR), magnitude and pace, and by *wicked problems* (e.g. what adaptation measures should be applied). The deep uncertainties about future changes have led to the emergence of a new planning paradigm in recent years: Adaptive Planning. In the light of this paradigm, under uncertain future changes, a *dynamic adaptive plan* must be designed. Such plan should be *robust* (perform well under multiple plausible futures) and *flexible* / *adaptable* (it can be adapted as conditions change or new information arises). The Adaptive Planning paradigm contains several methodological approaches, namely the 'Adaptation Pathways approach' (APs). The APs involves exploring and sequencing several possible measures (adaptation / risk management measures) and designing various pathways. It has been advocated that Adaptive Planning approaches are useful to support coastal climate adaptation planning, however, there are still few real cases of application, and it is necessary to explore their applicability into planning instruments, e.g. coastal plans. The Portuguese context offers critical cases to assess the feasibility of applying Adaptive Planning approaches, as several scholars have called for an adaptive coastal planning and management.

With this framework in mind, this research aimed to analyse to what extent Adaptive Planning approaches, namely the 'APs approach', can be introduced and applied into planning instruments used in coastal zones of port-cities, as a tool to support coastal climate adaptation – its planning and implementation – under uncertainty about future changes. To respond to this objective, the research was divided in two parts. Part A addressed the two main examples (reference cases) of application of Adaptive Planning approaches for planning for coastal climate adaptation / coastal risk management purposes – the Thames Estuary Project 2100 (TE2100 Plan) in London, and the Dutch Delta Programme (DP2014) – to examine how an Adaptive Planning approach was developed and applied in each case, and what were the key-elements required to develop a *dynamic adaptive plan* and essential in the Adaptive Planning approach used. In Part B (Portuguese case studies), the research focused on two recently developed 'Programmes for the Coastal Zone' (POCs) (that encompass the coastal zones of the metropolitan areas of Porto and Lisbon); such POCs claim that they have adopted a novel approach of adaptive planning and management. Part B has assessed if each POC has applied an Adaptive Planning approach, and whether and how the key-elements necessary to develop a *dynamic adaptive plan* were met in each case.

The main elements essential in an Adaptive Planning (identified based on the European Reference Cases) are: 1) to work with a wide range of plausible future scenarios and assess measures and strategies under such scenarios, 2) to identify critical thresholds and tipping-points (conditions under which a given measure or system becomes ineffective or unacceptable), 3) to develop a 'robust and flexible' set of measures to deal with uncertain future change, by using the APs' approach; 4) to monitor relevant changes, Plan's effects and new information, and regularly reassess the Plan, and if necessary, adjust / adapt it (its strategies, measures or their timing); and 5) an ongoing circular process of (adaptive) planning and management, which is associated to a continual and long-term process of coastal climate adaptation and iterative risk management (that feeds back lessons and new knowledge into the planning phase, and facilitates Plan's adaptations / refinements.

The Portuguese cases were compared to, and assessed on, the key-elements of Adaptive Planning. Although the POCs intended to launch a new approach of adaptive (coastal) planning and management, they have not devised or applied a true Adaptive Planning approach, and, in general, the identified key-elements are absent. Finally, this work has identified barriers to and difficulties in applying Adaptive Planning approaches in the Portuguese cases are outlined. Notwithstanding, in the future, there may scope for introducing a real Adaptive Planning approach in the selected POCs, provided that the key-elements above-mentioned are accomplished.

Keywords: Adaptive Planning and Management, Adaptation Pathways, dynamic adaptive plans, dynamic robustness, flexibility, deep uncertainty, coastal climate adaptation.

Resumo

As zonas costeiras das cidades portuárias são especialmente vulneráveis a riscos costeiros emergentes associados aos efeitos das alterações climáticas, nomeadamente à subida do nível do mar, a das pressões antrópicas sobre os ambientes costeiros. Enquanto focos de risco, as cidades portuárias costeiras confrontam-se progressivamente com a necessidade de se adaptar a, e gerir, riscos crescentes. Nas últimas décadas, a adaptação costeira climática – i.e. a adaptação com vista a reduzir riscos costeiros emergentes associados aos efeitos das alterações climáticas, nomeadamente os riscos de erosão, inundação e submersão – tem evoluído como um campo científico em si mesmo, reunindo um crescente corpo de conhecimento científico e experiência prática. Apesar disso, são reconhecidos défices de adaptação em várias cidades portuárias costeiras a nível internacional. Os riscos costeiros emergentes colocam desafios mais complexos ao planeamento e gestão das zonas costeiras: o planeamento da adaptação costeira climática depara-se com profundas incertezas sobre as alterações climáticas e os seus efeitos (e.g. a subida do nível do mar), magnitude e ritmo, e com ‘problemas complicados’ (e.g. que medidas de adaptação devem ser aplicadas). As profundas incertezas sobre as futuras mudanças levaram à emergência de um novo paradigma de planeamento: o Planeamento Adaptativo. À luz deste paradigma, perante mudanças futuras incertas, deve ser desenvolvido um ‘plano adaptativo dinâmico’ que seja: *robusto* (i.e. que tenha uma boa performance num conjunto alargado de cenários futuros) e *flexível* / *adaptável* (i.e. que possa ser adaptado à medida que as condições mudam ou nova informação surge). Este paradigma contém várias abordagens metodológicas, nomeadamente a abordagem dos “Adaptation Pathways” (APs, trajetórias de adaptação). A abordagem dos APs implica explorar e sequenciar várias possíveis medidas (medidas de adaptação / gestão de risco) e desenhar diversas trajetórias. Tem sido defendido que as abordagens do Planeamento Adaptativo são ferramentas úteis para apoiar o planeamento da adaptação costeira climática, contudo, existem ainda poucos casos reais de aplicação, e é necessário explorar a sua aplicabilidade em instrumentos de planeamento, e.g. em planos costeiros. O contexto português oferece casos críticos para avaliar a viabilidade de aplicar abordagens de Planeamento Adaptativo, uma vez que vários autores têm apelado a um planeamento e gestão costeira ‘adaptativos’.

Considerando este quadro, esta investigação pretendia analisar em que medida abordagens metodológicas do Planeamento Adaptativo, nomeadamente o método dos Adaptation Pathways (APs), podem ser introduzidas e aplicadas em instrumentos de planeamento usados em zonas costeiras de cidades portuárias, como uma ferramenta para apoiar a adaptação costeira climática – o seu planeamento e implementação – em face de incerteza sobre futuras mudanças. Para responder a este objectivo, a investigação foi dividida em duas partes. A Parte A focou-se nos dois principais exemplos (casos de referência) de aplicação de abordagens de Planeamento Adaptativo para planear a adaptação costeira climática / gestão de riscos costeiros – o Thames Estuary Project 2100 (TE2100 Plan) em Londres, e o Delta Programme holandês (DP2014) – para examinar como é que uma abordagem de Planeamento Adaptativo foi desenvolvida e a aplicada em cada caso, e que foram os elementos-chave para desenvolver um plano adaptativo dinâmico e essenciais na abordagem de Planeamento Adaptativo usada. Na Parte B (estudos de caso em Portugal), a investigação focou-se em dois Programas de Orla Costeira (POCs) recentemente desenvolvidos que abrangem as zonas costeiras das áreas metropolitanas do Porto e Lisboa; estes POCs alegam que adoptaram uma nova abordagem de planeamento e gestão adaptativos. A Parte B avaliou se cada POC aplicou uma verdadeira abordagem de Planeamento Adaptativo, e se (e como) os elementos-chave necessários para desenvolver um *plano adaptativo dinâmico* foram cumpridos em cada caso.

Os principais elementos-chave essenciais num Planeamento Adaptativo (identificados com base na análise dos Casos de Referência europeus) são: 1) trabalhar com, e preparar-se para um conjunto alargado de cenários futuros plausíveis e avaliar a eficiência de medidas e estratégias nesses cenários, 2) identificar limiares críticos e tipping-points (condições nas quais uma determinada medida ou sistema se torna ineficiente ou inaceitável), 3) desenvolver um conjunto ‘robusto e flexível’ de medidas, para lidar com futuras mudanças incertas, usando o método dos APs; 4) monitorizar alterações relevantes, os efeitos do Plano e nova informação, e reavaliar regularmente o Plano, e, se necessário adaptar / ajustar o Plano (as suas estratégias, medidas, ou o seu timing); e 5) garantir um processo contínuo (circular) de planeamento e gestão adaptativos, associados ao processo de adaptação costeira climática continuado e de longo-prazo e à gestão interactiva de riscos (que fornece feedbacks e retorna à fase de planeamento e viabiliza as adaptações e refinamentos do plano).

Os casos portugueses foram comparados aos elementos-chave referidos, i.e. avaliados em relação a cada um dos elementos-chave de uma abordagem de Planeamento Adaptativo. Apesar da intenção dos POCs de inaugurar uma nova abordagem de planeamento e gestão costeira adaptativos, estes Programas não desenvolveram nem aplicaram uma verdadeira abordagem metodológica de Planeamento Adaptativo, e, de um modo geral, os elementos-chave identificados estão ausentes nos POCs. Finalmente, a investigação identificou barreiras e dificuldades em aplicar abordagens de Planeamento Adaptativo nos casos portugueses. Não obstante, no futuro, poderá haver margem para introduzir uma verdadeira abordagem de Planeamento Adaptativo nos POCs selecionados, na medida em que os elementos-chave mencionados sejam assegurados.

Palavras-chave: Planeamento Adaptativo, Gestão Adaptativa, Adaptation Pathways, planos adaptativos dinâmicos, robustez dinâmica, flexibilidade, profunda incerteza, adaptação costeira climática.

INDEX

1. Theoretical Framework: Adaptive Planning for Coastal Climate Adaptation in port-cities

PRELIMINARY NOTE

This theoretical framework covers three main subjects: the transformations of port-cities' coastlines, coastal climate adaptation, and Adaptive Planning. In addition, it focuses on the Portuguese context, to identify some of the main problems in coastal management / planning practices.

Port-cities, from early times, suffered profound mutations in their coastal environments, intrinsically associated with changes in shipping and port activity. The body of knowledge and literature on port-cities' waterfront transformations increased exponentially over the last six decades, drawing on numerous and diverse cases of waterfront redevelopment occurred in many port-cities across the world. However, in the literature and research in this field, there are still few studies and references to cases that have specifically addressed emerging coastal risks and vulnerabilities associated with the effects of climate change (namely sea-level rise) and continual human pressures on the coastal zones of port-cities. Despite the increasing recognition of coastal port-cities as risk-foci in terms of exposure to extreme weather-related events and emerging coastal risks, actually, few ports and neighbour cities have started to deal with, prepare or plan for such risks and for changes in the climatic and physical conditions of coasts. Generically, within the literature on waterfront redevelopments in port-cities, it has been given scarce attention to the topic of coastal climate adaptation.

Meanwhile, since 1990's, scientific knowledge and research in coastal climate adaptation – i.e. adaptation to the effects of climate change, namely sea-level rise, and continued human impacts on coastal areas, and which translates into actions or measures to reduce the vulnerability of coastal socio-ecological systems to emerging coastal risks related with such effects – have expanded and advanced. The effects of climate change, sea-level rise and ongoing / increasing human pressures on coastal zones, are expected to exacerbate existing coastal risks or create new ones (namely the risks of flooding, erosion, submersion etc.), during this century and beyond it (IPCC SR5 2014; Wong et al. 2014; Nicholls et al. 2007). These projections are foreseen for most coastal port-cities worldwide (Hanson et al. 2011; Becker et al. 2015), and pose more complex challenges to coastal management, urban and port planning. Planning for coastal climate adaptation presents intricate challenges to spatial planning research and practice. The deep uncertainties in the projection of climate change and sea-level rise and in the physical modelling of coastal changes, the difficulty in reaching a clear consensus on what adaptation exactly is and how it should be implemented, the complexity associated with the existence of multiple actors with competing visions and preferences for adaptation options, among other factors, make coastal management more difficult, and hamper a proactive planning and implementation of adaptation. Thus, coastal climate adaptation is often deemed a wicked problem (Moser et al. 2012; Brown et al. 2014). Importantly, adaptation should proceed as an ongoing iterative process of planning and implementation of adaptation measures, monitoring, evaluation, learning, and feeding back lessons into planning. In the meantime, climate change and human pressures already have, and will continue to have, adverse impacts on the coastal socio-ecological systems of port-cities, wherefore the adaptation of these systems is gaining a growing importance for research, for spatial, urban, and port planning, coastal management, disaster and risk management, policymaking, and governance (Becker et al. 2015; Lazarus et al. 2016). Although knowledge and experience in coastal climate adaptation have increased in the last decades, internationally, several adaptation scholars and researchers have been emphasizing an *adaptation deficit*

– i.e. a gap between the real adaptation necessities of coastal socio-ecological systems now and in the future, and the adaptation actions actually implemented (Preston et al. 2011; Eskstrom and Moser 2014). While the barriers that hinder the planning and implementation of adaptation actions have been reported in research and literature, the enablers of adaptation remain under-explored. However, to reduce the *adaptation deficits*, further research is needed both on barriers and enablers to overcome such barriers and / or facilitate adaptation responses. There is also a need to investigate how coastal climate adaptation has been or should be *mainstreamed* into spatial planning systems and instruments, at different scales.

Recently, and in face of deep uncertainties about future climate change and its effects, a new planning paradigm has emerged in the literature: *Adaptive Planning*. This paradigm provides several conceptual and methodological approaches for planning under uncertainty and complexity about future changes. In the light of this paradigm, plans should be able to be adapted to changing conditions over time or as new knowledge arises, so that they can *survive* change. In their whole, the Adaptive Planning approaches seek to enhance the adaptability of plans and their measures. Among such approaches, the Adaptation Pathways is an approach for exploring and sequencing several possible adaptation actions over time. The Adaptive Planning approaches have been advocated in climate adaptation research as promising and useful for supporting climate adaptation planning and decision-making in face of changing and uncertain future conditions related with future climate change, physical and environmental changes, socioeconomic, political, technological developments, etc. Such approaches have inspired recent developments in climate adaptation and have been applied in research cases and in a few *real* cases. However, further research is required to test these approaches in different contexts and policy domains (and for climate adaptation ends), namely in coastal regions, and into spatial planning and policymaking. The potential applicability of Adaptive Planning approaches, mainly of Adaptation Pathways, into planning systems and instruments, is still little explored, and, therefore, it merits further analysis.

The Portuguese context presents several critical cases in terms of vulnerability of its coastal port-cities: the continental west coast is exposed to strong hydrodynamic patterns, several urbanized stretches of the coastline are already subjected to severe erosion and to flood risk, coastal management instruments have been marked by a certain *rigidity* and inability to cope with climate change-related risks, and there are multiple barriers precluding a more effective coastal management. These situations have led some authors to call for a more *adaptive coastal management / planning*.

This theoretical framework is structured as follows:

Section 1.1 addresses the transformations of port-cities' coastlines and synthesizes the main dynamics shaping such mutations and relevant for adaptation planning.

Section 1.2 focuses on coastal climate adaptation: its definition, adaptation options available, recent evolution of adaptation research and practice, the *adaptation deficit*, barriers to adaptation, trade-offs between adaptation options, role, and challenges for spatial planning.

Section 1.3 reviews the family of Adaptive Planning approaches, as an emerging paradigm for planning climate adaptation under deep uncertainty and complexity about future conditions and changes.
Each of the three previous sections contains a final diagram summarizing the main gaps identified.

Then, Section 1.4 focuses on the Portuguese context, and identifies key-problems in coastal management.

Section 1.5 sums up the main knowledge gaps that this work addresses and niches for further research.

1.1. TRANSFORMATIONS OF THE COASTLINES OF PORT-CITIES

Scientific and non-scientific literature and research on port-cities' transformations, and particularly on waterfront redevelopments, have grown extensively since the 1960s. In many cases, port-cities experienced deep interventions in their waterfronts, either within port jurisdiction areas and / or adjacent urban zones. Such interventions usually fall under the umbrella of 'waterfront redevelopments'.

Throughout the 21st century, port-cities will not only face challenges associated with the contemporary dynamics of shipping and port sector, their globalisation and inter-competitiveness, and with the regeneration of cities' economies and reinvention of their identities and vocations (Merk 2013a; Warsewa 2006), but will also have to deal with the effects of climate change (namely sea-level rise) and continual human pressures on coasts, and consequent changes in the physical conditions of their coastal environments (Becker et al. 2015, 2011; Hanson et al. 2011; Reguero et al. 2013; USEPA 2008; Sousa and Prista 2012; Hallegatte et al. 2011). However, for many coastal port-cities worldwide, the precise effects of climate change and human pressures, the associated emerging coastal risks and their potential impacts on ports and adjacent urban seafronts and estuarine zones, are not yet fully understood nor considered in spatial, urban, and port planning (Reguero et al. 2013; Becker et al. 2011; USEPA 2008).

1.1.1. FREQUENT TOPICS IN THE STUDY OF PORT-CITIES' TRANSFORMATIONS

There is an extensive literature on the transformation of port-cities' coasts (including port and waterfront areas). Within this field, it is possible to identify several topics which are frequently addressed:

The relationship between port and city, and its evolution
The port / city relationship has been a recurrent thematic, with its evolution in space and in time being often represented in models or diagrams (Hoyle and Pinder 1980; Hoyle 1998, 2000a; Ducruet 2011). These studies often observe the interaction between port and city (mostly in physical and economic terms) and the successive changes of the symbiotic notion of port-city or city-port. It is often observed a transition from an intimate dependency (connection) towards a physical or functional separation between port and city (disconnection), and underutilization of port and near-water areas by ports, and their subsequent reuse for new urban uses (in a sequence from port fixation to development, industrialization, decline, de-industrialization, obsolescence, redevelopment of derelict port).

Within this subject, research has focused mostly on the functional and spatial separation process, often dismissing sustained links between port and city. Few studies have analysed how important the port is for the city, and vice-versa, using indicators of port-city interdependence, e.g. the proportion of port traffic consumed in the city, or the share of city's trade on maritime transport (Ducruet 2011). Further research is needed to grasp to which extent ports constitute an advantage for cities' economies, as some cities with declining ports have succeeded, while others with prosperous ports have struggled to be competitive (Merk 2013b). Ports often generate various benefits, but these tend to spill-over beyond city's limits, while many negative environmental impacts are localized, thus, there is a need for policies that increase local benefits and reduce negative impacts (Merk 2013b; Hein 2016b).

Port transformations
Some studies also analyse the port transformations, e.g. expansion works, port relocation, reorganization, restructuring, shrinking, out-migration of port-related industries, etc., and factors leading to them (e.g. technological shifts in shipping and cargo handling, de-industrialization of port-cities, land-use conflicts between port and city) to explain such changes (Bruttomesso 2009; Ducruet 2011; Guimarães 2006; Portas 1998). Since the 1960s, with the introduction of containers and new loading technologies, ports suffered major changes, which in some cases led to an obsolescence /

underutilization of port areas or surroundings, and, in other cases, allowed the redevelopment of waterfronts for new urban purposes.

Waterfront redevelopments

Other studies analyse port-cities' waterfront redevelopments – the plans and interventions – discussing their spatial and functional programs (including land and water uses), driving forces, underlying narratives, objectives, management models, financing schemes, planning rationales, involved actors, and outcomes (Bruttomesso 2009; Ducruet 2011; RETE 2011; Portas 1998; Guimarães 2006; Galland and Hansen 2012), and many compile several international cases. Waterfront redevelopments usually aim to re-establish relationships between city and water, release port / city tensions, and create new areas for urban uses and new public spaces for water fruition, seeking a mix of uses instead of mono-functionality. However, there may be additional motivations, such as real-estate pressures, political willingness to attract investment (by rising revenue, or exploiting waterside rents), urban marketing, beautification purposes, etc.

The study of waterfront transformations was traditionally informed by experiences in developed countries, and more recently by cases in developing countries that demonstrate different driving factors and spatial-temporal scales in such transformations (Hoyle 1998, 2000b; Alemany 2015a; Hein 2014; Wang 2014; Akhavan 2017; Pavia 2011). Importantly, whereas some port-cities pursue both port and urban waterfront redevelopment, others pursue only one of these goals, and others none (Hein 2014).

Critiques to the 'euphoria' of waterfront redevelopments and their benefits

There is a critical strand of analysis that distances itself from the celebratory tone of most literature on waterfront redevelopments, and focuses on the outcomes, successes, and failures of waterfront redevelopments. It usually criticizes the fragility of the slogans of sustainability, greenery, liveability, prosperity and public good often promoted, and highlights that some projects fall short of sustainability and equity intentions (Bruttomesso 2009; Shaw 2013; Bolleter 2014; Boland et al. 2016; Scoppetta 2016; Ducruet 2013b). Examples of negative effects include: reconversions of old port areas for solely urban uses with no relation with the character of the port-city, or marked by consumption and leisure activities that erase former port uses (due to an intense exploitation of waterfronts for commerce and recreational uses); poor physical integration between the new waterfront with the rest of the city; little provision of labour and maritime- or port-related activities; gentrification over jobs and housing; weak social integration and scarce public participation (which is seems to be the Achilles' heel of many of these projects). Ducruet (2011) argues that it necessary further interdisciplinary research to classify the diverse policies of waterfront redevelopment and their impact on spatial development, on cities' economy, on social structure, and on environment, and to categorize typologies and outcomes.

Some studies focus on the transfer of best practices of waterfront redevelopment between port-cities. Waterfront redevelopment projects usually present common features that mediate their 'worlding': they are often signed by star-system architects and circulate as 'trophies' across the world (Hein 2016c, 2014; Pavia 2011); they resort to similar management models, e.g. public-private or urban development partnerships (Shaw 2013); and despite their variations, they frequently host identical functional programs, e.g. housing, restaurants, malls, museums, aquarium, cruise terminal, near-water public spaces, etc. (Bruttomesso 2009). Some authors have criticized the excessive standardization of waterfront interventions, the de-contextualization, loss of local identity and disregard for place-specificities (e.g. historical or natural features); and call for movements beyond best practices and context-based waterfront planning (Diedrich et al. 2016; Bolleter 2014; Desfor and Laidley 2011), without completely erasing port activities and with less-ephemeral values (Bruttomesso 2009).

Recent global trends in port sector and shipping, and the globalization in port-cities

Some authors have analysed recent global trends in port sector and shipping, which are reshaping flows of goods (i.e. containers, bulk and oil), namely the demand for deeper waters, in response to the increasing draught and length of ships; for free plain areas for containers; and for good accessibilities; and the implications of this for cities (Merk 2014; Busquets 2013). Contemporary ports are subjected to similar norms and technological requirements, e.g. same depths or cranes, and many seek to adjust to Post-Panamax ships and Triple E vessels (the largest in the world) (Merk 2014). While the increasing size of ships is defined by private shipping companies, port infrastructures are often publicly funded, and some urban ports may be less suitable to receive mega-ships, or to undertake large land claims and dredging works required for modern offshore terminals or deeper channels (Merk 2014; Llaquet 2012).[1]

A usual theme is the globalization of port-cities (Ducruet and Lee 2006; Merk 2013a, b; Hein 2014). Maritime trade represents now 90% of global trade volume (Ducruet 2011). Some scholars have studied and mapped maritime trade routes across world seas (Ducruet 2013a). However, further research is required to examine: i) possible increases in maritime trade and traffic in certain regions due to socioeconomic changes, influence of oil shipping networks, the widening of Panama Canal and Suez Canal, increases in maritime traffic from Asia; ii) the creation of new routes, e.g. due to ice-melting in the Artic, their possible redundancy or new port hierarchies (Chapapría 2014, 2015). Moreover, it is necessary to analyse how new seaports that are built from scratch on cities' outskirts are reshaping prior natural areas (Hein 2016a, b). In addition, despite the rise of cruise-ship tourism, and although nature and culture are largely commodified in cruising, surprisingly, the environmental and socio-cultural heritage issues and problems (linked to cruising) are rarely discussed (Hein 2016a; Aguiar 2013).

The sustainability of port-cities

The sustainable development of port-cities seems to have become a 'fancy object' or a new imaginary of ports and cities, even when many port and waterfront transformations are far from meeting sustainability in environmental, social and economic terms (Blok and Tschotschel 2016; Bolleter 2014; Hein 2014; Hall 2007). Both port administrations and real-state driven waterfront projects have employed claims of sustainability, which may ultimately obscure their implications in unsustainable growth (Hall and Stern 2013). However, some recent narratives on ports' sustainability have arisen with the increasing demand for ports reducing emissions and with the introduction of environmental and mitigation policies in ports (Andrade and Sierra 2014; Chapapría 2014; http://www.greenport.com/). Apparently, the adoption of mitigation policies by 'green-ports' has led to increases in the use and production of renewable energies (ibid). Nevertheless, further research is needed on their real effects: so far, little is known about the effectiveness of green policies and cleaner technologies applied by ports, and regulations on greener shipping; there are few comparative analyses of ports' impacts on their territory (environment) and port-cities' environmental performance (ibid, Merk 2013b).

Some port associations and port-cities' associations have facilitated the exchange of guidelines for the sustainable development of waterfronts, by disseminating guidebooks, good practices or brochures. Usually, this type of guidance already addresses mitigation issues, but offers little or brief clues for adaptation to climate change effects. For instance, Cittá d'Acqua (2000) mentions the need to ensure the quality of water and land environments, and the need for continuous strategies of regeneration in a long-term integrative planning of waterfronts. AIVP (2015) identifies a few cases in which problems of spatial

[1] Some ports are even considering the possibility of establishing limits to their own physical growth and ways to optimize their lands, maximize their efficiency and minimize their environmental impacts. Spain, for instance, has developed plans such as the DEUP – Delimitation of Port Spaces and Uses, and IMP - Infrastructure Master Plan (used in the Port of Barcelona) (Llaquet 2012).

organization of coastal zones and environmental risks (namely the risk of coastal submersion, and problems of preservation of coastal biodiversity) were addressed in port-cities.

Importantly, research on medium port-cities of Southwest Europe, and on the spatial development of their littoral, has been reduced (Alemany and Bruttomesso 2015). However, such cities present several specific problems that merit analysis: the economic crisis, strong real-estate pressures on the coast until the end of the 20th century, which led to unsustainable and long-term negative effects; the debility of planning enforcement on coasts, an emphasis on short-term profits, etc. (Bordato and Sánchez 2015).

The vulnerability and resilience of port-cities

The resilience of port-cities has gained relevance, though the concept is often applied with different meanings (e.g. the capacity of ports to adjust to evolving shipping demands, or the ability of ports and cities to recover from natural disasters) (Hein 2015, 2016b; Schubert 2015; Shu and Qin 2014). From early times, port-cities' coasts have suffered mutations in their natural and built environments; ports and urban built form have often been adjusted in response to different kinds of change, namely economic, socio-political, or environmental changes (Hein 2014).[2] However, in port-cities, the built environment of water-land interfaces, which serves both production and consumption needs, and the capital fixed in it, are difficult to remove and 'anchor' many actors in these spaces, which makes their quick elimination hardly possible (Hein 2014). Hence, adjusting port-cities' physical, social and institutional structures to changing conditions takes time, and the physical adjustment is the slowest of all (Hein 2014). Although ports and cities traditionally responded to water-related disasters (e.g. storms, floods, etc.), their future planning must consider the needs of port and city in light of climate change and sea-level rise effects, across their whole coastline (Hein 2016a).

Gradually port-cities are appearing on the 'frontline' of risks related with climate change. The recognition of port-cities as at-risk communities has led to the transfer of climate-related policies among them (e.g. novel forms of eco-cities, green / blue / eco-urbanism, green cooperation), but further research is needed to assess if such policies are prompting sustainable trajectories (Blok and Tschotschel 2016).

Some studies have documented post-disaster reconstructions of waterfronts of port-cities drawing on the cases of New Orleans after Hurricane Katrina (2005) and New York after Hurricane Sandy (2012) (Scoppetta 2016; Giovinazzi 2015; Giovinazzi and Giovinazzi 2008). In her critical analysis, Scoppetta (2016) argues that, in New Orleans, environmental risks were better dealt with in the 19th century than in the post-Katrina reconstruction (in which tax breaks were given to business and housing investments in areas damaged by the hurricane). For her, sustainability and resilience are often used as rhetorical terms that disguise unequally distributed costs and benefits. Despite the growing evidence of climate change, economic growth gains in political agendas, in detriment of the ecological and social pillars of sustainability (Scoppetta 2016).

Other studies report that not even the increasing signs of the vulnerability of port-cities' waterfronts to coastal risks have slowed down urban development in at-risk areas (Chemrouk and Chabbi 2016). In other cases, scholars have documented a lack of long-term land-use regulations to reduce climate change-related risks in port-cities' waterfronts, and call for more proactive disaster-risk reduction measures in spatial planning (Bautista et al. 2015).[3] (see also Note 1, Annexes).

[2] Importantly, the creation of wealth has been the main driver for such works, e.g. due to shipping demands. Port engineers, elites and citizens developed an ability to adjust the physical environment (on water and land), and long experience in controlling water or orientating water, e.g. through updates in architecture or docks to withstand floods, dredging of waterways, creation of canals, artificial islands (Hein 2014).

[3] Port-cities' coastlines are quite valued, but highly dynamic environments. Due to their particular exposure to climate change and sea-level rise effects, and their dependence on coastal resources, coastal port-cities constitute valuable cases for analysing long-term compromises between economic growth of ports and cities, risk-reduction, and coastal climate adaptation.

Impacts and conflicts on port-cities' coastal environments

The impacts of port and waterfront redevelopments on coastal environments – i.e. physical and environmental impacts – have also been studied (Bunce and Desfor 2007; Desfor and Laidley 2011; Llaquet 2012; Pearson et al. 2016). Coastal port-cities are major sources of impacts, both as consumer centres and as producers of adverse effects, e.g. generated by ports, port-related activities, coastal societies, especially middle-upper classes (Boschken 2013). The water-land interfaces of port-cities are prime examples of the ways in which inseparable human and biophysical processes have (re)produced socio-nature, however, it has been dedicated little attention to the social and biophysical vulnerabilities resulting from port and urban waterfront redevelopments (Desfor and Laidley 2011). Waterfronts are often seen as prior problematic spaces that became opportunity-spaces, with scarce analysis of tensions between social and natural systems, and conflicts arising from their transformation at several scales, and between multiple actors. However, both port or urban waterfront transformations have often implied intense human interventions on environment, mainly on water bodies and land formations, and thus, they are no longer untouched or pristine natural places, but highly modified places (Bunce and Desfor 2007). (For more on human interventions within waterfront transformations, see Note 2, Annexes).

Port and adjacent coasts concentrate multiple uses that are prone to conflicts, e.g. land and water uses, and uses of coastal natural resources. However, research on such conflicts (and informing management practices) has been scarce. There are still few studies analysing: a) conflicts in ports and adjacent coastal zones (namely environmental conflicts, conflicts among users with different risk perceptions and values, or conflicts between management modes); b) how such conflicts are solved (Pearson et al. 2016).

Coastal climate adaptation in port-cities

Over the 21st century, port-cities will not only face challenges related with the contemporary dynamics of port sector and shipping (e.g. globalisation, competitiveness between ports), and the regeneration of cities' economies (Merk 2013a; Warsewa 2006), but they will also have to deal with the effects of climate change, sea-level rise and continuing human pressures on coasts, and consequent changes in the climatic and physical conditions of their coastal environments (Becker et al. 2015, 2011; Hanson et al. 2011; Reguero et al. 2013; USEPA 2008; Sousa and Prista 2012). However, for many coastal port-cities across the world, the precise effects of climate change, sea-level rise and human pressures on coasts, and the emerging coastal risks and their potential impacts on ports and adjacent urban seafronts and riverfronts, are not yet studied neither considered in spatial, urban and port planning, and thus, they deserve further research (Reguero et al. 2013; Becker et al. 2011; USEPA 2008).

Moreover, there are deep uncertainties about how the emerging coastal risks (related with the effects climate change, sea-level rise, and human pressures), and their potential impacts, should be adequately dealt with and managed over time, in order to ensure the security, functioning and a more sustainable development of ports and coastal zones of port-cities (Reguero et al. 2013; Hanson et al. 2011).

Nevertheless, the adaptation of port-cities' coastlines (namely of port terminals) to the effects of climate change and sea-level rise has attracted a growing attention in recent years (Becker et al. 2015, 2011; Reguero et al. 2013; Sousa and Prista 2012; Hanson et al. 2011). Ports and port-cities are located in areas highly sensitive to the effects of sea-level rise, e.g. low-lying coastal zones and estuarine zones. The recent global rankings of port-cities in function of their exposure to climate change-related risks and extreme events (Hanson et al. 2011; Nicholls et al. 2008), the projections of impacts of sea-level rise and storm-surges for specific port-cities (Hallegate et al. 2011), and international surveys on ports' perceptions of climate change effects and on their efforts to enhance their resilience (Becker et al. 2011, 2015), have all contributed to raise awareness about the need for climate adaptation in port-cities, within scientific community and decision-making realms. This topic is discussed in more detail in Section 1.2.

1.1.2. Ports and cities, and their non-integrated approaches to coastal waters and lands

Port-cities' coastlines have often been intensively redesigned, recreated and reshaped by humans, either for shipping or urbanization purposes. The redesign and functionality of port-cities' water-land interfaces have been analysed by scholars of diverse disciplines, e.g. architecture, planning, engineering. However, coastal waters and lands acquire different values and functions for each discipline: some studies focus on port uses, port engineering and management, whereas others focus on urban, recreational, and symbolic functions and on the value of water proximity (Hein 2016a). Hence, each discipline often addresses individual aspects. The role of water as a connector between port and city and diverse areas along the coastline – i.e. an element that links natural forms, landscapes, jurisdictions – is often disregarded in literature on port-cities (Hein 2016a).[4] In addition, the functional and physical separation of port uses from near-water urban uses has led to little conversation between those who study and plan ports and urban waterfronts (Hein 2016a). Urban studies and port studies, their planning scholars and professionals, rarely address the redesign of waterfronts and ports in an integrated manner, i.e. not separately. As Hein (2016a) emphasizes, *contemporary interventions occur mostly independently from each other and do not consider water as an encompassing entity*.

Ports and cities are usually interested in different uses of coastal waters and lands, and adopt sectoral views and segregated approaches to the design of water-land interfaces (Hein 2016a). While ports profit from coasts for commercial uses and transform water-land interfaces to optimize their efficiency, cities seek coasts for the valorisation of urban environment, leisure and residence (Hein 2014). Therefore, ports and cities frequently dismiss how water, with its different uses and attributes, represents a shared valuable resource, but also a risk in face of climate change and sea-level rise effects on coasts, which demands joint and coordinated actions between them (Hein 2016a).

Despite the growing recognition of interconnected water systems and relations between port dredging and the need of infills alongshore, and the emerging interest in new forms of flood protection (e.g. super dikes, floating cities, green or blue urbanism, waterside parks, etc.), in general, the study of such issues has been detached from planning theorization (Hein 2016a). As rising sea levels threaten many port-cities worldwide, ports and cities are increasingly pressed to develop innovative ideas to reduce the risks of flooding and submersion. The Rising Currents exhibition led by the Museum of Modern Art in New York is an example of an initiative that addressed problems posed by sea-level rise in a port-city (MoMA 2011; Aerts and Botzen 2011), but a more thorough investigation on this topic is missing (Hein 2016a).

In this sense, Hein (2016a) calls for an *integrated planning of port, waterfront, port-city, in conjunction with a comprehensive study of the environmental and ecological role of water in each of those places, as a resource they share, and, with climate change, a risk to which they must collectively respond*. In the context of climate change and sea-level rise, the planning of port and urban waterfronts requires greater collaboration and coordination between public and private actors, and holistic and interdisciplinary approaches to coastal vulnerabilities (Hein 2016a). Despite the common challenge that emerging coastal risks pose to ports and port-cities, so far, joint, integrated and coordinated responses (between port and city) have been rare (Hein 2016a). More broadly, there is a generalized lack of integrated approaches to the planning and management of coasts (i.e. coastal waters and lands), articulating port and city actors (Hein 2014). However, this integrated planning is increasingly needed to respond to climate adaptation needs (and to effectively reduce emerging coastal risks) throughout the city, port, their coastlines, and neighbour coastal regions at a metropolitan scale (Hein 2016a; 2014).

[4] The interconnecting character of coastal waters, lands and ecosystems that surround ports and urban waterfronts has rarely been studied, though these issues are often addressed in natural coastlines (Hein 2016a).

The historical mutations of port-cities' coasts also hold lessons for the future: usually port terminals are developed by private companies, with little articulation with larger urban or regional planning; some port authorities (and some waterfront redevelopment projects) have disregarded long-term impacts of their interventions on the environment; comprehensive planning approaches including ports' and cities' actors in the planning of water-land interfaces have been rare (Hein 2014); and in general, the economic factors continue to be the main drivers of port and urban waterfront planning (Hein 2016b).

Besides that, few scholars are working on missing links between urban planning and port planning (Hein 2016a). The spatial segregation between ports and cities was accompanied by an academic and administrative compartmentalisation (Hein 2016a; Merk 2013b), and recent forms of port governance seem dissociated from urban governance (Hall 2007). Knowledge on port-cities is often fragmented or specific, not comprehensive, and not relevant for spatial planning and policymaking (Merk 2013b).

Finally, there are still few cases and references evidencing that processes of transformation of port-cities' waterfronts were used to tackle coastal climate adaptation needs. It is important to investigate examples in which adaptation issues are already being dealt with in port and urban waterfront planning.

1.1.3. Further research on conflicts, risks, and complex problems, in port-cities' coasts

There is a need for more systematic analyses on: a) conflicts, risks and impacts on ports and adjacent coasts; b) mitigation and adaptation solutions planned or implemented in different port-cities worldwide; and c) current conflict- and risk-management practices (Pearson et al. 2016). Recognizing conflict as a characteristic of ports and nearby coasts, Pearson et al. (2016) indicate several specific topics (or *domains of conflict*) that merit further investigation:

- the increasing vulnerability of valuable / productive coastal environments to climate change effects;
- environmental degradation problems and difficulty in sustaining the ecological integrity of coastal ecosystems, e.g. tensions between governments' conservation efforts and intense shore urbanization; loss of coastal ecosystems' services due to land claim for ports or urban areas;
- incompatibilities between uses of the coast and of its resources, benefiting some / excluding others;
- complex management problems with nested scales (spatial or temporal scales), e.g. issues crossing harbour-urban-marine-rural frontiers, or marked by uncertainty in environmental changes and risks;
- governance problems, e.g. overlapping jurisdictions, asymmetrical powers and roles, weak governance, lack of enforcement of regulations and environmental policies in ports and coasts;
- the definition of standards for controlling the environmental quality in ports and nearby coasts, and the ecological status of coastal ecosystems; and the evaluation of outcomes of environmental management responses used by city and port authorities, against the desired goals.

Pearson et al. also suggest possible methods for research on complex problems and risks on ports and adjacent coasts: 1) conflict matrices (often used by coastal managers to detect incompatibilities between uses and assess resources' status, but such tools need to be fitted to inform planning and risk-management); 2) DPSIR approach (i.e. analysis of *Drivers*, *Pressures*, *States*, *Impacts and Responses*) and enabling more strategic and operational decisions; 3) robust risk assessments and tools to explore scenarios and desirable futures (instead of a single probability); 4) participatory processes engaging researchers and actors in the identification of solutions, and integrating knowledge from biophysical and human sciences, i.e. interdisciplinary and actionable knowledge; and 5) an *adaptive approach* with a learning focus, which is linked to an *adaptive management*, and which is crucial to better manage environmental problems and risks in ports and coasts. However, building the institutional capacity to ensure such *adaptive management* will be a serious challenge for many port-cities (Pearson et al. 2016).

Diagram 1 sums up the main gaps found in the literature on the transformations of port-cities' coastlines.

TRANSFORMATIONS OF PORT-CITIES' COASTLINES (1.1)

Main topics analysed	Relationship port and city, and its evolution: from dependence to spatial separation (Hoyle 1998, 2000a; Ducruet 2011; etc.)	Port transformations, due to changes in shipping and port activity (Bruttomesso 2009; Ducruet 2011; Portas 1998; etc.)	Waterfront redevelopments (Bruttomesso 2009; Ducruet 2011; Portas 1998; Guimarães 2006; Hoyle 1998, etc.)	Critiques to the 'euphoria' of waterfront redevelopments and their benefits (Shaw 2013; Diedrich et al. 2016, etc.)	Recent global trends in port sector and shipping; globalization in port-cities (Merk 2014, 2013a, b; Ducruet 2013a, etc.)	Sustainability of port-cities; slogans and policies for sustainable development, their effects) (Bolleter 2014; Hall and Stern 2013; etc.)	Vulnerability and resilience of port-cities to environmental changes (Hein 2015, 2016b; Scoppetta 2016; Giovinazzi 2015; etc.)	Human impacts on port-cities' coasts (Bunce and Desfor 2007; Desfor and Laidley 2011; Pearson et al. 2016; Llaquet 2012)	Coastal climate adaptation in port-cities (ports and coasts) (Becker et al. 2015, 2011; Reguero et al. 2013; Hanson et al. 2011; etc.)
Gaps identified	Research has focused on the spatial separation process, disregarding sustained links between port and city (i.e. *how important the port is for the city, and vice-versa*), port-city interdependences (Merk 2013b; Hein 2016b; etc.)	Water as a *connector* between port and city, and their coasts, is often ignored in literature; little conversation between those who study and plan port and urban waterfronts. Integrated planning approaches (ports + cities) are rare (Hein 2016a)	Ports and cities often disregard how water represents a shared valuable resource, but also a risk (in face of climate change and sea-level rise), which demands joint and coordinated actions between them (Hein 2016a)	Calls for further research to classify the diverse policies of waterfront redevelopment: their impact on spatial development, cities' economy, social structure and environment, and categorize outcomes (Ducruet 2011)	In face of the demand for deeper waters (due to the growing size of ships), some urban ports may be less suitable to receive megaships, or to undertake large land claims and dredging for off-shore terminals (Merk 2014; Llaquet 2012)	Little is known on the effectiveness and outcomes of *policies* for sustainable development adopted by ports. Scarce policies dedicated to climate adaptation; greater emphasis on policies for mitigation of pollutant emissions, of energetic consumption	Despite evidences of climate change effects, economic growth gains, over social and ecological sustainability (Scopeta 2016; Chemrouk and Chabbi 2016); lack of land-use regulations to reduce climate-related risks in waterfronts (Bautista et al 2015)	Research on conflicts, informing management is scarce. Few studies on: environmental conflicts, conflicts among users with distinct risk perceptions; how conflicts are solved (in ports and nearby coasts) (Pearson et al. 2016)	In many port-cities, the effects of climate change and sea-level rise, and related emerging coastal risks for ports and urban coasts, are not yet grasped, nor addressed, in urban and port planning (Reguero et al. 2013; Becker et al. 2011; etc.)
	Further research on missing links between urban and port planning. Knowledge on port-cities is often not relevant for planning and policy-making (Hein 2016a; etc.)	Joint and coordinated responses to emerging coastal risks related with climate change and sea-level rise, between port and city, have been nearly absent. Ports and cities often adopt segregated approaches to the planning / management of coastal waters and lands. However, an integrated planning will be needed to deal with emerging coastal risks across city and port coastlines (Hein 2016a; 2014)		Economic factors have been the main drivers of port and urban waterfront planning (Hein 2016b). Little inclusion of local citizens in waterfront planning (Hein 2014)	Little attention to social and bio-physical vulnerabilities resulting from port and urban waterfront redevelopments (Desfor & Laidley 2011; Llaquet 2012; etc.)	There are still few cases and references evidencing that processes of redevelopment of ports and cities' waterfronts were used to address coastal climate adaptation needs.	It is necessary to further investigate cases in which coastal climate adaptation issues are already being dealt with in the planning of port and adjacent urban coastlines.	Calls for: a more *adaptive management* and a learning focus, for dealing with environmental problems and risks in ports and nearby coasts (Pearson et al. 2016)	Further research on: how changing climatic and physical conditions of coasts + emerging coastal risks, can be dealt with in the planning of port and urban coasts (Reguero et al 2013; etc.)

Topics and gaps with relevance for this research.

Diagram 1. Main topics analysed and gaps identified in 1.1.

1.2. Coastal Climate Adaptation

1.2.1. Drivers of change and increasing risks: climate change, human pressures, and their effects on coastal zones

Among the drivers of change and risk on coastal zones that are related with climate change, and which are already being felt and will likely be felt in the coming decades, the following should be enhanced (IPCC SR5 2014; Wong et al. 2014; Nicholls et al. 2007):

- sea-level rise (SLR), namely global mean sea-level rise, relative sea-level rise (i.e. regional variations of SLR), and increases in extreme sea levels experienced during extreme events, e.g. storm surges, and due to mean sea level rise;
- changes in precipitation patterns, and changes in extreme weather and climatic events in several regions, e.g. increases in warm temperature extremes, heat waves, droughts, increases in the number of heavy precipitation events;
- increases in air temperature and increases in ocean temperatures [5];
- possible (although still uncertain) modifications in storm patterns (i.e. in the intensity, frequency and routes of storms);
- increased CO_2 concentration in seawater, and ocean acidification (i.e. lower pH of seawaters), with negative impacts for coral reefs and other organisms.

Due to SLR, coastal areas are expected to increasingly experience coastal flooding, erosion and submergence, during this century and beyond it (IPCC SR5 2014; Wong et al. 2014). In addition to SLR, which is deemed the main climate change-related driver of change and risk on coasts, the population and assets exposed to coastal risks, and human pressures and impacts on coastal ecosystems, are expected to increase significantly in next decades, due to demographic growth, socioeconomic and urban development (IPCC SR5 2014; Wong et al. 2014), and thus, such factors will also drive changes and risks on coasts.

Climate change effects, and SLR in particular, will exacerbate risks that already exist for coastal natural and human systems, and / or create new ones (IPCC SR5 2014), namely the risks of flooding, erosion, permanent submersion, rising water tables (i.e. rise in groundwater levels and impeded drainage), saltwater intrusion into surface and ground-waters, *coastal squeeze* (i.e. the narrowing or total loss of coastal ecosystems and land areas, associated to the inland movement of shoreline with SLR), degradation of coastal habitats, and negative biological effects (Wong et al. 2014; Linham and Nicholls 2010; Nicholls 2011), which will be particularly relevant for coastal cities.[6]

Different coastal systems will respond differently to climate change effects and related risks (Linham and Nicholls 2010). Coastal risks are interconnected with each other, and result from complex and combined interactions between climate change effects, natural climate variability / processes, and anthropogenic pressures. Such risks do not affect coasts uniformly, but vary according to topography, sediment supply and transport, geology, hydrodynamic processes, wave patterns, presence and type of

---

[5] The increases in sea temperatures lead to changes in species and ecosystems, namely increased coral bleaching and mortality, shifts in species ranges and distribution, decline in the extent of saltmarshes, mangroves and seagrasses (Wong et al. 2014); as well as changed circulation, reduced incidence of sea ice at higher latitudes, pole-ward migration of species, increased algal blooms (Nicholls et al 2007).

[6] The main biophysical impacts of SLR are: increasing flood damage, loss of dry-lands (SLR contributes to erosion and submersion), wetland loss and changes, saltwater intrusion, rising water tables and reduced run-off in lowlands (Wong et al. 2014; Nicholls et al. 2007). Coastal urban areas are also exposed to other climate-related risks, such as: extreme precipitation, inland flooding, heat stress (growing frequency and intensity of heat waves), air pollution, water scarcity, drought, etc. (IPCC SPM 2014). In Europe, increases in extreme rainfall are projected to further increase the risks of coastal and river flooding and flood damages, e.g. increased economic losses and people affected by flooding in coasts and river basins, particularly during peak river discharges (IPCC IAV 2014). SLR will likely reduce the return periods of extreme inundations, and higher subterranean waters may cause instability of structures located on coasts (Wong et al. 2014).

defences, and adaptive capacity of socio-ecological systems.[7] Thus, coastal systems are subjected to both human-related and climate change-related drivers of change and risk, as well as to natural climate variability. For many coastal changes and risks, climate change-related drivers are difficult to detach from human-related drivers (Wong et al. 2014) (**Figure 1**).

Anthropogenic drivers of change and risk on coasts (i.e. human pressures on coastal ecosystems) often arise from: increasing or continual socioeconomic and urban development on coastal zones; coastward migration; coastal urbanization or industrialization, and associated land use changes (e.g. motivated by aesthetical and recreational attractiveness of coasts, growing mobility, favourable taxes or insurance schemes, etc.); changes in sediment delivery (mainly reduction)[8]; changes in run-off; land reclamation; pollution; excessive input of nutrients from rivers and waterways into sea; and hypoxia[9]. The effects of human pressures on coastal ecosystems are often very difficult to separate from the effects of climate change and natural processes (Wong et al. 2014) (see more in Note 2).

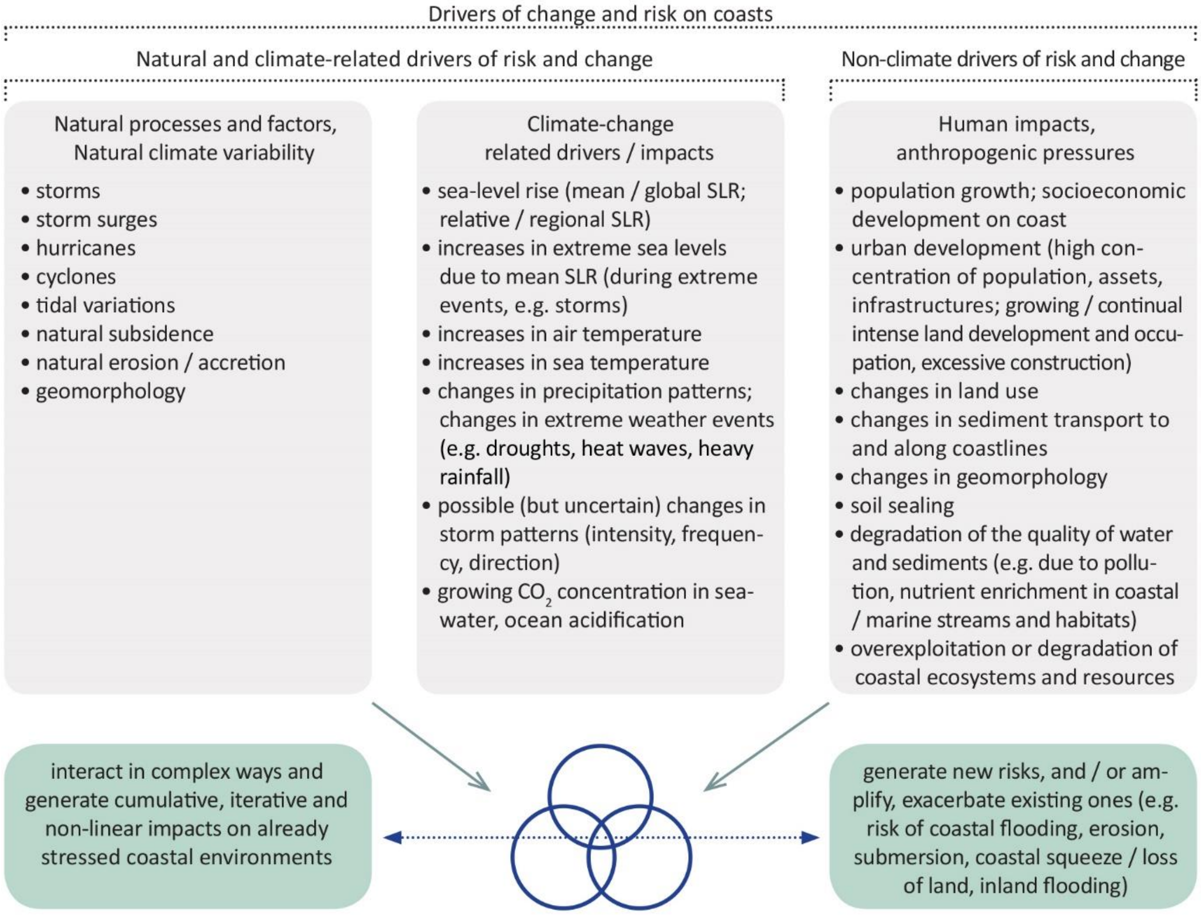


Figure 1. Drivers of change and risk on coasts. Source: own elaboration based on the literature reviewed.

[7] Both the rate of RSLR and coasts' declivity will influence the rate of landward movement of the shoreline, and the degree of submersion. Shallower coastal slopes (like estuaries) will experience greater shoreline recession. In different coastal settings, SLR might trigger, for instance, inland migration of coastal habitats, submersion of low-lying lands, cliff erosion (Linham and Nicholls, 2010). Shoreline changes are also influenced by several interacting factors, e.g. sediment supply and transport, engineering structures, wave patterns, etc. (Wong et al. 2014).

[8] Human activities in rivers, drainage basins and coastal plains have impacted coasts by changing the delivery of sediments. Sediment trapping behind dams, water diversion, sand and gravel mining in river channels, all contribute to reduce sediment delivery (Wong et al. 2014). Human withdrawals of water and the construction of dams on rivers have had significant impacts on natural water and river flows (IPCC IAV 2014).

[9] The presence of excessive nutrients in coastal waters causes eutrophication and decomposition of organic matter, and it leads to decreased oxygen concentration – i.e. hypoxia (Wong et al. 2014).

Hence, coastal ecosystems (i.e. dunes, beaches, reefs, saltmarshes, wetlands, etc.) suffer cumulative non-linear impacts from human, climatic and natural drivers. However, human pressures often affect coastal ecosystems' integrity, resilience, functions, and services (Nicholls et al. 2007), raising serious problems to cities with high levels of interference in these systems, such as port-cities. Regardless of the importance of climate change, humans have been the main drivers of change of coastal ecosystems (Nicholls et al. 2007)[10], and are expected to further exacerbate their pressures (Wong et al. 2014). One of the most visible expressions of the cumulative impacts is *coastal squeeze*, which affects many urbanized coasts worldwide. In the presence of hard structures parallel to shoreline, and with erosion[11] and SLR, coastal ecosystems are prevented to naturally migrate inland and become squeezed. The deterioration or loss of coastal ecosystems leaves human settlements more vulnerable, since such ecosystems provide multiple services (e.g. they act as buffers against storm and wave impacts) (ibid).

In synthesis, the interactions between climate change effects (namely SLR), natural climate variability and human pressures put coastal cities at risk. As their cumulative impacts become more apparent – through, for example, more frequent, expanded or deeper coastal floods, aggravated erosion, greater *coastal squeeze*, degraded natural defences, damages to infrastructures – coastal adaptation will gain greater relevance (Linham and Nicholls 2010). Even if CO_2 emissions were reduced to zero, sea levels will continue to rise for the next centuries, which makes adaptation in coastal areas indispensable (Wong et al. 2014).[12] This long-term commitment to SLR implies a long-term commitment to adaptation.

Nevertheless, there are still important knowledge gaps in the comprehension of the processes that induce changes and risks in coastal systems (related to climate and human drivers, and their complex interactions), and in the projection of SLR and its impacts (Wong et al. 2014). Risk and vulnerability assessments for coastal zones still need to be improved, which implies further consideration of interactions between natural and human sub-systems, and more inter-disciplinary approaches targeted at highly vulnerable areas (e.g. high-density coastal cities, populated deltas, port-cities), and also at the at scale of physiographic units (e.g. coastal cells, estuaries) (Nicholls et al. 2007) (Note 3).

1.2.2. Coastal port-cities as 'risk-foci'

Coastal and estuarine cities are often densely populated, highly dynamic areas, seen as 'hotspots'. These cities are increasingly vulnerable to emerging coastal risks, due to the combined potential effects of climate change, SLR, population growth, urban pressures, soil subsidence (Jeuken et al. 2014, p.4, 2). In the main port-cities of the world, the exposure of population and assets to coastal risks is expected to increase exponentially during this century, due to the combined effects of SLR, population growth, socioeconomic development, and urbanisation (Hanson et al. 2011; Nicholls et al. 2008) (Note 4). Ports are usually located in highly vulnerable and risk-sensitive areas. The past impacts of extreme weather events (e.g. hurricanes, cyclones, storm surges, typhoons, strong storms, winds, swells, thunderstorms)[13] felt in some port-cities, namely in their ports, coastal urban settlements, infrastructures, economic activities, etc., demonstrate the pertinence of improving the preparation of port-cities to climatic variability and changes in the physical conditions of coasts (Wong et al. 2014). The need to locate port

---

[10] In the 20th century, direct impacts of human activities on coasts were more significant than impacts of climate change (Nicholls et al. 2007).

[11] At global scale, shorelines have, in general, undergone net erosion over the last century. Multiple natural and human-related drivers (e.g. decreased sediment delivery, subsidence, river damming) contribute to coastal erosion (Wong et al. 2014).

[12] Recent estimations indicate that with present global warming, there is already a commitment to 1.3m SLR above current levels. Since IPCC SR4 (2007) several studies have projected SLR, all expecting a growing exposure in low-lying coastal zones (Wong et al. 2014). The inevitability of SLR will likely collide with current patterns of urban development on coasts and challenge the viability of many coastal settlements worldwide (Nicholls et al. 2007). Coastal adaptation will gradually become indispensable and emphasize the need of finding new forms of reducing the vulnerability of coastal socio-ecological systems and enhancing their adaptability to changing risks (Wong et al. 2014).

[13] Several extreme weather events occurred in the last decade in port-cities illustrate the potential impacts on ports and coastal urban areas, e.g. Hurricane Katrina in Mississippi ports, Sandy in New York port and city (Wong et al. 2014), Storm Cynthia in France (Nicholls 2011).

terminals on coasts will remain due to shipping requirements, thus, the consideration of climate change effects in port planning, and through their life cycle, will be crucial (Wong et al. 2014). However, so far, there are few assessments of the risks and potential direct and indirect impacts on ports and adjacent coastal areas, on mid- / long-term scales (Wong et al. 2014) (for some exceptions see e.g. USEPA 2008).

Due to SLR, ports are likely to suffer impacts on their infrastructures and activities, namely: the reduction of the freeboard (i.e. height available above sea level) of platforms and breakwaters, problems of navigability under bridges, on water accesses, port entrances. Moreover, possible changes in storm patterns could cause alterations in waves' direction and incidence, and in sediment transport (Reguero et al. 2013). On their whole, these impacts may entail increasing damages in ports and protection works, delays in port operations, and difficulties in managing dredging works.

Climate change and SLR (and the associated risk of coastal flooding) may generate localized effects on ports, but also on port-cities' waterfronts (e.g. seafronts, estuarine zones, their built and natural environments, public spaces, critical infrastructure), on mortality, human health (Reguero et al. 2013). Furthermore, port-cities might be affected by indirect impacts on port-dependent sectors, supply chains, energy redistribution, shipping lanes; on the concentration of population and assets on coasts, and on coastal economic activities like tourism, trade, leisure, fishing, agriculture, industry (Wong et al. 2014). Overall, the vulnerability of port and coastal urban areas to floods will be exacerbated with SLR, which might cause worse or more frequent damages and disturbances on port-cities.

Although port-cities are important *risk-foci*, the precise effects of climate change, SLR and human pressures, and the associated emergent risks that ports and port-cities might experience, remain under-researched. Further investigation is necessary to understand how these risks will affect ports and adjacent urban coasts, and on the best ways to tackle them and ensure their secure functioning and a more sustainable development (Reguero et al. 2013). Port authorities have been more focused on the mitigation of pollutant emissions and energetic consumption than on adaptation (Wong et al. 2014). Nevertheless, some ports have shown interest in understanding: how extreme climatic events will change and affect them (e.g. variations wind speed, the probability of changes in storm patterns); how much sea levels will rise; what modifications might be required in port terminals, protection works, risk management, monitoring, maintenance, insurance, workforce, technology, height of platforms and drainage systems (Scott et al. 2013). Some ports have contracted risk assessments. The most urgent concern of ports is often related with the need to elevate the height of port infrastructures as a first measure to tackle SLR; and in some cases, this need is already considered in the construction of new port facilities or updates to existing ones (Sousa and Prista 2012), e.g. in Singapore port (land claims), Norfolk Marine Base in USA; Tokyo port; Langosteira Port (Coruña, Spain). Some ports have begun to adopt norms and codes that consider the emerging risks in the design of ports and coastal defences (Reguero et al. 2013). However, in general, many ports worldwide have not yet prepared for the effects of SLR and climate change (USEPA 2008). The changing and future climatic and physical conditions of coasts need to be further considered in risk assessments, in the planning and management of ports and adjacent coastlines, at regional and local scales (Reguero et al. 2013).

In sum, further research is required to understand how emerging coastal risks might affect port-cities, and how such risks can be appropriately managed in the planning and management of ports and nearby coasts. Climate change and SLR already have and will continue to have adverse impacts on the coastal socio-ecological systems of port-cities, wherefore their adaptation – i.e. the reduction of their vulnerability and the enhancement of their adaptability and responsiveness – will gain an increasing importance for scientific research, spatial and port planning, coastal management, policy-making, governance, disaster and risk management (Becker et al. 2015; Lazarus et al. 2016). In port-cities, to adapt the port and urban coastal zones to changing climatic and physical conditions will be essential to maintain the economies of cities and regions that such spaces sustain (Hanson et al. 2011).

1.2.3. THE CONCEPTS OF 'CLIMATE ADAPTATION' AND 'COASTAL CLIMATE ADAPTATION'

Climate adaptation is now conceptualized as the process of adjustment of human systems, natural systems, or both, to actual or expected *climate* (i.e. anthropogenic climate change and natural climate variability), and its effects, and it aims to reduce or avoid climate-related risks and harm, or exploit beneficial opportunities. In the case of natural systems, human interventions intend to facilitate the adjustment of such systems to climate change effects (IPCC SR5 2014). According to the 4th IPCC Report, adaptation involves *initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects* (IPCC SR4 2007). While adaptation can reduce risks related with climate change, there will be limits to its effectiveness, especially with greater rates of human-induced climate change (IPCC SR5 2014).[14]

Adaptation to climate change involves taking actions to reduce climate change-related risks or to take advantage of opportunities from climate change. Hence, adaptation measures aim at reducing risks or adjusting an activity to account for the effects of climate change. There are also adaptation measures that address barriers hindering individuals or organizations from adapting (HM Treasury 2009, p.8).

Climate adaptation is also seen as a means for enhancing resilience – the capacity of systems (human or ecological) to deal with risks and hazards, by answering, absorbing disturbances, reorganizing and maintaining their essential functions, identity and structure. Despite the growing interest in the concept of resilience, which can be perceived from the perspectives of psychology, engineering or ecology, planning systems tend to privilege the psychological and engineering dimensions. Usually, there is a great difficulty in moving from recommendations to the implementation of this notion, which runs the risk of being politicized instead of becoming a dominant feature of coastal socio-ecological systems. To overcome this gap, scholars call for further understanding of human-environment interactions and socio-ecological dimensions of resilience (Flood and Schechtman 2014; Nicholls 2011) (Note 5).

Coastal climate adaptation, in its turn, involves measures, strategies or solutions to reduce coastal risks, lessen or avoid potential adverse impacts (and the vulnerability to coastal hazards), or bring benefits, to coastal human and / or ecological systems (Wong et al. 2014; Nicholls 2011). It encompasses technologies, scientific and practical knowledge, techniques, tools, equipment, approaches, practices, and capacities (e.g. institutional, technical, financial capacities), which are applied to minimize coastal risks, mainly the risks of flooding, erosion and submersion[15] (Wong et al. 2014; Nicholls 2011). Adaptation options can be engineered solutions (physical / structural measures), planning strategies, risk management schemes, management tools, legal instruments, regulations, designs, financial schemes, etc. Generically, coastal climate adaptation translates into a wide set of actions, including societal and institutional measures to implement and reassess adaptation and its results (Note 6).

For the purpose of this work, coastal climate adaptation is understood as the process of adjustment of socio-ecological systems to the effects of climate change, human pressures, and natural climate variability, on coastal zones; it includes measures, strategies or actions that aim to reduce, avoid, moderate or manage emerging / changing coastal risks associated with the effects of climate change

[14] Furthermore, adaptive capacity is the ability of human, institutional and natural systems to adjust to potential effects of climate change, to answer to adverse impacts, or take advantage of opportunities (IPCC SR5 2014). Adaptation to climate is not a new practice, societies and individuals have long adjusted to climate variability, extremes and changing environmental conditions, but with varying degrees of success (IPCC SR5 2014; Burton 2004). However, the current climate adaptation is different from the old practice of human adjustment to a climate often seen as stationary: it deals with a climate that is changing at faster rates due to anthropogenic interference (Burton 2004). Adaptation can contribute significantly to the well-being and security of people, maintenance of ecosystems, their functions, and services, and to safeguard assets (IPCC SR5 2014). However, greater rates of climate change will increase the likelihood of exceeding limits to adaptation (which arise from interactions among climate change, biophysical and socioeconomic constraints) (IPCC SPM 2014).

[15] Usually, coastal adaptation options focus on the risks of flooding, erosion and submersion, as these are main impacts associated to SLR on coasts. Technologies to cope with rising water tables, saltwater intrusion, biological impacts are less developed (Linham and Nicholls 2010).

(e.g. SLR) on coasts – namely the risks of coastal flooding, erosion, submersion – and their potential adverse impacts for socio-ecological systems.

1.2.3.1. COASTAL CLIMATE ADAPTATION: TYPOLOGIES AND OPTIONS

Coastal adaptation options are usually systematized in three main typologies, according to the terminology disseminated by the IPCC since 1990: *protection* (*hard* or *soft*), *accommodation*, and *retreat* (Dronkers et al. 1990; Wong et al. 2014; Nicholls 2011; Linham and Nicholls 2010; Hoepffner et al. 2006; Veloso-Gomes et al. 2006a; Griggs 2005)[16] (**Table 1**, and **Figure 2**).

Coastal adaptation approaches					Level of experience	
Typology	Main objective	Shoreline management		Adaptation option	Developed countries	Developing countries
Protection	Increase robustness + Enhance preparedness	Hold-the-line (the existing coastline, or the line of defences)	Hard Protection	Seawalls	High	High
			Hard Protection	Dikes	High	High
			Hard Protection	Storm surge barriers	Medium	Low
			Hard Protection	Closure dams	High	High
			Soft protection	Beach nourishment	High	Medium
			Soft protection	Artificial sand dunes	High	Low
			Soft protection	Dune rehabilitation	High	Low
		Advance the line		Land claim	High	High
Accommo dation	Enhance flexibility + Increase preparedness	Flood zones occupied, but in different ways; improved capacity to deal with floods		Rising elevation	Medium	Medium
				Flood proofing	Medium	Medium
				Flood hazard mapping	High	High
				Flood warning systems	High	High
				Land use changes	Medium	Med / High
				Floating agriculture	Low	High
	Revise mal-adaptation	Conservation		Wetland restoration	High	Low
Retreat	Improve adaptability + Enhance preparedness	Retreat / relocation / removal / 'give space to water'		Planned retreat / setback	Med	Med
				Managed realignment	Med / high	Low
				No active intervention	Med / high	Med / High

Table 1. Coastal adaptation typologies and main options. Source: Adapted from Linham and Nicholls 2010.

[16] Veloso-Gomes et al. (2006b, p.114-120) developed several alternatives for adaptation planning for coastal urban settlements (i.e. for a hypothetical case of seafront urban settlement, drawing on case of an at-risk urban settlement in Northwest Portugal – Furadouro).

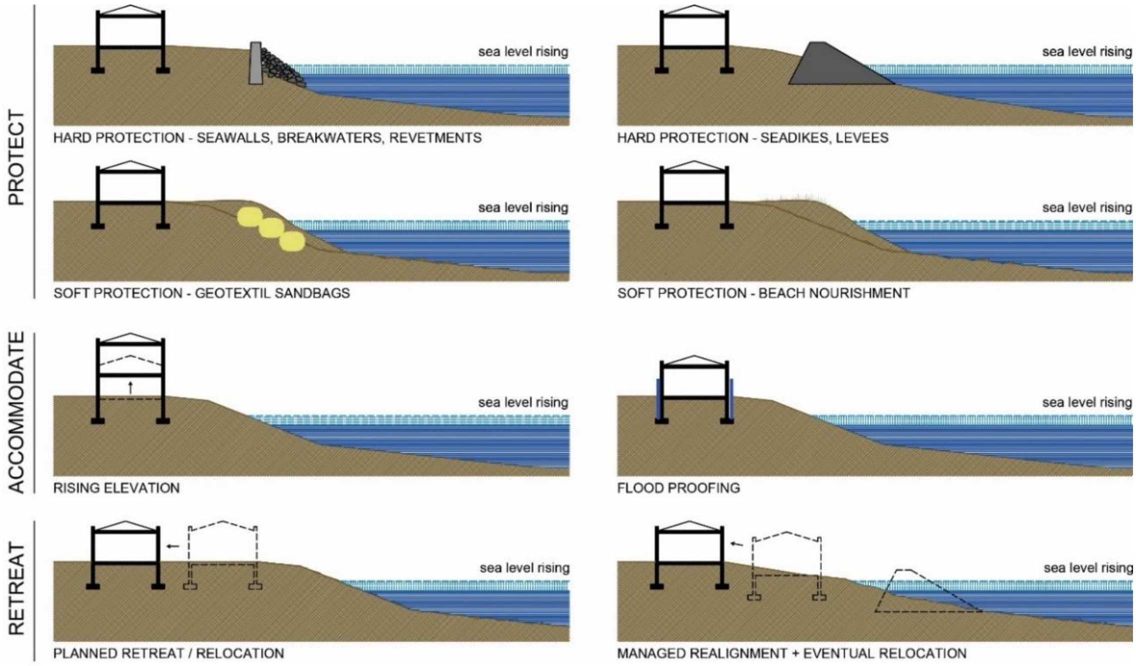


Figure 2. Coastal adaptation options. Source: own elaboration, adapted from several authors.

Protect options seek to hold the existing line, i.e. existing coastline or line of defences. Protection includes: hard defences (e.g. seawalls, dikes, storm surge barriers, flood levees); soft defences (e.g. beach nourishment, dune rehabilitation, artificial dunes); and land claim / reclamation, which implies advancing the existing line. Protect solutions are typically applied to defend vulnerable valuable or dense urban areas, critical infrastructure and properties. They have been traditionally preferred, driven by societal desire to build close to / on coasts, and use their resources.

Accommodate options usually entail measures such as: adjustments or modifications of building codes to waterproof standards, flood-hazard mapping, flood warning systems, flood-resistant agricultural systems, etc. Generally, accommodation enables that vulnerable zones continue to be occupied and used, but it requires the acceptance of a greater degree of flooding and the recognition that some values located on coasts may change, as well as improvements to human ability to cope with floods, e.g. by adjusting construction methods, changing land uses, enhancing preparedness, etc. These measures include: new regulations requiring physical changes to buildings or infrastructures (such as rising the elevation of buildings or infrastructures, e.g. rising houses on pillars), information systems to increase awareness of coastal risks and enable coastal populations to prepare beforehand, improvements to storm-water management and waste-water drainage systems, adjustments to critical infrastructure (namely electricity plants, grids or bridges), building storm shelters, etc.

Retreat options imply proactive and planned withdrawal from the coast. Retreat options include: *managed realignment* (i.e. the removal or breaching of existing hard defences, allowing the inland migration of wetlands or the creation of intertidal habitats), and *planned retreat* (also called *coastal setback*, it involves the relocation of built assets, infrastructures and residents out of at-risk areas, or the total removal of built forms). Retreat aims to reduce the risks of coastal flooding and erosion, and it may be the only viable option when nothing else is possible.

In sum, the most appropriate adaptation measure depends on several factors (e.g. physical attributes, environmental and socioeconomic values of a certain coastal zone) and some combinations of these three approaches may be the most adequate response; and the selected measures should be reviewed over time (Wong et al. 2014; IPCC SR5 2014). The three main typologies of coastal adaptation are usually embedded into institutional measures, plans, policies, laws, regulations, adopted by national or subnational governments, e.g. land-use or coastal management plans (see Note 7).

1.2.3.2. Coastal climate adaptation as a *wicked problem*

In coastal areas, the management of the adaptation process is challenging and intricate, due to:

- The existence of complex interactions and non-linear dynamics in coastal social-ecological systems;
- Deep uncertainty in climate and SLR projections and predictions of coastal changes (Wong et al. 2014); ongoing uncertainties and difficulties in the evaluation of causation in complex multi-component processes that embrace physical, biological and human systems (IPCC SR5 2014);
- Different visions on how to deal with SLR (*pessimists* versus *optimists*) (Nicholls 2011);
- Lack of consensus on what exactly adaptation is, and lack of agreement or ambiguity about how adaptation should be implemented and progress (Wong et al. 2014; Moser et al. 2012);
- The presence of multiple actors with different, often conflicting values, visions, interests and preferences for adaptation options (Wong et al. 2014; Moser et al. 2012);
- Complex decisions and situations implied in coastal adaptation actions, which are associated with potential large consequences, long timeframes, and numerous climatic and non-climatic influences that change over time, and across multiple scales and contexts (IPCC SR5 2014);
- Numerous management goals for coasts. As Nicholls (2011) notes, *coastal management needs to consider the balance between protecting socioeconomic activity and human safety and the habitats and ecological functioning of the coastal zone under rising sea levels*. During the last century there were large losses of coastal habitats (direct and indirect destruction), even though most countries seek protect their coastal ecosystems and their services (Nicholls 2011).

Although in some countries coastal management practices already show successes in adaptation to multiple stresses and risks on coasts, the environmental changes underway and expected pose more intricate challenges ahead. These challenges are particularly difficult in coastal port-cities, due to high concentration of people, assets and critical infrastructures (e.g. ports) in low-lying zones, and their inability to shift to other places, great societal dependence and impacts on coastal resources and ecosystems (which often are strongly degraded), the existence of overlapping jurisdictions, policies and regulations on coasts (under port or urban administration) (Wong et al. 2014) (Note 8).

Therefore, coastal adaptation is often connoted as a *wicked problem* (Wong et al. 2014; Moser et al. 2012), and planning for coastal climate adaptation is deemed a multi-scalar and interdisciplinary problem, which crosses disciplines of natural and social sciences and engineering (Nicholls 2011). Coastal adaptation involves decision-making in a changing world, with ongoing uncertainty about the severity and timing of climate-change impacts (IPCC SPM 2014) (Note 9) (**Figure 3**).

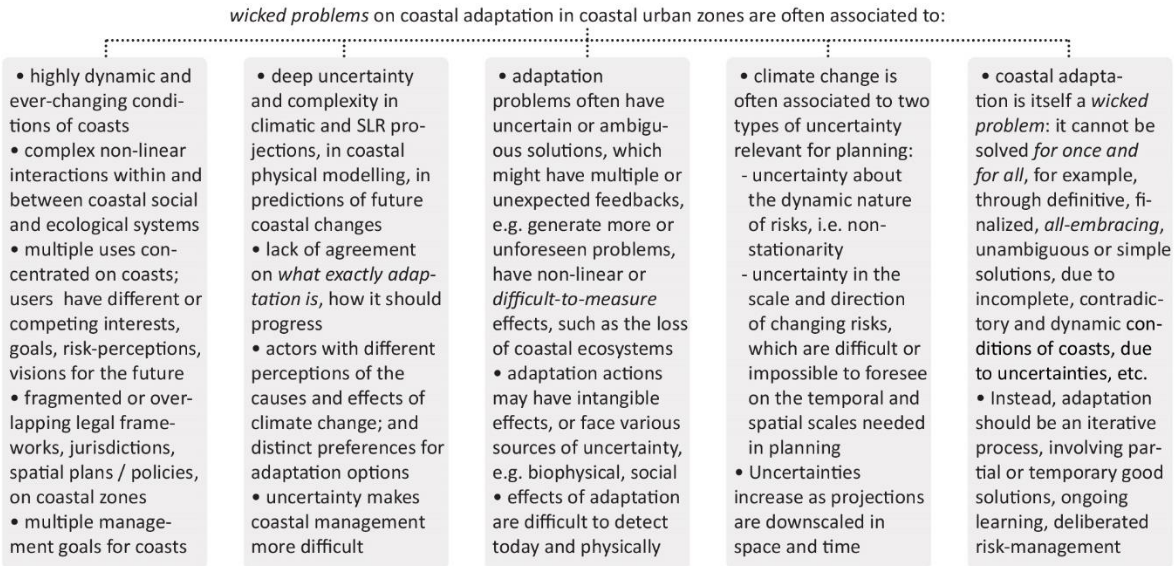


Figure 3. Coastal climate adaptation as a *wicked problem*. Source: own elaboration, based on Moser et al. 2012; IPCC SR5 2014; Wong et al. 2014; Brown et al. 2014; Ranger et al. 2013; Veloso-Gomes and Taveira-Pinto 2003; etc.

1.2.3.3. Coastal climate adaptation as a process

Coastal climate adaptation should not be reduced to the selection and application of a technical option among the 'protect, accommodate or retreat' typologies. Instead, it should be an ongoing and iterative process – a continuous cycle with various sequenced steps or phases (Linham and Nicholls 2010). Klein et al. (1999) proposed a framework of four key-steps for coastal adaptation processes (**Figure 4**). The non-coverage of any of these steps constrains the overall realization of adaptation (Klein et al. 1999).

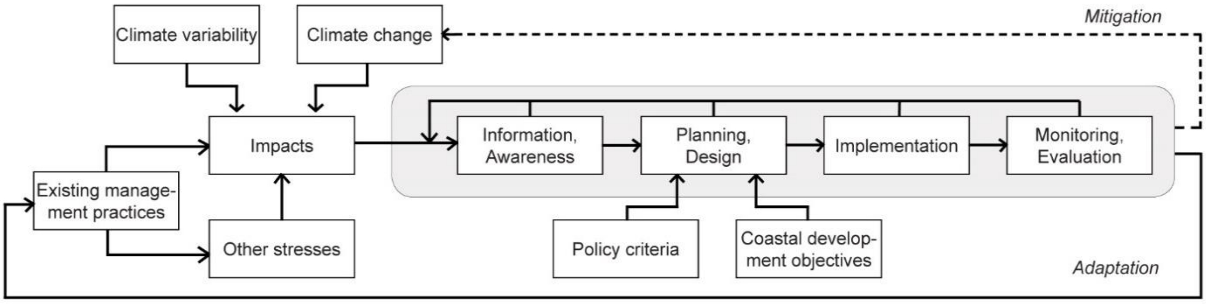


Figure 4. Iterative process of coastal climate adaptation (grey area). Source: Klein et al. 1999. Adaptation processes interact with existing coastal management practices, policies and objectives. Existing management practices, in conjunction with climate variability, climate change and other (human-driven) stresses, generate impacts. The 'planning and design' stage addresses three questions that often planners and decision-makers deal with: *when*, *where* and *how adaptation should be implemented*. The answers will be influenced by local contexts, policies, existing coastal management plans and objectives. Monitoring and evaluation enable adjustments of policies, contributing to the robustness of adaptation processes to uncertainty.

Linham and Nicholls updated this framework, and highlight that coastal climate adaptation should involve a sequence of: 1) analysis and prioritization of risks and opportunities (including data collection, dissemination and awareness-raising); 2) preparation of responses to reduce risks (planning and design of adaptation options); 3) decision-making / selection; 4) application of measures; and 5) monitoring and revision of results (continuous assessment and feeding back lessons into planning to improve future interventions). This multistage process influences the overall success of the selected option(s), though it remains a challenge, especially in developing regions (Linham and Nicholls 2010).[17]

Furthermore, under uncertainty and complexity, this iterative process should involve: the assessment of the widest range of possible scenarios and impacts (e.g. low-probability impacts with large consequences), the analysis of potential trade-offs and benefits between alternative adaptation options, and monitoring and learning, which are essential for an effective adaptation (IPCC SPM 2014). The existence of uncertainty in climate projections and 'imperfect knowledge' should not impede adaptation to proceed: *planning for adaptation can and should start before all uncertainties are reduced to a minimum* (Klein et al. 1999). The continual and iterative nature of the adaptation cycle is expected to deal with *incomplete knowledge*. Given the inherent uncertainties in long-term planning, adaptation options should be designed and applied in a way that enables their adjustment as time unfolds, changes occur, and new knowledge gets available. Though this framework could be widely applicable, it has not been used consistently, except in countries with a long-standing active coastal management and accurate data. Further research on its applicability in more contexts is needed (Klein et al. 1999) (Note 10).

[17] The whole adaptation process presents several challenges: knowledge about local specific impacts of climate change and human stresses on local areas needs to be improved for many coastal regions; more participation is needed in transparent, inclusive, multi-disciplinary and negotiated ways (during the whole adaptation process); monitoring and revision of measures implemented should not be dismissed (they propitiate cost-savings); the changing needs for adaptation knowledge and techniques (which evolve over time) need be carefully and constantly assessed (Linham and Nicholls 2010). It is necessary to deepen knowledge of local coastal systems (the more it is known, the more assertive adaptation solutions can be, but uncertainties will always remain), and to provide more technical assistance to collect local data (Linham and Nicholls 2010). Monitoring and evaluation are often ignored, but essential to a 'learning-by-doing approach' required to deal with uncertainties related with adaptation, SLR and coastal management in general (Nicholls 2011).

1.2.4. Recent evolution of coastal climate adaptation

Since the 1990s, coastal climate adaptation has expanded as a scientific field itself, with an increasing theoretical production and practice (Wong et al. 2014; IPCC SR5 2014). In the last decade (since IPCC SR4 2007), knowledge and experience in coastal climate adaptation have evolved and increased (Wong et al. 2014; IPCC SR5 2014). More specifically:

- Knowledge on adaptation options has expanded and improved. The range of adaptation options has widened, with greater recognition of ecosystem-based measures. Coastal climate adaptation options have increasingly included measures based on: community participation and inclusion of local knowledge, i.e. community-based adaptation[18]; on ecosystem-based adaptation[19]; Integrated Coastal Zone Management; adjustment of governance structures and institutions; disaster-risk reduction; alongside with the traditional approaches from engineering and technology.
- Novel tools for assessing future coastal adaptation options, and future decisions, were developed.
- Research on adaptation governance and institutional contexts has advanced.
- Efforts and advancements have been made towards the integration of adaptation into existing policy and regulatory frameworks (also called *mainstreaming*), and towards adaptation implementation. In some cases, there have been progresses in implementing adaptation, and more experience in coastal climate adaptation application and practice has been acquired.
- The identification of *good practices* has received an increasing attention.
- Studies and estimations of costs and benefits of coastal adaptation options, at global, sectoral or local scales, as well as studies on the costs of SLR impacts, have increased.
- The understanding of the barriers and constraints to adaptation has advanced, and to a lesser extent of enablers and opportunities for adaptation (Wong et al. 2014; IPCC SR5 2014).

Furthermore, in coastal adaptation research and literature, there is a growing emphasis on the flexibility criteria, for instance, through: approaches that use a wide range of possible climate scenarios (rather than a single most-probable scenario) to support decisions on long-term adaptation; choice and design of measures that will likely work well under diverse climatic and SLR scenarios; ongoing learning which implies the evaluation, and possible revision or modification of adaptation measures (as external conditions change over time) (IPCC SR5 2014; Wong et al. 2014); implementation of *low / no regrets* measures (i.e. measures that provide benefits to society and environment regardless of future climatic evolution, or seek to ensure that next generations will have the same options available today, or are 'reversible' or flexible by keeping future options open) (Linham and Nicholls 2010).

It can also be observed a gradual shift from a previous focus on cost-benefit and cost-efficiency analyses of adaptation options, towards multi-criteria analyses that consider several risks and uncertainty dimensions, trade-offs between adaptation options, their various side-benefits and externalities (IPCC SR5 2014), broader developmental goals, and ethical issues (IPCC IAV 2014).

---

[18] Community-based adaptation (CBA) resorts to bottom-up approaches, learning-by-doing approaches and local empowerment strategies (based on local knowledge, community perceptions' and adaptive capacities). CBA is common in developing countries, and often it involves the elaboration and implementation of locally-driven adaptation strategies focused on both climate change impacts and development deficits of vulnerable communities (Wong et al. 2014; IPCC IAV 2014).

[19] Ecosystem-based adaptation (EBA) relies on coastal ecosystems and their services as a means for adapting. It usually involves the protection, conservation or restoration of coastal ecosystems that act as buffers against storms, inundations and erosion, e.g. dunes, wetlands, mangroves, saltmarshes, or oyster reefs. It is often considered a 'no / low-regret option'. However, further research is required to produce quantitative estimations of the capacity of such coastal ecosystems to reduce wave, storm surge and SLR impacts, and to provide more accurate cost-benefit analyses and comparisons with other adaptation options (Wong et al. 2014). EBA options are also called *nature-based defenses* (Reguero et al. 2014; Langridge et al. 2014; Kochnower et al. 2015), *green or soft infrastructure* (Lennon et al. 2014; Coleman 2011), or *ecological designs* (Dyson and Yocom 2015).

Knowledge and experience in coastal adaptation have advanced more in developed countries than in developing countries (IPCC SR5 2014).[20] However, climate change impacts and adaptation costs are expected to be higher in societies with lower levels of development, weaker response capacity, less human or financial resources (IPCC SR5 2014; Wong et al. 2014). Some low-lying regions may face high annual impacts and adaptation costs, which can reach several points of their GDP.

The analysis of *good practices* of coastal adaptation has received a growing attention, with several guidebooks, compendiums, portfolios and inventories of coastal adaption solutions being produced in scientific and non-scientific domains, mostly in developed nations. These documents usually provide useful information and guidance on adaptation options, their advantages, disadvantages, costs, requirements, implications, and examples (Linham and Nicholls 2010; NYC Planning 2013; DEHP 2013; USAID 2009; Scott et al. 2013; Esteves 2014; Aiken et al. 2014). In general, the documentation of *good practices* of coastal climate adaptation has improved, with lessons being derived from experiences with demonstrated better results (Wong et al. 2014). Such *good practices* represent a first step for raising awareness (in general public, politicians, planners, etc.), and some adaptation actions have been supported by this type of literature (Wong et al. 2014). Nevertheless, frequently, these references circulate between different coastal contexts with distinct local ecosystems, and, in their transfer, there is the risk of underestimating contextual factors, local drivers and barriers to adaptation, local conditions. Developing countries / regions often lack knowledge, experience, assistance in coastal climate adaptation, and sometimes they 'copy' measures and designs from other contexts, which may lead to excessive socioeconomic or environmental costs (Linham and Nicholls 2010). Moreover, the adaptation measures applicable in a particular coastal environment may not be feasible in other coastal contexts (Linham and Nicholls 2010). In addition, careful attention should be paid in the interpretation of some literature on good practices of adaptation, as some normative principles and guidance are established ex-ante and need to be distinguished from ex-post evaluations of adaptations implemented (Wong et al. 2014). Adaptation efforts may benefit substantially from the diffusion of technologies or management practices, but their effective use depends on suitable institutional, regulatory, socio-cultural contexts. The success of knowledge transfers also depends on the improvement of policy frameworks and on the capacity to absorb, employ and fit technologies to local conditions (IPCC SR5 2014).

Finally, climate adaptation has been embedded in some planning processes, however, with a still limited implementation of adaptation actions (IPCC SR5 2014).[21] Governments at international, national and subnational levels, have developed adaptation plans / policies or strategies, and / or integrated adaptation into broader development plans (IPCC SR5 2014; Eakin and Patt 2011; Preston et al. 2011). However, the adaptation policies developed to date, at national and subnational levels, often adopt incremental measures. Moreover, most studies on adaptation have been limited to risk and vulnerability assessments, and, to a lesser extent, to adaptation planning, with very few assessments of processes of implementation of adaptation actions and their effects (ibid) (Note 11).

In Europe, adaptation policy has been developed at EU level, at national, subnational, and local levels in EU countries, with scarce systematic information on current implementation and effectiveness of such policies (Biesbroek et al. 2010). Importantly, in some cases, adaptation is being integrated into coastal management, environmental protection, spatial planning, disaster-risk reduction (IPCC SR5 2014).

[20] UK, Netherlands, USA, Australia are among the countries with more literature available and cases implemented (Esteves 2014).

[21] Since the IPCC SR4 2007, the number of national and subnational plans and strategies on climate adaptation has increased significantly, namely at local level in urban areas, in both developed and developing countries (IPCC SR5 2014).

1.2.5. CURRENT STATUS OF CLIMATE ADAPTATION RESEARCH AND PRACTICE

Wise et al. (2014) identified four types of studies on climate adaptation (in research and literature):

- Reports and evaluations of adaptation initiatives / actions in developed countries, which demonstrate that, despite the increasing number of risk assessments, evidence of adaptation action are still scarce;
- Analyses of barriers to adaptation, which provide reasons for the limited translation of vulnerability assessments and adaptation plans into real actions, as well as analyses of enablers of adaptation;
- Reports of adaptation practices occurring in developing countries and resource-dependent communities, mainly through ecosystem-based and community-based adaptation approaches, and incremental or *low-regret* measures;
- More recently, adaptation studies have also focused on developing methodological approaches and tools to support and inform climate adaptation planning, decision-making and implementation, in contexts characterized by deep uncertainty, long timescales, differentiated knowledge, distributed powers, and competing values – also called *decision-oriented approaches* (Wise et al. 2014).[22]

Despite the increasing recognition of the need to adapt to the effects of climate change, effective *on-the-ground* implementation of adaptation actions has been reduced. Drawing on their review of several cases of climate adaptation, these authors highlight that, commonly, efforts to adapt (as reported in the literature over the last decade) have not led to substantial rates of implementation of adaptation actions, and climate adaptation plans often lack links to implementation (Wise et al. 2014).

Climate adaptation is in a *nascent stage*, as there are still few examples of adaptation processes underway, namely in coastal zones cities (Hurlimann and March 2012; Hurlimann et al. 2014).[23] International literature has demonstrated that usually coastal municipalities adopt a reactive / event-driven or *wait-and-see* approach to climate adaptation. Evidence shows that, in many cases, local governments have not started to directly integrate or address coastal climate adaptation into local plans or policies, while in other cases, they have done this, but in inconsistent or fragmented ways, or without addressing key-drivers of risk and change (Hurlimann and March 2012; Moser et al. 2012; Storbjork and Uggla 2015). Moreover, there is also a frequent mismatch between the urgency for proactive adaptation of scientists and scholars, and the low sense-of-worry and slow approach to adaptation adopted by local governments (Storbjork and Uggla 2015).

Although climate adaptation is increasingly prioritized in directives and strategies at European level and Member States level, in practice, there is little concretization of proactive adaptation (Gray et al. 2016). In some cases, the adoption of top-down policies on adaptation has led local public administrations or agencies to develop risk assessments and mainstream adaptation guidelines, but with little translation of these efforts into practical local adaptation actions or steps (Gray et al. 2016; Tompkins et al. 2010). Indeed, in developed countries, the scarcity of practical examples of adaptation, or the relatively rudimentary level of adaptation action and progress, have given rise to concerns about the real capacity for adaptation action in such countries (Gray et al. 2016; Ford et al. 2011; Preston et al. 2011; Biesbroek et al. 2010).

Despite the steps for mainstreaming adaptation into local planning, policymaking and decision-making can already be found, several challenges remain in their concretization (IPCC SR5 2014). Municipalities and local planners often face difficulties in adaptation planning, namely: insufficient or inadequate guidance, lack of data on local vulnerabilities and potential impacts; scarce or weak linkages with

---

[22] See more in Eakin and Prat (2011) in Note 12. Some authors have compared adaptation cases focussing on flood risk (e.g. Wilby and Keenan 2012; Ward et al. 2013), and on climate-proofing of coastal cities (Aerts et al. 2009, *in* Jeuken et al. 2014, p.2).

[23] Ford et al. (2011) also highlight that in adaptation literature, it is crucial to distinguish between *intentions or proposals to act and adaptation actions themselves* (the latter explicitly recognize climate change effects as a motivator to act, and are actually implemented).

subnational and national governments for implementing adaptation actions locally. An effective implementation of adaptation policies demands greater coordination across governance scales (namely national, subnational, and local) and sectors (IPCC SR5 2014).

Other studies report cases in which coastal adaptation policies set by higher-level governments (and integrated within local planning) have provided unclear goals, means and insufficient guidance for local governments, have generated local controversy, have not fostered local ownership of adaptation responses; or tend to focus on limiting new urban development, without offering solutions to deal with existing assets at risk (Hurlimann et al. 2014).

Even in cases where coastal municipalities have already defined adaptation policies or measures for coastal zones, urban development and construction may proceed in risk-prone waterfront areas, if regulations and guidelines are interpreted as *negotiable* (Storbjork and Uggla 2015; Storbjork and Hjerp 2014; Clarke et al. 2016). The effectiveness and application of adaptation policies are strongly influenced by how they are negotiated in day-to-day planning practices (Note 13).

In medium and small coastal cities and their local governments, there is a general lack of adaptation to climate change and SLR (Barnett et al. 2014). At local levels, it is often difficult to reach consensus on the need for adaptation and how it should be implemented, e.g. usually there is confusion or little agreement on what adaptation measures should be applied (Barnett et al. 2014). Locally, adaptation raises equity issues, such as *who are the winners and losers of adaptation decisions*, and *how its costs and benefits are distributed*, i.e. *who pays and who benefits* (Hurlimann et al. 2014).

At the scale of coastal municipalities, decisions on adaptation are usually more dependent on consensus between local constituencies (i.e. municipal governments, communities, key-actors), and consensus are often quite difficult to achieve. The difficulty in reaching local consensus on adaptation is often related to: i) different perceptions of risks, of climate change, SLR, and their effects; ii) local resistance to external experts' risk assessments; iii) competing interests, values and expectations on coasts; iv) insufficient agreement on the goals of adaptation and which measures should be applied; v) different preferences for the distribution of costs and benefits of adaptation actions or inaction; and vi) insufficient inclusion of local knowledge and values in coastal planning / management (Barnett et al. 2014).

In general terms, coastal climate adaptation efforts are still scarce. Although literature provides increasing evidence of coastal regions in which climate adaptation is starting to be addressed, in general, it is still in early stages. In some countries, coastal management practices already show improvements in the reduction of risks and vulnerabilities on coasts, however, the climatic, environmental, and physical changes underway, and expected for the future, pose more demanding challenges ahead (Moser et al. 2012). Over the last decade, implemented actions were mostly incremental (focusing on proximate causes of risk), rather than transformational (Wise et al. 2014; Moser et al. 2012).[24] Adaptation science and research have had a modest impact on real adaptation planning, policymaking and decision-making. In addition, many adaptation plans have not been implemented (Moser et al. 2012; Wise et al. 2014).

Gradually, practical experience and expertise in the field of climate adaptation have been increasing, and adaptation has expanded as an own field of expertise (Bloemen et al. 2018, p.3). There is a growing body of literature on climate adaptation (see also Note 12).

[24] Most often, coastal climate adaptation is not being translated into new big policies or fundamental changes, but in incremental changes to policy, planning and management, alterations to governance structures, or provision of new arrangements (Ekstrom and Moser 2014).

1.2.5.1. ADAPTATION DEFICIT IN COASTAL PORT-CITIES

Although knowledge and experience in coastal climate adaptation have progressed in recent decades, internationally, adaptation scholars and researchers have reported an '*adaptation deficit*' – a gap between the needs of coastal socio-ecological systems for coastal adaptation now and in the future, the assumed adaptive capacity of these systems, and the adaptation solutions actually implemented. Several authors have attempted to explain the *adaptation deficit* (Burton 2004; Fankhauser and Dermott 2013; Preston et al. 2011; Ford et al. 2011) (see Note 14 and Note 15).

Such deficit is usually understood as the gap between the current state of a system and a state that minimizes adverse impacts from current and future climate conditions. It is often related to weak policies that lead to growing human and economic losses from natural climate variability and climate change, low capacity to manage impacts from extreme weather events, weak disaster-risk management, etc. (IPCC SR5 2014). Developed nations usually have greater capacity to manage the risks related with the climate, but such capacity does not necessarily translate into the implementation of adaptation actions. Despite the existence of several institutions focused on adaptation, identified adaptation needs have not always been adequately addressed. There is a mismatch between such adaptation needs and the funds available for adaptation. The provision of financial resources for adaptation has been slower than for mitigation, in both developing and developed countries. Current adaptation and developmental deficits will likely increase the vulnerability to current and future climate variability and climate change, and merit further investigation (IPCC SR5 2014).

Regarding coastal zones, in specific, the adaptation deficit has also been documented by various authors, but with slightly different meanings:

- Ekstrom and Moser (2014) define the adaptation deficit as the persistent gap between the assumed ability of coastal communities to adapt to climate change and the on-the-ground evidence of their progress to adapt, as well as the gap between what might be considered well-adapted society to the existing climate, and the actual and inadequate adaptation achievements of that society. The adaptation deficit exists not only in developing countries and poor communities, but also developed countries and rich regions, especially in areas where there is an inadequate preparedness for disasters, a continuing development in risk-prone zones, or increasing losses from extreme weather events.
- Wong et al. (2014) interpret the adaptation deficit in terms of costs of potential SLR impacts, costs of adaptation, and also costs of the current adaptation deficits (in situations in which coastal defences are not adapted to the current climate variability and related risks), especially in developing regions.
- Some authors suggest that the adaptation deficits manifest in cases where little action is taken compared to the level of threat, and inertia prevails (e.g. Huang-Lachmann and Lovett 2015).
- Nicholls (2011) highlights the need for more analyses of the adaptation deficit on coastal urbanized zones, in light of climate change and SLR effects (Nicholls 2011). Wong et al. (2014) also note that the adaptation deficits deserve further research.

Although a wide range of measures is available in coastal climate adaptation and used in coastal management, at local levels, there is usually insufficient knowledge on adaptation, and scarce information to plan, assess and select adaptation options, especially in developing countries / regions (Wong et al. 2014). Actually, there is a lack of references evidencing how coastal climate adaptation really happens and is carried out locally (Hurlimann et al. 2014).

Notwithstanding the multiple objectives underlying coastal climate adaptation (e.g. the reduction of risks to vulnerable coastal populations and sectors, the protection and preservation of coastal ecosystems and their functions, the improvement of coastal management and governance), in practice, efforts and actions towards adaptation often fall short of such goals, and meanwhile '*development continues in high-risk coastal areas, coastal ecosystems continue to degrade in many regions, coastal freshwater resources are being overexploited in many highly-populated areas, and vulnerability to coastal disasters grows*' (Wong et al. 2014). As Wong et al. (2014) note, *the multiple goals of coastal adaptation* are still *aspirational* and difficult to meet. For instance, in Rotterdam – a port-city extremely vulnerable to coastal and river flooding – climate adaptation measures for reducing flood risk have been put forward, based on the Dutch rich knowledge in flood risk management. However, such measures are challenged by *a growing flood risk due to land use changes in the old port areas and new development in un-embanked areas* (Francesch-Huidobro et al. 2016).[25]

Despite the growing attention given to climate change effects by researchers, planners and politicians, there are still few specific approaches to ports (Becker et. al 2015). There are scarce references and examples of ports that are already planning for, or adapting to, the effects of climate change and SLR (Reguero et al. 2013; USEPA 2008). On its report of the effects of climate change on US ports, the United States Environmental Protection Agency noted that *most US ports do not appear to be thinking about, let alone actively preparing to address, the effects of climate change* (USEPA 2008). While the risks associated with climate change are not substantially different from risks that ports have historically faced (and most ports already have defences for dealing with flooding, waves and winds), the level of risk will increase as sea level rises and if storm patterns change (Becker et al. 2011). Becker et al. examined adaptation options available for seaports and coastal built areas, at a global scale (for adaptation to climate change and SLR effects). Their study focused on: a) measuring the resources and time that might be required to implement *hard* and *soft* defences in several seaport-cities, b) surveying port authorities of nearly 180 ports to find out how ports perceive climate change effects and potential impacts in their operations, e.g. on dredging, and c) understand how they plan to adapt to changing climatic and physical conditions, and what policies ports have been adopted (if any) to address climate adaptation issues. The authors found that, although port authorities across the world are quite concerned with the impacts of climate change, *generally port community is not taking proactive action to adapt* (Becker et al. 2011, p.16). Despite the multiple studies projecting climate change and SLR and associated changes on coasts, and despite the growing number of risk assessments, little consideration has been attributed to the planning of adaptation actions that will be required to protect seaports and coastal communities, as sea levels rise. Globally, the majority of ports is not yet implementing adaptation measures.[26] Even scarcer seem to be the references and cases in which port's and city's stakeholders jointly address their future needs for coastal climate adaptation, and discuss adaptation measures for their coastlines, in an integrated way (Becker et al. 2015).

In synthesis, there are still few studies specifically focused on coastal climate adaptation needs in coastal port-cities, their ports and adjacent urbanized coasts.[27] Therefore, the advanced study of adaptation plans, policies and measures that port-cities might require in short, medium and long-term to effectively reduce changing coastal risks, will become progressively required (Scott et al. 2013; Hanson et al. 2011; Reguero et al. 2013; Becker et al. 2011) (Note 16).

---

[25] For Francesch-Huidobro et al. (2016), in many coastal deltaic port-cities, integrating climate adaptation measures (and efforts to improve the local environment and ecosystem), with urban development and economic growth remains a challenge and can be a source of tension between urban planners and hydraulic engineers. Urban development in the flood-prone and un-embanked areas (i.e. areas not protected by dikes), as seen in Rotterdam, Guanghzou, or Hong Kong (the latter with rapid growth) has contributed to an increasing flood risk.

[26] Among 93 surveyed ports, nearly 50% did not address climate adaptation, 10% had climate change-related insurance, 30% considered climate change into design guidelines, 10% had funding for adaptation, 12 % addressed adaptation in strategic plans (Becker et al. 2011).

[27] Actually, a large proportion of literature and research on coastal climate adaptation still focuses on coastal areas with low urban densities. There is a generalized lack of references for acting in urbanized coasts (beyond protection options) (Esteves 2014). Aside from ports, there are significant gaps in the analysis of adaptation for specific coastal sectors, such as tourism (Wong et al. 2014).

1.2.5.2. Some coastal adaptation experiences in coastal port-cities

There is still a reduced number of studies and practical cases in which port-cities, their port and adjacent urban coasts, have been planned for coastal climate adaptation, or actually adapted. Observed long-term coastal adaptation to SLR has been limited to a small number of major projects, such as:

- the Venice Lagoon Project (Norman 2009; Wong et al. 2014).
- the Thames Estuary 2100 Project in London (EA 2012; Ranger et al. 2013).
- the Delta Programme in Netherlands (Norman 2009; Wong et al. 2014), namely the Sub-Programme for the Rhine-Meuse Delta (Haasnoot et al. 2013).
- the HafenCity Project in Hamburg (SLR and rising water levels were tackled through the elevation of ground-floor in the redevelopment of waterfront areas) (Restemeyer et al. 2015; Schubert 2015).
- coastal protection works in Tokyo and Shanghai, which consider local SLR (Wong et al. 2014).
- some specific practices in countries like Netherlands, Australia, Bangladesh, etc. (IPCC IAV 2014).

Furthermore, over the last decade, adaptation has received increasing attention in some major port-cities, and, at the local level, some public agencies and local governments have initiated and developed their adaptation agendas based on scientific projections of climate change and SLR (Sousa and Prista 2012). Examples of port-cities that have recently advanced their own adaptation policies / plans, strategies, steps or initiatives, include:

- London. In addition to the Thames Estuary 2100 Project (EA 2012), the city of London developed an adaptation strategy (Mayor of London 2010).
- Rotterdam. The city adopted the Rotterdam Climate Proof Programme (RCP 2010).
- New York. The New York City Panel on Climate Change 2010 conducted a study for analysing risks and adaptation measures for critical infrastructure located on coastal areas of NY. Moreover, the city developed the *Vision 2020: New York City Comprehensive Waterfront Plan* (Aerts and Botzen 2011).
- San Franscisco (through the San Franscisco Bay Conservation and Development Commission 2009).
- Etc. (see more in Table J in the Appendix).

These examples contain some common features: 1) the use of future scenarios of climate and physical conditions for long-term horizons (e.g. 2030, 2050, 2100) according to current levels of knowledge; 2) modelling of potential spatial and physical impacts on consolidated coastal urban areas, critical infrastructures and port areas; 3) political support and commitment to address adaptation; and 4) recognition of potential higher costs if adaptation actions were not undertaken (Sousa and Prista 2012).

1.2.6. Barriers to adaptation

Over the last decade, several studies have documented barriers that preclude coastal climate adaptation – its planning and implementation (Ekstrom and Moser 2014; Ford et al. 2011; Storbjork 2010; Barnett et al. 2013). Such barriers help to explain (at least in part) the adaptation deficit. Some of the barriers that usually hinder coastal climate adaptation in port-cities are outlined next.

The lack of scientific knowledge and uncertainties about the future impacts of climate change and SLR (IPCC SR5 2014), about future physical changes in coastal systems (Linham and Nicholls 2010; Nicholls et al. 2007) are barriers frequently reported. There is a great difficulty and complexity in determining the effects of climate change and potential risks on ports and urban coastlines in the spatial-temporal scales used in port and urban planning (i.e. absence of information downscaled to local areas) (Reguero et al. 2013). While port administrations often lack means to assess the likelihood of possible impacts on their infrastructures (USEPA 2008; Reguero et al. 2013), local governments lack knowledge about coastal systems and assistance to assess and design adaptation measures (Linham and Nicholls

2010). Risk assessments made at national or regional levels are too general to capture effects on specific ports and urban coasts (Becker et al. 2015; Scott et al. 2013). There are often gaps between the scientific information on climate change effects on coasts and the type of data planners need (Wong et al. 2014).

Municipalities and local planners often face difficulties in adaptation planning, e.g.: insufficient or inadequate guidance; lack of data on local vulnerabilities and potential impacts; lack of reinforced linkages between national and subnational governments for implementing adaptation actions locally; weak or ineffective coordination across different governance levels and sectors (IPCC SR5 2014).

In most cases, port and urban planning are not sufficiently prepared to deal with climate change and SLR projections, their uncertainty, and long temporal scales. There is a common mismatch between the current projections of SLR (e.g. for the next 80 years) and the timeframes of port planning (e.g. for 50 years, though port infrastructures *live* longer). The highly competitive nature of ports requires them to adapt to rapid economic changes, and manage conditions they can feel now and historic data, which may impede them from including long-term adaptation in their planning (Becker et al. 2015; Reguero et al. 2013; Scott et al. 2013; USEPA 2008), but meanwhile climate change effects are being felt.

There is also a discrepancy between the spatial scale of port jurisdictions and the scale of climate change effects and emerging risks for port-cities' coasts. Whereas ports might be able to protect their own areas, the planning of adaptation measures for the port-city coastline requires the engagement of more actors besides ports (Becker et al. 2015). However, so far, few ports integrate larger commissions or action-groups focused on the study of coastal climate adaptation (USEPA 2008). Usually, ports are not covered by local planning instruments, and thus, they remain outside plans that protect the *public good*. While port operators make decisions and investments on their areas *as a business*, spatial planning does not sufficiently safeguard long-term social interests on port infrastructures (Becker et al. 2015).

Moreover, the lack of public acceptance of certain adaptation measures, namely retreat options, is often documented (Wong et al. 2014). Usually, there are conflicts of interest among actors with different risk perceptions, priorities and visions, which hinder consensus on coastal adaptation (Nicholls et al. 2007).

In addition, there is a great inertia in several aspects of socioeconomic systems, which is one of the main barriers to coastal adaptation. Inertia exists in: the conformation of coastal adaptation policies and measures in major port-cities (Hanson et al. 2011)[28]; in the patterns of urban settlement in coastal zones, in which social resistance to change is common and challenges long-term planning (Scott et al. 2013; Nicholls et al. 2007); in integrating adaptation into municipal agendas, routines and practices of planning and decision-making (Storbjork 2010); in institutional behaviours, and in resource consumption trends, coastal communities' lifestyles and cultures (IPCC SR5 2014). The social acceptability of adaptation policies is strongly influenced by the extent to which they foster / depend on changes in local lifestyles.

Although the lack of knowledge of the climate system (and of climate-related risks and risk management) is a barrier commonly mentioned, Burton (2004) notes that the lack of scientific knowledge may not be a major cause of the adaptation deficit and of rising losses from extreme weather events, but, instead, the fact that the available knowledge is not used effectively. Though more and better knowledge would be helpful, e.g. for designating risk zones, the existing knowledge could be used more efficiently, in ways that enabled more timely actions or more rapid results (Note 17).

Table 2 contains a more detailed list of barriers, which help to explain the common slow progress on coastal adaptation observed at local scales (namely institutional, financial, and informational barriers).

[28] The planning and construction of great modern coastal protection structures can require nearly 30 years, thus, decisions on the adaptation of port-cities (through protection or other options) expectable for 20150 should be taken today (Hanson et al. 2011).

Table 2. Barriers to coastal climate adaptation in coastal port-cities. Source: own elaboration, based on several authors.

Type	Barriers
Institutional barriers, governance issues	Scarce coordination and integration of institutions and governance structures, i.e. lack of coordination between agencies / departments, intra- and across diverse levels of coastal governance; institutional fragmentation (IPCC SR5, 2014; Ekstrom and Moser 2014; Storbjork and Uggla 2015; Wong et al. 2014; Moser et al. 2012). Inadequate contact between agencies or administrative units involved in coasts; difficulty in implementing a truly integrated approach (Storbjork 2010).
	Rigid / self-reinforcing institutions, un-coordinated actions (Eakin and Patt 2011). Difficulties in realizing effective multi-level governance and in integrating adaptation coherently into policy sectors and across scales (Biesbroek et al. 2010).
	Poor integration of policies (IPCC SR5 2014), i.e. horizontal and vertical integration. Ex: poor integration of local coastal initiatives and actions with higher policies; difficulty in translating national recommendations on adaptation into local plans / policies for coasts; ambiguous or contradictory goals in coastal policies (Wong et al. 2014). Ineffective coastal management practices, weak governance (Nicholls et al. 2007); event-driven risk management (Storbjork 2010).
	Legal hindrances (Ekstrom and Moser 2014). Constraints arising from and between existing laws / regulations, across policy domains, or long-term impacts of past decisions / policies (Biesbroek et al. 2010); institutional path-dependency.
	Lack of clarity on the roles responsibilities of each agency in coastal management (Barnett et al. 2013). Inexistence of lead agency to make decisions on coastal climate adaptation, to apply and monitor adaptation (Ekstrom and Moser 2014). Complexity of overlapping / confusing governance arrangements for coastal management (O'Riordan et al. 2008)
	Slowness in developing more responsive institutions that effectively integrate climate adaptation, difficulty in changing institutions (Ford et al. 2011; Ekstrom and Moser 2014); difficulty in institutional learning; inertia in integrating climate adaptation into municipal agendas, routines and practices of policymaking, planning, decision-making (Storbjork 2010).
	Planning that over-emphasizes short-term results and profits, or does not sufficiently anticipate consequences in a timely way, or underestimates the complexity of adaptation as a process (IPCC SR5 2014). Adaptation demands long-term planning, which is difficult to achieve in local administrations, due to short-term electoral mandates (Campos et al. 2016).
Socio-cultural barriers	Lack of public awareness of climate change, SLR, their long-term effects and related risks (Ford et al. 2011; Wong et al. 2014; Hoepffner et al. 2006); low sense of urgency (Adger et al. 2009); SLR seen as *a slow problem* for next generations.
	Reduced public concern for coastal climate adaptation (Ekstrom and Moser 2014; Hurlimann and March 2012).
	Ethical issues related with diverse objectives within societies, different interpretations of 'successful' adaptation (Adger et al. 2009); distinct values, attitudes, perceptions, interests among actors (Ekstrom and Moser 2014; Moser et al. 2012).
	Inertia, status-quo mentality; resistance to change, opposition to changed regulations by affected parties (Ekstrom and Moser 2014). Inertia in the conformation of coastal adaptation policies in major port-cities (Hanson et al. 2011), in patterns of coastal urban settlement (Scott et al. 2013; Nicholls et al. 2007); coastal communities' lifestyles and cultures, and institutional behaviours (IPCC SR5 2014). Wait-and-see attitude, or reactive approach (Ekstrom and Moser 2014).
	Different social preferences for adaptation options, e.g. according to social status and exposure conditions (Wong et al. 2014). Conflicts of interest between actors with divergent priorities, expectations and visions for the future, different risk perceptions, conflicting values and interests on coasts (Nicholls et al. 2007; Storbjork 2010). Lack of community support.
Financial barriers	Lack of funding for risk assessments, adaptation options' assessment, planning and implementation (Ekstrom and Moser 2014, Wong et al. 2014; Moser et al. 2012; Storbjork and Uggla 2015; Hurlimann and March 2012; Burton 2004). Economic constraints in developing or developed countries. Other priorities than adaptation; more pressing problems.
	Resource and funding constraints. Insufficient budget for the development of adaptation measures / policies. High economic costs of certain coastal adaptation options (Wong et al. 2014). Local competition for limited funds available from regional, national, international budgets (Ekstrom and Moser 2014; Campos et al. 2016). The financial resources allocated to adaptation usually do not match with the increasing needs of coastal adaptation (IPCC SR5 2014).
Political barriers	Lack of political will / commitment to climate adaptation (Ekstrom and Moser 2014; Ford et al. 2011; Wong et al. 2014; Preston et al. 2011). Political short-termism; lack of vision; not connecting short-term priorities to long-term goals (ibid). Focus on short-term goals, in contrast to long-term climate change, idea that adaptation can be left to later (Burton 2004); low conviction on the need to adapt, vision that planning's main goal is to promote growth (Hurlimann and March 2012).
	Lack of mandate / requirement from higher levels to initiate coastal adaptation at local levels; or adaptation has not yet been brought into policy agendas (Ekstrom and Moser 2014; Storbjork and Uggla 2015). Discrepancy between national adaptation guidelines and local actions; preference for short-term risk-reduction over long-term strategic planning (Ford et al. 2011). Reluctance to cede local authority to higher-level plans for adaptation, or changed land-use regulations.
	Avoidance / fear of politically 'hot' topics: e.g. property rights' issues, legal repercussions (Ekstrom and Moser 2014); compensation issues, lack of authority of local governments, fragmented land ownership (Hurlimann and March 2012).
	Lack of scientific knowledge on: climate change and its effects (Ekstrom and Moser 2014), future coastal change (Linham and Nicholls 2010), coastal systems (Nicholls et al. 2007). Insufficient knowledge of the climate system and of the management of climate-related hazards, or, more importantly, available knowledge is not used effectively (Burton 2004).

	Scientific uncertainty (IPCC SR5 2014; Ekstrom and Moser 2014), about climate change, SLR, their impacts, magnitude, rate, coastal physical change. Lack of knowledge about the future can result in delayed / scarce action (Adger et al. 2009). Uncertainty about future coastal change; difficulty in reaching scientific agreement on coastal projections; large difficulties in predicting how coastal processes will react to management options adopted (O' Riordan et al. 2014).
Informational + communicational	Scarcity of locally-relevant information. Lack of understandable or accessible science; inability of experts to communicate risks to staff, officials, or general public, in relevant ways (Ekstrom and Moser 2014). Lack of detailed data; gaps between the climate information provided by scientists and the one that planners and decision-makers need (Wong et al. 2014; Pires et al. 2012; Hansen 2010), little provision of thresholds / indicators for planners (Nicholls et al. 2007).
	Discrepancy between the temporal horizons used in climate projections and risks assessments and the horizons used in projects / plans for urban development (Klein et al. 1999). Port and urban planning are not *equipped* to deal with the long temporal scales of coastal climate adaptation and uncertainty of climate change projections (Becker et al. 2015). Discrepancy between the port jurisdictions and the scale of climate change effects and related risks in port-cities.
	Lack of knowledge on how to start adaptation; adaptation is relatively 'new' (lack of familiarity with *how to do it*) (Ekstrom and Moser 2014). Common confusion / lack of agreement on what adaptation is, what adaptation options are available, how adaptation should progress; still scarce evidence of progresses in adaptation processes (Campos et al. 2016). Municipalities and local planners often face difficulties in adaptation planning, e.g. insufficient or inadequate guidance, lack of data on local vulnerabilities and risks (IPCC SR5 2014).
Issues specific of the adaptation process	Lack of guidance for local governments, planners (Ekstrom and Moser 2014); lack of technical assistance for coastal adaptation planning (Linham and Nicholls 2010; Hurlimann and March 2012; Burton 2004), and for risk assessments.
	Lack of information, data, or local specificity in risk assessments; no data at higher resolution, no local records (Ekstrom and Moser 2014). Lack of data downscaled to ports and coasts (Reguero et al. 2013; Becker et al 2015; Scott et al 2013).
	The existence of unclear goals of adaptation, e.g. *adaptation to what, by whom, when and how*; segregated approaches to the management of coastal adaptation, within and between different scales (O' Riordan et al. 2014).
	Scarce participation of local communities and actors in coastal adaptation processes (IPCC SR5 2014). Little inclusion of local knowledge and cultural and symbolic values, which may result in undervaluation of places, cultures (Adger et al. 2009; Barnett et al. 2014). Resistance to outside experts' impact assessments; little agreement on goals of adaptation (Barnett et al. 2014); discrepancy between local perspectives and scientific views on climate change impacts (Fincher et al. 2014). Little consideration of coastal cultures, place-attachment, place-identity; fear of loss, issues of legitimacy, e.g. right to decide if a place should receive *protect*, *accommodate* or *retreat* options (O' Riordan et al. 2014). Participatory approaches in adaptation planning are still unusual / not standard practice (Preston et al. 2011).
	Difficulty in the negotiation and mediation on adaptation options between multiple interested parties; lack of agreement on adaptation options and goals of adaptation (Ford et al. 2011; Ekstrom and Moser 2014; Barnett et al. 2014; Campos et al. 2016). Difficulty in allocating costs and benefits of coastal adaptation options (IPCC SR5 2014; Barnett et al. 2013).
	Lack of public acceptance of certain adaptation options. Short-term thinking which limits the range of considered options (Ekstrom and Moser 2014; Wong et al. 2014). Public opposition to retreat options, e.g. concerns on fairness of retreat; lack of compensatory mechanisms; rapid coastal urban development (and legislations facilitating it) often hinder retreat approaches (Wong et al. 2014). Political implications of retreat options (Wong et al. 2014; Esteves 2014), which pose complex challenges to local governments. Little integration of long-term planning, risk-reduction measures, urban policies, financial assistance, compensation systems – needed to apply retreat.
	Inexistence of mechanisms enabling certain adaptation options (e.g. communities feel they deserve protection due to their past legacy of provision of coastal defences; complexity of applying strategic plans for the long-term; lack of arrangements fostering social and institutional learning (among coastal communities, planners, and insurers); inexistence of means for ensuring agreements over planning and financing of adaptation (e.g. in retreat). Controversy about lack of compensation in some adaptation options (O' Riordan et al. 2014).
	Equity and justice issues, e.g. *who are the losers and winners of adaptation decisions*, *how the costs, losses, benefits of adaptation are distributed* (Hurlimann et al. 2014; O'Riordan et al. 2014; Campos et al. 2016; Ekstrom and Moser 2014).
	Lack of conduct in transferring climate adaptation from policy principles into practice (Hurlimann and March 2012). Lack of enforcement of adaptation policies adopted. In some cases, coastal adaptation measures exist but are negotiable (e.g. coastal setback policies) in function of the attractiveness of coastal areas (Storjorbk and Hjerp 2014), or pressures of social networks formed around certain architecture projects for risk-prone coastal zones (Clarke et al. 2016).
	Lack of monitoring of adaptation options and their effectiveness, insufficient evaluation of adaptation measures / policies; scarcity of resources dedicated to monitoring of existing conditions, and of adaptation options applied, their outcomes; confusion on *what to monitor and evaluate* (Ekstrom and Moser 2014; IPCC SR5 2014; Campos et al. 2016). The often assumed high adaptive capacity of developed countries and weak perception of the importance of evaluating adaptation plans, reluctance of institutions to critically analyse planning processes (Preston et al. 2011).
	Structural / technological barriers: unfeasible / unaffordable / environmentally unacceptable solutions. Ex: political need to show positive return on investments; risk of misspending public funds; negative side-effects, visual, social, physical, or environmental impacts of some adaptation solutions) (Ekstrom and Moser 2014; Campos et al. 2016; IPCC SR5 2014).

Finally, the diverse barriers usually do not act alone, but interact with one another (Wong et al. 2014). It is difficult to grasp which barriers matter most in each context, but if planning wants to enable adaptation, and if adaptation is to progress successfully across the stages of its process, it is crucial to analyse such barriers (Ekstrom and Moser 2014; Moser et al. 2012; Wong et al. 2014). Despite the increasing understanding of the barriers that hinder coastal adaptation processes, there is little evidence of how these barriers emerge, are tackled, overcome or attenuated in different contexts (Barnett et al. 2013). Ekstrom and Moser (2014) call for more systematic analyses of why there are persistent adaptation deficits, which implies understanding barriers to adaptation, and exploring possible ways to close such deficit (namely aids, strategies, enablers and facilitators), and how these change over time in different contexts. Few studies have concentrated on enablers, opportunities and driving forces of coastal adaptation (Huang-Lachmann and Lovett 2015) (Note 18).

Evidence of adaptation to contemporary climate change effects are still beginning to appear, thus, it is important to grasp what is precluding or delaying this process, and how to overcome such hindrances, and to improve readiness (Ekstrom and Moser 2014; Ford et al. 2011). As climate change effects are felt, governments and communities, will progressively need institutions and governance structures *built for change* – i.e. adjustable to mutable conditions (Ekstrom and Moser 2014). As a continuous process, adaptation should imply institutional arrangements that foster the consideration of long-term drivers of change and risk, and iterative experimentation of adaptation measures, learning and readjustment (Eakin and Patt 2011). *Adaptive institutions* able to govern systems' processes, instead of *rigid, self-reinforcing institutions* and *un-coordinated actions*, are needed to push adaptation forward (Eakin and Patt 2011).[29]

1.2.7. Trade-offs between coastal adaptation options in port-cities

Traditionally, the solutions to deal with risks of coastal flooding and erosion resorted to hard protection structures, with a tendency for 'hold-the-line' approaches or protecting the coastline 'against nature'. Many coastal cities are now highly dependent on artificial defences (Nicholls et al. 2007; Wong et al. 2014). Though the economic development on coasts reinforces the idea that 'protection is worth it', the costs and impacts of such measures are questionable (Nicholls 2011). Some recent studies suggest that hard defences might be inadequate or not sufficient to cope with uncertainties and problems arising from SLR, climate change, and human stresses on coasts, and may potentially cause negative impacts on coastal ecosystems and on the spatial, visual, or ecological quality of coasts (Lazarus et al. 2016; Francesch-Huidobro et al. 2016; Esteves 2014). In some port-cities the level of protection now offered by hard defences might prove insufficient in near future (Huang-Lachmann and Lovett 2015).

Global studies on adaptation costs and benefits have focused mostly on hard protection, although other adaptation measures available may be possibly cheaper or socially preferable (Wong et al. 2014). Furthermore, as Wong et al. (2014) note (while referring to projections of coastal risks), *few studies consider adaptation and those that do generally ignore the wider range of adaptation measures beyond hard protection options. Integrated studies considering the interactions between a wide range of RSLR impacts, as well as trade-offs between diverse adaptation options are missing*. Therefore, further research is required on possible compromises between coastal adaptation measures, and their potential interactions with the effects of SLR and climate change (Wong et al. 2014). For instance, the costs and benefits soft protection and ecosystem-based adaptation measures are largely unknown, though these may provide additional benefits through ecosystem services (Wong et al. 2014).

---

[29] For instance, boundary organizations (involving scientific community, policymakers, at-risk societies, key-actors) can play key-role in facilitating adaptation and learning processes (Eakin and Patt 2011). Therefore, their existence is often considered an enabler.

Protection measures (hard and soft) are not the only adaptation solution available for port-cities. Some authors argue that, in port-cities, it might be wiser and more adequate to foster adaptation processes that strategically combine several adaptation measures, and balance strategies / policies for short, medium and long-term, namely through (Hanson et al. 2011; Reguero et al. 2013):

- approaches of joint urban and port management of relative SLR;
- upgrading of existing coastal protection structures and port infrastructures;
- planning, namely land use planning / zoning, focused on reducing exposure and vulnerability to current and future coastal risks, e.g. through the allocation of future urban development outside risk-prone areas, or relocation of existing buildings or infrastructures / retreat options;
- space / land reservation for future adaptation options, e.g. different protection schemes / types;
- establishment of *non-aedificandi* zones, new land use and building restrictions on coastal areas;
- elaboration of new building codes and regulations for waterproof construction;
- implementation of warning and evacuation systems, emergency and action plans, which are extremely important for port-cities with less resources;
- increasing mechanisms for shared or private accountability of risks, e.g. insurance, subsidies, means or instruments for co-accountability of potential impacts and costs;
- establishing acceptable levels of risk, and procedures in case of defence failure.

As Hanson et al. (2011) highlight, planned retreat is possible, but very problematic and expensive, and thus, less likely to happen in the medium / long-term than improvements or updates to existing coastal defences, mainly due to political difficulties and high costs of relocation (Hanson et al. 2011). On the other hand, some scholars argue that in the future retreat options may be increasingly demanded, rather than suggested (Esteves 2014). Other authors highlight that greater innovation is needed to generate long-term strategies that better balance growth pressure with dynamic coastal processes, in coastal urbanized areas (Dyckamn et al. 2014; Francesch-Huidobro et al. 2016).

In the past, a flood control approach was often chosen because it allowed development, which brought prosperity, but today its disadvantages are recognised: it is expensive (or even economically infeasible in some places), detrimental for nature, and it may increase vulnerability (if development in the hinterland is not restricted) (Restemeyer et al. 2017).

The increasing awareness of the adverse side-effects of hard protection structures on the processes of erosion and sediment transportation[30] has led to a growing preference for other alternatives (Linham and Nicholls 2010). In some coastal regions, the construction and improvement of hard defences have been restricted (due to high costs or undesired environmental impacts), and there has been a gradual shift from the traditional ‘hold-the-line’ with hard defences to more flexible approaches and soft measures (Esteves 2014). Potential rises in costs of constructing / maintaining hard defences (even to higher values than the assets protected) have led some local governments in UK, USA and Australia to consider hard defences economically or environmentally unsustainable (DEHP 2013). Despite that, hard protection continues to be the most preferred and trusted option to protect high-valued real-estate assets (Linham and Nicholls 2010).[31]

[30] In some coastal regions, hard protection structures were built arbitrarily, as immediate responses to storm damages or economic pressures, with little attention to their adequacy and efficiency in mid / long-term, and to physical and urban processes underway. In some cases, coastal defenses turned into environmental problems, aggravating erosion in adjacent areas. Planned retreat is less acceptable in urban settlements, especially if it is decided based on predictions of risks for 2100. Resettlement / realignment are challenging topics (Veloso-Gomes et al. 2006a).
[31] As Esteves (2014) highlights, apparently, few adaptation options (other than protection) seem to be available for coastal communities facing risks in short / medium-term or already vulnerable to flooding and erosion) (Esteves 2014). However, in their study, Dyckman et al. (2014) note that in USA there has been a gradual transition from hard to soft approaches (soft stabilization) in coastal cities, despite the existence of ideals and regulations for planned retreat (Dyckman et al. 2014).

The question raised by Becker et al. (2011) – *will ports become forts?* – leads to further questions: how would port-city' populations receive such fortified landscapes, e.g. hardened or sand-naked seashores? what would be the impacts of mega-hard defences on physical, environmental, and recreational values of coasts, e.g. on sea views, accesses, ecosystems' services? would such defences generate new tensions between ports and cities?

Adaptation scholars have estimated that, without adaptation, there will be a steep increase in the likelihood of floods in several port-cities worldwide, due to urban and socioeconomic development and SLR (Hanson et al. 2011). These projections reinforce the need to find 'new', more innovative and improved coastal adaptation solutions, adequate to different coastal environments of port-cities, and which go beyond the simple maintenance / update of current standards of protection. Decisions regarding where and how port-cities will (re)develop or expand to will assume primary importance on their exposure to coastal risks. Vulnerability will be aggravated if urban development continues in flood-prone zones (Hanson et al. 2011).

Therefore, it is necessary to improve knowledge on coastal adaptation measures (within the *protect*, *accommodate* and *retreat* typologies), focusing on: 1) their advantages, disadvantages, requirements, costs, repercussions, benefits; and 2) possible combinations, trade-offs, synergies and co-benefits between diverse measures (Nicholls 2011; Wong et al. 2014; Linham and Nicholls 2010; Scott et al. 2013). It will be important to develop more accurate assessments and reliable comparisons of adaptation measures, e.g. through multi-criteria analysis.[32] The uncertainties regarding the type of coastal adaptation measures that will be necessary (e.g. the type of protection), their future effectiveness, likelihood of failure, feasibility, adequacy, and about the durability and maintenance requirements of existing defences, merit further analysis (Hanson et al. 2011; Becker 2011; Nicholls 2011; Scott et al. 2013). There might be substantial trade-offs between different adaptation options, within and across regions, but managing such trade-offs implies: tools to understand interactions and to support decision-making at local levels; improved coordination across scales and sectors; and greater institutional capacity to plan and apply integrated responses (IPCC SR5 2014).

1.2.8. Coastal adaptation intricacies

In theory, coastal climate adaptation should be context-specific and place-based, being influenced by local social, economic, environmental, and physical conditions (IPCC SR5 2014). The most adequate measures for each place should vary from case to case, in function of local conditions, and it may be necessary a combination of several complementary measures (Wong et al. 2014).[33] However, some scholars have emphasized the need to develop solutions more appropriate to each place, noting that adaptation measures should be better tailored to local conditions, reviewed, and if necessary adjusted to changing conditions over time (Wong et al. 2014; DEHP 2013; Linham and Nicholls 2010).

Furthermore, adaptation planning and implementation are conditioned by the socio-cultural context, mainly by societal values, expectations, interests, risk perceptions, lifestyles, behaviours, and culture (IPCC SR5 2014; Adger et al. 2009). Thus, an effective adaptation planning and decision-making should

[32] It is necessary to develop methods for identifying and prioritizing coastal adaptation options that take into account their short and long-term effects, near and longer goals of sustainable adaptation (Nicholls et al. 2007). The range of measures available in coastal adaptation (and in coastal management), and the possibilities for combinations, may be enhanced by developing risk assessments with scenarios of climatic and socioeconomic changes (Wong et al. 2014). The evaluation of the level of success and effectiveness of adaptation measures, also implies a constant monitoring, assessment, ongoing learning, and feedback of lessons into planning (Linham and Nicholls 2010).

[33] There is no single 'best solution' for reducing risks across all coastal settings. Each situation should entail an assessment of local needs and measures that work better with the characteristics of each site. The use of complementary adaptation solutions helps to avoid potential failures in each solution, and enables a place to become able to respond uncertain changing risks (Linham and Nicholls 2010).

entail the evaluation and mediation of different values and interests (IPCC SR5 2014; Adger et al. 2009), and consider ethical implications of adaptation decisions and actions for societal and ecological systems.

Coastal climate adaptation usually raises issues of justice and equity related with the rights, values, visions, experiences, perceptions, and interests of those who are affected / benefited with adaptation (IPCC SR5 2014; Fincher et al. 2014), and with procedural, distributional, spatial and temporal dimensions of fairness of adaptation measures for local communities (Graham et al. 2015, 2014). Little attention has been paid to issues of fairness related with local impacts and adaptation measures (Graham et al. 2015), and to culture and the diverse 'lived values' within communities (Graham et al. 2014). Though it is increasingly recognised that public participation and inclusion of local knowledge and values facilitate adaptation processes and their effectiveness, *these have not been consistently used in existing adaptation efforts*; and in most cases public participation on coastal adaptation is still insufficient or weak (IPCC SR5 2014), namely in seaport contexts (Becker et al. 2015).[34]

In practice, all adaptation measures entail adverse or collateral effects that may be disadvantageous in relation to other developmental goals or other adaptation goals (IPCC SR5 2014). Furthermore, coastal adaptation should ensure social justice, but also ecosystems' integrity (environmental sustainability). In this sense, coastal climate adaptation is not free of conflicts, and a sustainable adaptation process will depend on a wider recognition of the distribution of costs, losses, damages and benefits resulting from it (Hurlimann et al. 2014). In this process, it will be extremely important to grasp how the roles, responsibilities and costs of coastal adaptation will be allocated, e.g. *who should bear the costs* (Barnett et al. 2013). One of the main challenges of planning for coastal climate adaptation will be the definition of successful measures, considering that there will likely be inevitable losses (Hurlimann et al. 2014). Theoretically, planning has adequate tools to timely reduce or avoid coastal risks, but in practice, it may fall short of this goal (Hurlimann et al. 2014).

Ultimately, adaptation measures may fail to meet their goals or lead to ***maladaptation***, i.e. increase risks to other systems, sectors or groups, burden the most vulnerable, have exaggerated costs, reduce incentives to adapt, establish trajectories that limit future options, or cause negative side-effects or externalities (Barnett and O'Neill 2010; Marino and Ribot 2012; Macintosh 2013; IPCC SR5 2014). As Marino and Ribot note, climate change involves *redistribution* of risks and impacts, therefore, it is necessary to explore adaptation policies and measures, but also their potential effects for vulnerable communities. A limited comprehension of the consequences of adaptation measures *can inadvertently reproduce or deepen the damages they intended to redress*, or produce additional harm to already *injured* groups (Marino and Ribot 2012). A weak planning that does not timely anticipate adaptation actions can result in maladaptation (IPCC SR5 2014). Lack of adaptation, adaptation failures, or *maladaptations* (e.g. two much, too little, or wrong types of actions) can lead to decline, abandonment or disinvestment in coastal areas, and deeply influence future societal choices on adaptation (Nicholls 2011)[35] (Note 19). Further research is needed into real cases of adaptation, and their classification according to planning type, adaptation needs, etc. The scarcity of documentation of cases restrains the dissemination of knowledge, theory-building and *empirical analysis of adaptation via planning* (Hurlimann and March 2012). There is a critical need to reduce adaptation deficits and provide evidence on concrete cases.

---

[34] Port planning, in specific, needs be more attentive to two factors: the population potentially vulnerable to extreme coastal events and emerging coastal risks in the port-city, and the network of stakeholders that depend on port's functionality. The potential impacts of extreme weather events, and SLR effects, will likely be borne by ports, port-related actors, local governments, communities, etc., thus, the engagement of a wider range of actors in adaptation process in port-cities is indispensable. A greater inclusion of public perceptions, concerns, and expectations, during the whole adaptation process (mainly in risk assessment and planning stages) is needed (Becker et al. 2015).

[35] For example, the existence of high / growing concentration of population and economic activities on coasts, limited insurance, potential shifts in the responsibility for risk management from state governments to those at-risk, may result in greater inequality (IPCC IAV 2014). Globally, the benefits of adapting will be higher than the socioeconomic costs of inaction. Without adaptation, tens of millions of people would be affected by floods or coastal land loss during this century (Wong et al. 2014, Nicholls et al. 2007).

1.2.9. The 'mainstreaming' of adaptation into planning, governance, and institutions

The integration of climate adaptation into planning and decision-making, usually called *mainstreaming*, is deemed an essential step to promote the transition from the preparation (planning) to the real implementation of adaptation (IPCC SR5 2014). Generally, climate adaptation is not carried out alone, but in the context of already existing policies in spatial and urban planning, environmental and coastal management practices (Wong et al. 2014). It is often aligned or merged into the frameworks of Integrated Coastal Zone Management (ICZM), Disaster-Risk Reduction, Adaptive Management, etc. Adaptation is likely to advance more if it is integrated into such frameworks, as it shares common goals with them, e.g. reducing vulnerability, averting risks, etc. (Wong et al. 2014; Moser et al. 2012), and most existing practices of coastal management already cope with flooding and erosion risks. Therefore, responses to SLR and climate change effects should be applied within the broader framing of coastal management plans, practices and objectives, however, in many countries it is still necessary to improve systems of coastal planning and management, and develop institutions able to introduce and enforce regulations for clearer coastal governance (Nicholls et al. 2007). In this sense, a greater understanding of the role of institutional adjustment in coastal adaptation is needed (Note 20).

Though the governance and institutional contexts in which adaptation decisions are made are crucial in enabling or precluding coastal adaptation, the institutional factors and roles in adaptation (and in the transition towards more sustainable coasts) remain under-researched. Practically, there are no analyses on: how to design effective policies and institutional arrangements for coastal climate adaptation? which institutional arrangements and governance structures are adequate in which coastal biophysical and social systems? what institutional changes are occurring / should occur? (Wong et al. 2014).

1.2.10. The need of monitoring and evaluation of adaptation through indicators

It is necessary to design appropriate metrics for identifying and measuring successful adaptation, e.g. indicators of success and outcomes of adaptation policies (Eakin and Patt 2011; Ford et al. 2011; Biesbroek et al. 2010). For Burton (2004), it is necessary to develop a more operational view of adaptation, addressing the following issues: a) how adaptation will be defined and measured, e.g. can adaptation objectives be specified in a manner that enables its progress to be assessed; b) is it logic to set targets for adaptation as there are for mitigation, e.g. reduce the costs of natural disasters by x%.

There are still conflicting views on the selection of adaptation indicators, due to the different values attributed to adaptation needs, options, and outcomes, many of which cannot be captured or comparable by metrics. The indicators that seem to be most useful for policymaking and learning are those that track the process, implementation, and the extent to which targeted objectives are met. A narrow focus on quantifiable costs and benefits can bias decisions in detriment of ecosystems, future generations and vulnerable groups, whose values are often under-represented (IPCC IAV 2014).

In face of the current lack of tools for evaluating adaptation planning in developed nations, in addition to the common (often biased) idea that wealthy countries have a high adaptive capacity, Preston et al. (2011) call for further evaluation in climate adaptation planning. The authors developed a framework of criteria for evaluating adaptation planning, which can be applied in the evaluation of individual adaptation plans (Preston et al. 2011) (Note 21).

1.2.11. The role of spatial planning in coastal climate adaptation

Spatial planning has a crucial role to play in facilitating climate adaptation (Hurlimann and March 2012; Hurlimann et al. 2014; Tribbia and Moser 2008). The spatial configuration of cities and territories, the ways land is used and developed, have a critical influence on the exposure of coastal socio-ecological systems to climate-change related risks. Moreover, land-use planning is considered one of the most effective tools to reduce the vulnerability to extreme weather events, and to timely minimize potential risks and impacts (Hurlimann and March 2012).

Theoretically, if done well, spatial planning can deliver adaptation responses to emerging coastal risks and SLR, in ways that are socially and environmentally sustainable, but in practice, planning practices may fall short of such goal (Hurlimann et al. 2014).[36] Nevertheless, planning can still play a positive role in climate adaptation, as one part of the adaptation process (Hurlimann and March 2012).

Hurlimann and March (2012) summarized six main capacities of planning to facilitate coastal climate adaptation: 1) ability to act on and coordinate matters of collective concern and public benefit; 2), ability to manage and mediate competing interests; 3) capacity to reflect and act across several spatial and temporal scales and governance levels while reflecting and acting on local conditions; 4) ability to reduce and deal with uncertainty, e.g. through mechanisms to deal with uncertain changing conditions in coastal socio-ecological systems and in climate, namely new planning tools and flexible policies / plans that can be adapted to unexpected change; 5) capacity to gather spatial knowledge sets, namely downscaled climate and SLR projections; and 6) orientation towards the future with potential to deliver long-term benefits (Hurlimann and March 2012).

Hurlimann and March (2012) identified key challenges to planning for coastal climate adaptation:

1. increasing collective and political conviction regarding the necessity to adapt, which implies raising public awareness and political commitment.
2. enabling equitable and fair processes and outcomes, incorporating often misrepresented interests of future generations and non-human species, i.e. intergenerational, intra-generational and environmental equity; and fostering wide, transparent participation of all in planning and decisions.
3. shifting planning systems from passive to proactive, i.e. changing planning's tendency for controlling and regulatory roles towards a more proactive positioning that can directly shape change and effect adaptation. Given the *relative irreversibility* of urban settlements (opposing the adaptability notion), in urbanized coastal regions, planning needs to shift from 'regulator' of new development to a proactive stance in the adaptation of existing built form, over the medium- and long-term.
4. The temporal horizons of planning and decision-making instruments and processes need to be extended to consider long-term climate-related impacts, namely SLR (Hurlimann and March 2012).

One of planning's major difficulties will be to define measures of successful coastal adaptation, considering that such success may be elusive and losses are inevitable, and that adaptation is an ongoing no-end process of responding to change (Hurlimann et al. 2014). Hurlimann et al. also call for *a greater role for local-level strategic planning processes to articulate the adaptation futures for local communities, with resources allocated to achieving this*. These ideas are aligned with an emergent theoretical body on coastal adaptation that identifies a series of pre-conditions required for successful and sustainable coastal adaptation.

[36] In theory, spatial planning is well equipped to cope with, avoid or reduce coastal risks (related with SLR and climate change). However, there is disagreement on the assumed capacity of planning to effectively address adaptation. In some cases, planning has failed to address climate-related impacts, generated detrimental effects in climate or the environment, urban environmental externalities (Hurlimann and March 2012). See also Storbjork and Hjerp (2014) in Note 22.

1.2.12. PRINCIPLES FOR SUSTAINABLE AND SUCCESSFUL COASTAL CLIMATE ADAPTATION

Several authors have identified a range of requisites for successful and sustainable coastal climate adaptation processes (Hurlimann et al. 2014; Barron et al. 2012; Moser et al. 2012), namely:

- vertical integration among different levels of government; and horizontal integration between different government departments, agencies (planners from diverse agencies), across jurisdictions;
- extended engagement of stakeholders;
- collective agreement among local actors regarding the types and timing of adaptation actions;
- integration – i.e. *mainstreaming* – of adaptation into all decisions;
- reinforcing / enhancing of legal frameworks for adaptation action;
- distribution of the costs and benefits of adaptation measures to actors according to levels of risk;
- clear adaptation guidelines / plans developed and adhered by all levels of government.

Hurlimann et al. (2014) sum up these aspects in three main requisites: 1) enabling local ownership of adaptation responses; 2) developing collective and coordinated forms of adaptation action based on broader negotiation between local communities and diverse government levels, and 3) ensuring fairness of adaptation implementation across space and time.

The 1st requisite implies: a) meaningful communication, b) giving time for information about risks to settle in local communities, c) safeguarding that communities inform adaptation processes, d) negotiating trade-offs between different adaptation options; e) developing and implementing iterative adaptation pathways that are locally-owned. The 2nd requisite implies: a) greater coordination between institutions and individuals during planning and implementation; b) preparedness of all to *make sacrifices to achieve collective benefits*; c) conflict-resolution tools; and d) potential reconfigurations in institutions (including planning systems). The 3rd requisite implies: a) more formal, consistent and transparent processes for negotiation, mediation and conflict resolution; and b) clearer / more explicit acknowledgement of the distribution of losses, benefits, winners and losers from impacts and from adaptation measures (though adaptation may never be free of conflicts).

A successful coastal adaptation also requires institutions able to consider and negotiate the demands and needs of *ever-changing landscapes* in ways that are legitimate, so that the planning institutions and at-risk communities can 'survive' change over time. Moreover, successful adaptation needs to be sustainable in social and environmental ways, which implies both social justice and environmental integrity, and the adaptation process should itself be sustained over time (Hurlimann et al. 2014). For these authors, successful and sustainable coastal adaptation policy will be *policy that progresses carefully, deliberatively, flexibly, fairly, and patiently*. Urban planning needs to address these issues to be a sustainable institution for adaptation (Hurlimann et al. 2014).

Spatial planning should account for the dynamic and uncertain nature of coastal environments, adopt longer temporal horizons, and consider wider implications of decisions, time-lags in climate, seas' and coasts' behaviour, possible physical or environmental thresholds, and lead-times required for societal responses (Moser et al. 2012). Coastal planning / management should become more 'adaptive' to better respond to long-term coastal climate adaptation needs and challenges (Moser et al. 2012) (Note 23).

Importantly, this emergent theory on the requisites for sustainable coastal climate adaptation has been based more on reason than evidence, as there are still little references about how adaptation really occurs at local scales (Hurlimann et al. 2014), and it requires more empirical support. Some normative principles have been advanced *a priori*, and do not result from post-evaluations of real cases of adaptation (Wong et al. 2014). While there seems to be some agreement on principles for adaptation, there is little evidence of why certain principles are effective in certain contexts, which points to the need of further research on this topic (Wong et al. 2014) (Note 24 and Note 25).

1.2.13. Synthesis: knowledge gaps and research needs

Climate change, SLR, and continual human pressures, generate cumulative and non-linear adverse effects on coasts, aggravating already existing risks, and / or creating new ones. These risks and their potential impacts pose more complex challenges to planning in coastal port-cities. The changing climatic and physical conditions of coasts, and the emerging coastal risks, demand a response, a continuous process of adaptation during this century and beyond it. It is necessary to achieve a greater understanding of these threats, and on the other hand, improve knowledge on coastal climate adaptation, its mainstreaming into spatial planning, the planning implementation and monitoring of adaptation actions.

Need for vulnerability / risk assessments in coastal port-cities; improve their usability for planning

For many coastal port-cities worldwide, knowledge on the effects of climate change, SLR and human pressures on coasts, and on related coastal risks still needs to be improved. Generically, ports and cities need to achieve a greater understanding of the projected changes on climate and on the physical conditions of coasts, and analyse potential risks and impacts that might occur (i.e. direct and indirect impacts on ports, urban coasts, and dependent sectors) (Reguero et al. 2013; Becker et al. 2015; USEPA 2008). More systematic analyses of risks and potential impacts that coastal port-cities may experience are needed, considering the influence of relative / regional SLR, and of socioeconomic and urban trends, on the vulnerability of socio-ecological systems (Wong et al. 2014; Lazarus et al. 2016).

Many projections of SLR, shoreline change, coastal risks, are not provided at the spatial-temporal scales that planners and decision makers need (i.e. there is a lack of detailed data and estimations) (Wong et al. 2014). Hence, it will be particularly pertinent to identify current and future exposed areas to flooding, erosion, submersion (and their extension), and to assess the implications of the existence of population and assets on potentially vulnerable areas of port-cities (Hanson et al. 2011). Moreover, there are few references on: how to use projections despite their uncertainty levels; how to integrate the results of modelling and simulation tools into planning (existing planning instruments and land-use regulations) and translate them into adaptation strategies (Pires et al. 2012; Hansen 2010). It is necessary to improve the usability of climate and SLR projections, and make data and methods more accessible (Note 26).

Need to study coastal climate adaptation in port-cities, and reduce the adaptation deficits

As mentioned, there are still scarce studies and references to cases that specifically address coastal climate adaptation needs in coastal port-cities – their ports and nearby urban coastlines (Scott et al. 2013; Hanson et al. 2011; Reguero et al. 2013; Becker et al. 2011). Therefore, further research is required on coastal adaptation measures that port-cities need to reduce, avoid and manage emerging coastal risks in their ports and adjacent urban coasts (Hanson et al. 2011; Scott et al. 2013; Reguero et al. 2013; USEPA 2008; Becker et al. 2011). The advanced study of adaptation solutions (including plans / policies, their measures and technical solutions) that port-cities will require in short-, medium- and long-term will be progressively required. Further efforts towards the advancement and evaluation of the portfolio of adaptation options available for each port-city (port and urban coast) are needed (ibid).

Although coastal adaptation to effects of climate change, SLR and anthropogenic impacts is increasingly recognized as a need in many coastal regions of the world, there is still a deficit of effective planning and implementation of adaptation actions. Several studies have documented the ‘adaptation deficit’– the gap between the adaptation needs of coastal socio-ecological systems, and the adaptation actions, measures or plans actually implemented, namely in coastal port-cities. Further research is required on ways to overcome or eliminate the barriers that hinder adaptation, during the various stages of its process, and especially on enablers for adaptation.

Need to mainstream coastal climate adaptation into planning (spatial and port planning)

Further research is required on the integration of adaptation into planning (i.e. *mainstreaming*), as well as on the planning and implementation of adaptation processes (Wong et al. 2014; Nicholls 2011; Nicholls et al. 2007). In this sense, it is necessary to investigate: i) how adaptation has been / can be integrated into spatial planning and policymaking, and its instruments, namely in spatial, urban and port planning and coastal management, at subnational and local levels; and ii) how coastal climate adaptation has been / can be applied in practice, *on-the-ground* (Wong et al. 2014; Nicholls 2011; Nicholls et al. 2007). It is important to learn more about adaptation in practice and integrate this knowledge in the elaboration of coastal spatial plans and policies (Nicholls 2011).

The factors related with climate change, SLR, human pressures, and their effects on coasts, the changing physical and environmental conditions of coastal environments, and the emerging coastal risks, should be taken into consideration in the future planning, design, management and maintenance of ports and adjacent coastal urban areas (Reguero et al. 2013; Wong et al. 2014; Hanson et al. 2011), and incorporated in the design criteria for port infrastructures and urbanized coastlines. Moreover, the existing knowledge on coastal adaptation needs to be progressively embedded into plans, projects, programs, strategies, regulations for ports and urban coastlines, at regional and local scales (Wong et al. 2014; Reguero et al. 2013; Nicholls 2011; USEPA 2008). Adaptation scholars have called for more analyses of: how future climatic and physical conditions of coasts can be properly addressed and dealt with into planning, management, policymaking and design of ports and adjacent urban coasts; and how changing coastal risks can be adequately managed in plans, in ways that ensure a more sustainable development of these territories (Reguero et al. 2013; Hanson et al. 2011). Above all, it is necessary to develop means to adequately integrate and deal with climate adaptation into spatial planning instruments and regulatory frameworks, at local levels.

Need to advance the study of adaptation options, their efficacy, costs and benefits

As seen, a balanced combination of several types of adaptation measures might be the wisest and most adequate approach (Linham and Nicholls et al. 2010; Wong et al. 2014; Klein et al. 1999), namely in coastal port-cities (Hanson and Nicholls 2012; Hanson et al. 2011; Reguero et al. 2013). It is necessary to further examine possible trade-offs between diverse adaptation measures (Wong et al. 2014), considering their efficacy, costs, and benefits. In many cases, there is still scarce knowledge on coastal adaptation at local scales, and insufficient information to assess, select, design, and monitor adaptation measures, especially in developing regions (Wong et al. 2014), thus, it is necessary to offer further guidance on this (Linham and Nicholls 2010; Wong et al. 2014; DEHP 2013) (Note 27).

Need to increase awareness, participation and inclusiveness

Scholars who have been studying coastal climate adaptation in port-cities have underlined the need to: enhance local awareness of risks, and of costs and benefits of coastal adaptation in port's and city's actors; broaden public participation in the adaptation process (in its several stages); develop joint assessments of coastal adaptation options involving port, local governments and coastal communities (Hanson et al. 2011; Becker et al. 2015). There is a growing recognition that public participation will become an essential component of coastal climate adaptation processes in port-cities, being crucial for the effectiveness and acceptability of adaptation measures (Becker et al. 2015; Scott et al. 2013). A deeper cooperation of port and city actors in the analysis of risks and adaptation options is also essential to achieve fairer and more sustainable adaptation processes in coastal port-cities. It is necessary to reduce gaps between the local perceptions and expectations of involved actors on adaptation, and the adaptation plans / policies and measures applied in ports and adjacent coasts (Becker et al. 2015).

Need of integration, improved coordination, and effective multi-level governance

Few studies have addressed the adaptation needs of ports and urban coasts in integrative ways, i.e. coordinating port, city and coastal actors (Becker et al. 2015). However, in port-cities, it will be necessary to inform and guide coastal adaptation planning and decision-making in more integrated ways (Becker et al. 2015; USEPA 2008; Ekstrom and Moser 2014). Thus, it is essential to improve coordination between involved parties (port, city, and their actors), and between governance levels (Hanson et al. 2011). In port-cities, this will involve an improved multi-level governance, cross-scale coordination, and more effective planning systems at national, regional, and local scale (Hanson et al. 2011; Wong et al. 2014), and demand better coordination between diverse planning agencies than before (Eakin and Patt 2011). In addition, in coastal climate adaptation it is necessary to improve the cooperation between science and planning (Wong et al. 2014; Dias et al. 2011), and undertake more interdisciplinary research involving natural and social sciences (see Note 28).

Need to improve the negotiation / mediation of conflicts on coastal adaptation as a wicked problem

In port-cities, it will be important to manage and balance the different interests of those affected by potential impacts and by adaptation actions (Hanson et al. 2011). Equitable and sustainable coastal adaptation processes require: i) negotiations on the distribution of costs and benefits of adaptation measures / policies (Hurlimann et al. 2014); ii) adequate means to allocate the responsibility, costs and benefits of adaptation measures (or, ultimately, costs or impacts of inaction) (Barnett et al. 2013, 2014). It is important to develop means to facilitate and improve the negotiation and mediation of interests and conflicts (between different interests on coasts, preferences for adaptation options) (Hanson et al. 2011; Becker et al. 2015; Hurlimann et al. 2014; Barnett et al. 2014). A more transparent negotiation on costs, benefits, 'winners' and 'losers' of adaptation decisions, depends on the existence of mediators, negotiators and facilitators – roles that planners should assume (Hurlimann and March 2012).

Need for a more 'proactive' and 'adaptive' approach to coastal climate adaptation

In face of the adaptation deficits that exist in many coastal port-cities, and considering the uncertainties in climate and SLR projections and in coastal physical modelling, among other complexities and difficulties (associated with coastal *wicked problems*), it is imperative to develop tools and means that enable planners and decision-makers to proactively plan and implement adaptation – the process, its plans / policies and their measures. A more proactive approach to coastal climate adaptation (in detriment of traditional reactive responses) is needed (Nicholls 2011). This implies the consideration of longer timescales (and long-term effects) within planning, i.e. spatial planning, port planning and coastal management (Scott et al. 2013; Nicholls et al. 2007; Hoepffner et al. 2006; Moser et al. 2012). In port-cities, a proactive approach to adaptation will also imply *strengthening adaptive management and governance capacity to manage increasing risks in port cities* (Hanson et al. 2011).

In complex and uncertain environments, an effective adaptation needs to be iterative and adaptive, that is, strategies can be adjusted as new information and knowledge emerges or conditions change. The analytic methods for planning and decision-making under uncertainty – also called Adaptive Planning approaches – seem to be better prepared to deal with multiple and changing risks, and short- and long-term effects (IPCC SR5 2014). The topic of 'Adaptive Planning' is discussed in **Section 1.3.**

This research agenda needs to be carried out in spatial planning (coastal, urban, and port planning). While much of the existing research and literature has pushed forward coastal adaptation, much more effort is needed to achieve more sustainable adaptation processes, and bridge the afore-mentioned gaps.

Diagram 2 provides a synthesis of the main gaps identified in the literature on coastal climate adaptation.

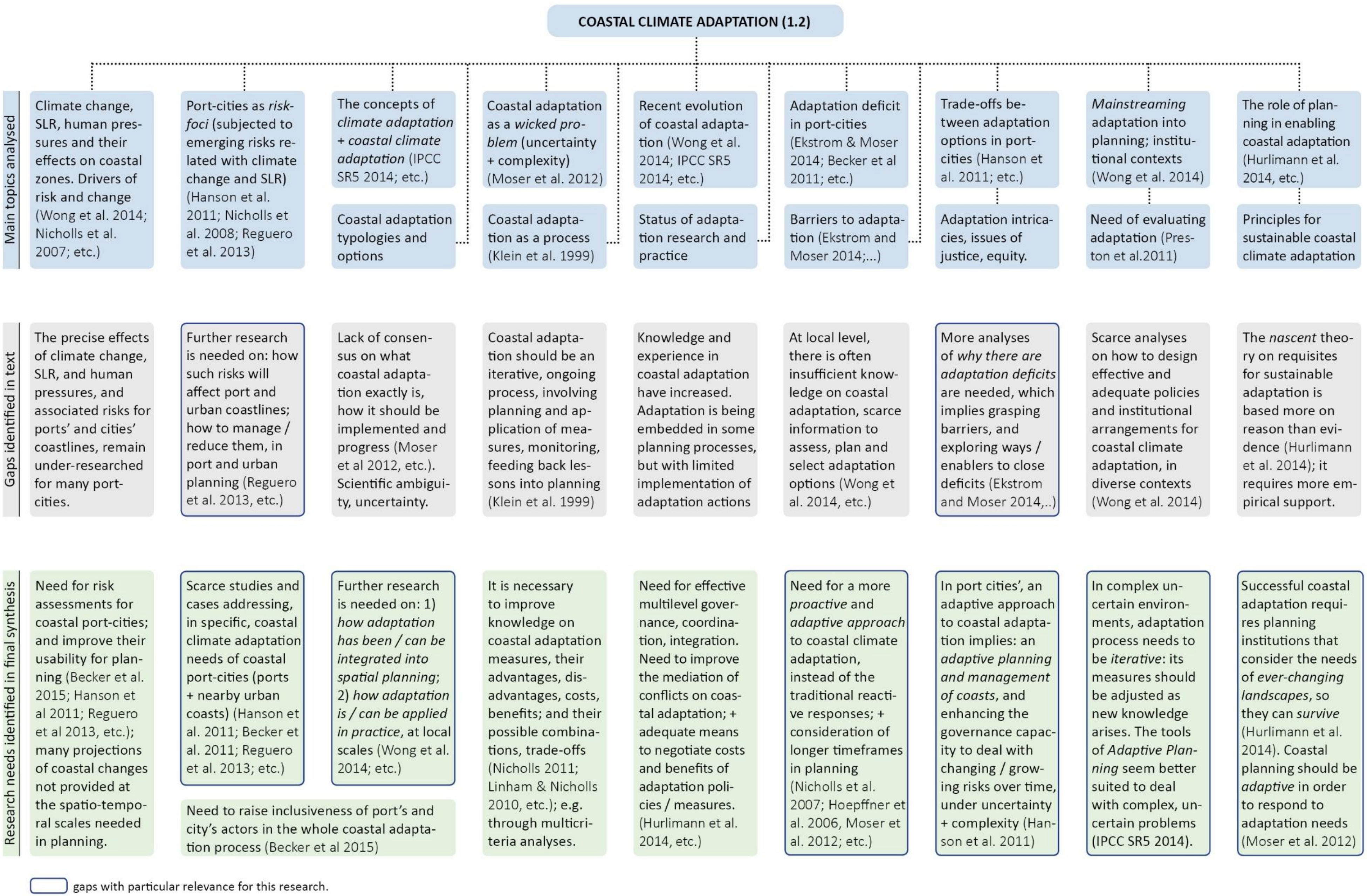


Diagram 2. Main topics analysed and gaps identified in 1.2.

1.3. ADAPTIVE PLANNING

1.3.1. INTRODUCTORY NOTE: 'ADAPTIVE PLANNING AND MANAGEMENT' FOR COASTAL CLIMATE ADAPTATION

Planners and decision-makers are faced with deep uncertainties regarding multiple external factors related to future climatic, environmental, and physical changes, as well as socioeconomic, political or technological developments, and their effects, changing societal values, interests, etc. To deal with these uncertainties, a new planning paradigm has emerged in the literature: Adaptive Planning. In light of this paradigm, planners need to design 'adaptive plans' – i.e. plans that can be adapted to future uncertain and changing conditions over time (Haasnoot et al. 2013; Walker et al. 2013; Ranger et al. 2013). This paradigm encompasses several approaches for planning under uncertainty and inter-temporal complexity, namely the Adaptation Pathways' approach.

Adaptive Planning approaches have been increasingly recommended across the academic literature on climate adaptation (Ranger et al. 2013). In face of the generalized lack of implementation of climate adaptation actions, and as priorities move from risk assessments to adaptation planning and concretization, in climate adaptation literature and research there have been calls for more decision-oriented approaches – also called Adaptive Planning approaches (Wise et al. 2014). Such approaches are deemed more suited to deal with difficulties in long-term planning for future uncertain conditions related with climate change effects, changing or unexpected risks, shifting interests of at-risk populations, contested values, and long timeframes. In this sense, the Adaptive Planning approaches, especially the Adaptation Pathways, have inspired recent developments in climate adaptation planning (Wise et al. 2014), and have recently been applied in research cases and in a few practical cases.

This section starts with a review of the approaches of the family of Adaptive Planning, focusing, in particular, on the Adaptation Pathways (APs). Then, it identifies cases in which the APs' approach was applied for planning coastal climate adaptation (in 'real' cases, research cases, and into plans / policies). Subsequently, it outlines key-principles that should guide the design of 'adaptive plans' and 'adaptation pathways'. Finally, it presents some directions for further research on Adaptive Planning.

1.3.2. TOWARDS A MORE ADAPTIVE COASTAL PLANNING AND MANAGEMENT

Coastal systems are inherently complex and dynamic, and thus, in coastal climate adaptation there may be no simple or definitive solutions, but partial and temporary solutions (Moser et al. 2012). Adaptation is a process to be managed over time. Hence, some authors have emphasised the need for an *adaptive planning* of coastal zones, or an *adaptive coastal management* (Moser et al. 2012; Brown et al. 2014). Uncertainties and complexities in climate projections and in coastal modelling, and the lack of predictive and reliable information, have led to calls for more *adaptive approaches* for managing climate-related risks, and for an *improved decision support for adaptive coastal risk-management* (Moser et al. 2012).

For Moser et al. (2012), an adaptive coastal management implies an ongoing and iterative process of: risk analysis, planning and assessment of adaptation measures, decision-making, evaluation of adaptation measures applied and ongoing learning. It should be used a 'portfolio of solutions', instead of a single technical solution, especially *low-regrets* solutions; and decisions with long-term horizons should seek to enhance *robustness* and *flexibility*, which implies adjustability / adaptability (regarding the when and which measures should be applied). For Brown et al. (2014), adaptation options can be *best assessed through adaptation pathways*. Adaptation Pathways are sequences of actions that can be used to respond to multiple drivers and uncertainties, and which are guided by indicators (e.g. the magnitude of SLR) help to determine when it is necessary to adapt and how. Multiple pathways keep future adaptation responses open for the future. Some adaptation pathways may lead to undesirable futures, and alternative pathways will be sought to avoid this (Brown et al. 2014) (Note 29).

1.3.3. ADAPTIVE PLANNING UNDER UNCERTAINTY AND CHANGE

The deep uncertainties surrounding climate and SLR projections, the physical modelling of future coastal changes, and future environmental, socioeconomic, or political conditions, cannot be totally removed, thus, there is a need to investigate *how to make good decisions with the existing information* (Ranger et al. 2013) (Note 30). In long-term planning, many uncertainties cannot be reduced, as they involve unknowable aspects in external changes, systems' models, valuation of models' results by future stakeholders, lack of agreement on the desirability of alternative actions. However, climate change science and research have focused more on *what will happen*, rather than *which actions available today might best serve in the future, considering that not everything is predictable* (Walker et al. 2013).

Walker et al. (2013, p.957, 971) sum up four main ways of dealing with deep uncertainties in planning:

- **Resistance.** It involves planning for the worst-case scenario. It might be very costly, and the plan may not work so well because of surprises.
- **Resilience.** It seeks to ensure that, regardless of what might happen, the system is able to recover quickly. It accepts possible short-term pain (negative system performance) and focuses on recovery.
- **Static robustness**. It seeks to reduce vulnerabilities of the plan under a wide range of future conditions. In this approach, it is developed a static robust plan. It implies searching for the actions that are most robust across multiple models and several assumptions. A *static robust plan* should perform satisfactorily (but not optimally) under a broad range of plausible futures according to predefined criteria. In a *static robust plan*, adaptation over time is not explicitly considered, and the actions foreseen are mainly 'anticipatory' (it does not include actions to adapt the plan over time).
- **Dynamic robustness** (also called **flexibility**). It involves the capacity to change plans (their measures) over time, as knowledge gets available, or changes occur in the system. It does not focus on developing a plan that is optimal for a specific future projection or best prediction; instead, it considers a wide range of plausible futures (scenarios), and it searches for those actions that are more robust (i.e. that achieve a reasonable level of goodness across the myriad models and assumptions). A *dynamic robust plan* is adaptable (its adaptation may occur through anticipatory, concurrent, and reactive actions). A *dynamic robust plan* is more suitable to cope with changing and unexpected future conditions (Walker et al. 2013, p.957-958, 971) (Note 31). This approach involves designing plans that can be changed over time as more is learnt or changes occur (Ranger et al. 2013).

Traditionally planners assumed that a good plan was a '*static robust plan*', which was expected to be perform satisfactorily under several probable scenarios, however, if the future unfolded in different ways than expected, the plan fails (Walker et al. 2013; Haasnoot et al. 2013). *Static Robustness* relies on the scenarios projected, so if they fail, measures fail too; it disregards other alternative future scenarios and, thus, possible alternative measures; and it dismisses new scientific knowledge that may emerge (Kwadijk et al. 2010). Given these drawbacks, other approaches for planning under deep uncertainty and for risk-management have been advocated (Kwadijk et al. 2010; Haasnoot et al. 2013), namely approaches based on *Dynamic Robustness*.

The multiple uncertainties (about climate change, future environmental, socioeconomic, technological, political changes, etc.) have led to the emergence of a new paradigm for planning under deep uncertainty about future changes – so-called ***Adaptive Planning*** (Haasnoot et al. 2013, p.485, 496; Walker et al. 2013; Kwakkel et al. 2015, p.374). According to this paradigm, in face of deep uncertainties, planners must design an *adaptive plan / policy* or a *dynamic adaptive plan / policy*. Such plan / policy must be: *robust* (i.e. perform satisfactorily well across a wide range of plausible future scenarios), and *adaptive / adaptable* (i.e. it can be adapted over time to changing or unforeseen / unexpected future conditions, and, thus, it can '*survive*' change) (Haasnoot et al. 2013, p.485, 496; Walker et al. 2013, p.956, 955, 972, 958; Jeuken et al. 2014, p.2; Kwakkel et al. 2015, p.374; Ranger et al. 2013; Maier et al. 2016, p.159) (Note 32).[37]

The notion of 'deep uncertainty' has fostered the development of adaptive planning and policymaking approaches; climate change and socioeconomic changes have led to an increasing recognition of the need for *robustness* and *flexibility* in systems and plans (Bloemen et al. 2018, p.2).[38]

According to the paradigm of Adaptive Planning, a plan should '*allow for its dynamic adaptation over time to meet changing circumstances*' (Haasnoot et al. 2013, p.485). Adaptive Planning is related with '*the ability to change plans based on new experience and insights*', with '*correctability of decisions, extensive monitoring of effects, and flexibility*' (Haasnoot et al. 2013, p.486). Flexibility can also be related with '*keeping options open*' and serves as an indicator to assess the *robustness* of strategies under uncertainty (Haasnoot et al. 2013, p.486). Thus, the idea of finding a 'static optimal plan' is replaced by the idea of designing a 'dynamically robust plan', i.e. *a plan that will be successful in a wide variety of plausible futures, through the ability to adapt the plan dynamically over time in response to how the future unfolds'* (Kwakkel et al. 2015, p.374).

Several methodological approaches for designing *dynamic adaptive plans* (that are *dynamic robust* and *adaptive*) exist and have been proposed, within the family of Adaptive Planning (Walker et al. 2013; Haasnoot et al. 2013; Kwakkel et al. 2015; Ranger et al. 2013):[39]

- Adaptive Policymaking (Walker et al. 2001; Walker et al. 2013; Haasnoot et al. 2013; 2012).
- Adaptation Tipping-points (Kwadijk et al. 2010; Haasnoot et al. 2013; Walker et al. 2013).
- Route-map / Adaptation Pathways (Haasnoot et al. 2012, 2013; Walker et al. 2013; Reeder and Ranger 2011).
- Dynamic Adaptive Policy Pathways (Haasnoot et al. 2013; Walker et al. 2013).
- approaches derived from Adaptive Management of Holling (1978) (e.g.Van der Voorn et al. 2015).

All these Adaptive Planning approaches are deemed *valuable* for designing *adaptive plans/policies*. Some Adaptive Planning approaches resort to specific techniques to support planning and decision-making under deep uncertainty, e.g.: *Decision-trees*, *Roadmaps*, *Real Options Analysis* (ROA), *Backcasting*, *Assumption-Based Planning*, *Robust Decision-Making* (Haasnoot et al. 2013, p.486).

Most of the above-mentioned Adaptive Planning approaches consider the ability to change plan / policy based on new knowledge and information, in a planning circle (Pahl-Wostl 2007; Ranger et al. 2010; Swanson et al. 2010; Willows and Connell 2003), which also known as 'iterative risk management'. An *iterative risk management* implies a cycle of steps, namely: the assessment of risks, the identification of options that are robust across a set of possible futures, the choice and implementation of decisions, and the evaluation and revision of choices as new information arises (*in* Haasnoot et al. 2013, p.486).

---

[37] The first theories on 'adaptive plans' date back to John Dewey's work (1927), who argued that plans should be treated as 'experiments', subjected to continual learning and adaptation according to experience and new insights over time (Haasnoot et al. 2013; Walker et al. 2013). The first applications of 'dynamic adaptive plans' occurred in environmental management (Holling 1978; McLain and Lee 1996).

[38] In the last decades, the recognition of the non-stationarity of risks and drivers of change, of climate change as a trend-breaker, and the occurrence of extreme weather events, led to calls for '*a paradigm shift from the prevailing 'predict and control' regime to a 'flexible and adaptive' regime in which the long-term horizon of climate change and socioeconomic changes, and associated scientific uncertainties, are explicitly taken into account. In that sense, climate change provides new incentives for the need to plan ahead and to anticipate extreme events*' (Zevenbergen et al. 2018).

[39] The Adaptive Planning approaches are often given different names, namely: *approaches for planning and decision-making under deep uncertainty* (Haasnoot et al. 2013); *decision-oriented approaches* (Wise et al. 2014; Ranger et al. 2013); *approaches for designing a sustainable adaptive plan*, or also *planning approaches for adaptation under deep uncertainty* (Walker et al. 2013). While this family of approaches is relatively novel in climate adaptation literature, it has roots in long-standing theories (Ranger et al. 2013). According to Walker et al., most of the conceptual approaches for designing a sustainable adaptive plan have their origins in an approach for long-term planning named 'Assumption-Based Planning' (Walker et al. 2013, p.955) (see Note 33 and Note 34). Such approaches help to build a more 'robust' plan / strategy (that performs well according to defined criteria under a wide range of possible future states of the world; which differs from the more traditional approach that seeks to optimize a plan / strategy to a particular risk level (e.g. to a single scenario) (Ranger et al. 2013).

The Adaptive Planning approaches are useful to deal with uncertainty about future conditions and changes. All these approaches favour and seek to enhance: the capacity to adapt plans (*adaptability*), the flexibility of plans / policies (e.g. by *keeping options open* for the future), monitoring of the world and *correctability* of the plan as changes occur and new information emerges. These approaches have been advocated to support climate adaptation planning and decision-making (Haasnoot et al. 2013; Walker et al. 2013).

In the field of climate adaptation, scientists and experts have developed and used several of the approaches for planning under (and dealing with) deep uncertainty, namely the Adaptation Pathways' approach (Reeder and Ranger 2011; Haasnoot et al. 2013; Wise et al. 2014; *in* Bloemen et al. 2018). The interest for '*long-term plans that can adapt to changing situations under conditions of deep uncertainty'* has increased (Walker et al. 2013, p.955).

1.3.4. Adaptive Planning approaches

This Section identifies the main Adaptive Planning approaches currently used and explains how they work. It builds on the work of Walker et al. (2013) and Haasnoot et al. (2013), among other authors.[40]

1.3.4.1. Adaptive Policymaking

Adaptive Policymaking (APM) is an approach for designing a 'dynamic robust adaptive plan' (Haasnoot et al. 2013, p.487; Walker et al. 2013, p.961). Walker et al. (2001) developed APM for designing 'dynamic robust plans, in face of multiple uncertainties. APM is an Adaptive Planning approach which is rooted in *Assumption-Based Planning* (Haasnoot et al. 2013, p.485). APM supports the implementation of long-term plans despite the existence of uncertainties (Walker et al. 2013, p.961).

Haasnoot et al. define APM as a *stepwise approach* for producing a 'basic plan', which describes *'a planning process with different types of actions (e.g. 'mitigating actions' and 'hedging actions') and signposts to monitor to see if adaptation is needed*' (Haasnoot et al. 2013, p.485), and which includes 'contingency actions' to adapt the plan to new information over time (Haasnoot et al. 2013, p.486). The APM approach not only specifies 'contingency plans', but also signposts and 'triggers' (conditions under which the policy should be reconsidered) (Walker et al. 2001).

APM defines a *course of action* to be followed according to well-defined objectives (Haasnoot et al. 2013). It takes into account ways in which a plan might fail and foresees actions that can be activated to avoid it, and a monitoring system to detect the timing for response actions, however, it does not specify how such actions should be sequenced (Haasnoot et al. 2013).

APM involves 5 stages required to develop an 'adaptive plan' (**Figure 5**).

[40] In their article, Haasnoot et al. (2013) present an overview of main approaches for designing *adaptive plans* – i.e. the existing *Adaptive Planning* approaches, which support decision-making under deep uncertainty – and explain how they can be used to generate a *dynamic adaptive plan* (Haasnoot et al. 2013, p.485, 486). In a similar way, Walker et al. describe and compare several methodological approaches for designing a *sustainable adaptive plan* – which belong to the family of Adaptive Planning approaches (Walker et al. 2013, p.955; 958).

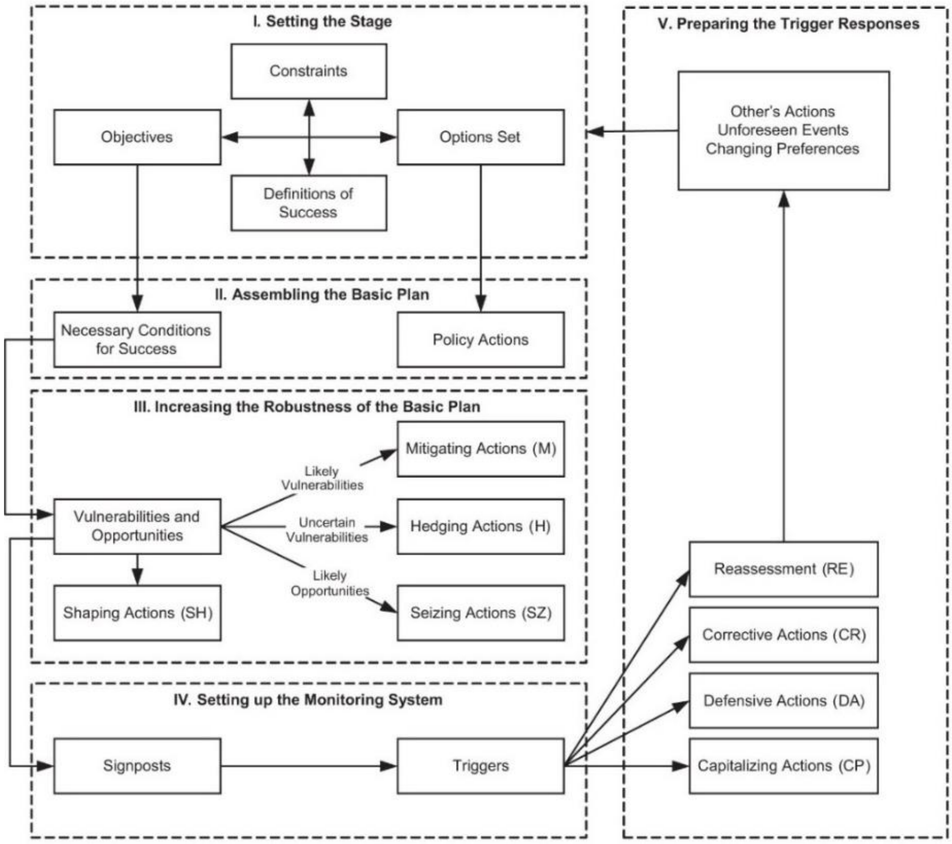


Figure 5. Stages of the APM approach for designing an 'adaptive plan'. Source: Haasnoot et al. 2013, p.488.

The stages of the APM approach are:

I. *Setting the stage*. Analyse the existing conditions of a system, and define the objectives of the Plan (to be developed in the future) (Kwakkel et al. 2010a, *in* Haasnoot et al. 2013, p.487). This implies a 'definition of success' and constraints (Walker et al. 2013, p.962).

II. *Assembling of the Basic Plan*. Specify the way(s) through which the objectives will be achieved, and, in this way, assemble the 'basic plan'; i.e. define the conditions and actions necessary to achieve objectives (Kwakkel et al. 2010a, *in* Haasnoot et al. 2013, p.487). This means identifying conditions for (ways to) achieving objectives and define the policy actions needed (Walker et al. 2013, p.962).

III. *Increasing the Robustness of the Basic Plan* – i.e. preparation of actions to increase the robustness of the Basic Plan, namely *mitigating*, *hedging*, *seizing* and *shaping* actions. This involves making 'basic plan' more robust by devising four types of actions: mitigating actions (which reduce the likely adverse effects of a plan), hedging actions (which reduce uncertain / unknown adverse effects of the Plan), seizing actions (which seize potential opportunities), and shaping actions (which reduce failure or enhance success) (*in* Haasnoot et al. 2013, p. 487; Walker et al. 2013, p.962). This implies identifying opportunities and vulnerabilities, and then defining 'mitigating, hedging, seizing, and shaping' actions. These actions are anticipatory and concurrent (Walker et al. 2013, p.962).

IV. *Setting up the monitoring system*. Defining the monitoring system, including *signposts* (to see if the plan is meeting its objectives and if adaptation is needed) and *triggers* (to evaluate if further measures are necessary). This monitoring system should monitor and evaluate the performance of the Plan and indicate if actions need to be taken (and which and when). This implies 'signposts' (information that should be tracked to determine whether the plan is meeting the conditions for its success) and 'triggers' (critical values of the signpost variables, beyond which additional / new actions should be taken) (Kwakkel et al. 2010a, *in* Haasnoot et al. 2013, p.487; Walker et al. 2013, p.962).

V. *Preparing trigger responses*, i.e. preparation of 'contingency actions' to respond to the triggers, namely *capitalizing*, *defensive*, *corrective*, or *reassessment* actions. This step involves the specification of four types of actions that can be activated / triggered by a critical value / trigger: *defensive actions* (which clarify the plan, preserve its benefits, or meet outside challenges in response to specific triggers, and which leave the plan unchanged); *corrective actions* (adjustments to the plan); *capitalizing actions* (to take advantage of opportunities to improve the performance of the plan); and a *reassessment of the plan* (initiated if the assumptions underlying the success of the plan lose their validity) (Kwakkel et al. 2010a, *in* Haasnoot et al. 2013, p.487; Walker et al. 2013, p.962). The actions of Step IV are reactive (Walker et al. 2013, p.962).

As seen in **Figure 5**, APM has two phases: (1) the design phase, in which the *dynamic adaptive plan*, the monitoring program, and pre- and post-implementation actions, are designed, and (2) the implementation phase, in which the plan and the monitoring program are implemented, and actions are taken, if necessary. After the *dynamic adaptive plan* is established, the plan is implemented, and monitoring is initiated (Walker et al. 2013, p.961-962)[41] (Note 35).

APM was applied in the expansion of the Port of Rotterdam, flood risk management in the Netherlands considering climate change, airport planning, urban transport, Maglev rail transport, energy transitions, etc. (Walker et al. 2013).

1.3.4.2. Adaptation Tipping-points

Adaptation Tipping-points (ATP) are points / conditions under which the existing management / adaptation strategy ceases to be effective and a new strategy is necessary. Kwadijk et al. (2010) explain that, in climate adaptation, an ATP is the *point where the magnitude of change due to climate change or SLR is such that the current management strategy will no longer be able to meet the objectives*, and a *new management strategy is needed* (Kwadijk et al. 2010). Hence, ATP can be used to identify under which conditions an adaptation measure / action can no longer meet its goals (its *sell-by date*), and a shift to other measure / action is required. An ATP can be triggered by diverse factors, for example: physical, ecological, technical or socioeconomic thresholds (Kwadijk et al. 2010; Haasnoot et al. 2013).

The ATP approach provides useful information about '*what*' and '*when a critical point might be reached*'. It addresses basic questions that decision-makers often face, for instance: *how much climate change and sea level rise can the current strategy cope with*; *what are the most urgent effects*; *when will these effects occur* according to scenario a, b, c; and *what measures will be needed by then* (Kwadijk et al. 2010), and under which conditions the objectives are no longer achieved. As Walker et al. explain, ATP help to identify under what conditions will a given measure / action fails and new actions will be required; and detect the timing required for implementing such actions, under different climate projections. If new projections arise, the timing of actions can be updated (Walker et al. 2013).

ATP are useful to deal with uncertainties in climate and SLR projections (Kwadijk et al. 2010). In addition, this approach is used in the design of Adaptation Pathways: the reaching of an ATP requires new actions to meet the objectives. According to Haasnoot and Jeuken, an ATP refers to conditions under which the *status quo (i.e. current management action)*, a policy action, or a range of actions, will fail. An ATP is reached when the magnitude of (external) change is such that a given action / measure

[41] Here, the term 'trigger' refers to conditions under which a predefined action to change the plan must be taken (Haasnoot et al. 2013, p.486).

can no longer meet the policy objectives, and new actions are required to meet such objectives. The timing of an ATP (i.e. the *use-by-date* of actions) is scenario-dependent. In this sense, a plan can be updated if new information emerges (e.g. if new climate scenarios are developed, the timing of ATPs timing, and, thus, the timing for implementing new actions, may be adjusted (Haasnoot and Jeuken).

Kwadijk et al. (2010) developed the ATP to analyse for how long the Dutch water and flood management system would be effective under diverse climatic and SLR scenarios.[42] The concept of ATP appeared in response to the request of Dutch policymakers to facilitate the updating of plans in accordance with new climate scenarios (Haasnoot and Jeuken) (**Figures 6** and **7**).

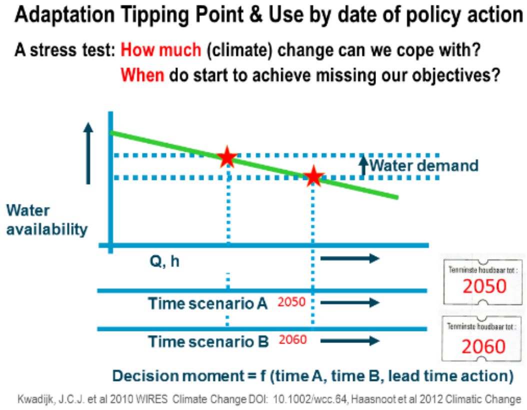


Figure 6. Example of an ATP. If water availability (Y axis) decreases over time (X axis), due to e.g. climate change, there may be a point at which there is insufficient amount to supply the demand (dashed lines, indicating the minimum acceptable values of water availability, i.e. the ATPs). The timing of such ATP (sell-by year of the status quo or policy action) may come earlier in a fast-changing climate (scenario A) and later in a slower changing climate (scenario B). Source: *in* Haasnoot and Jeuken.

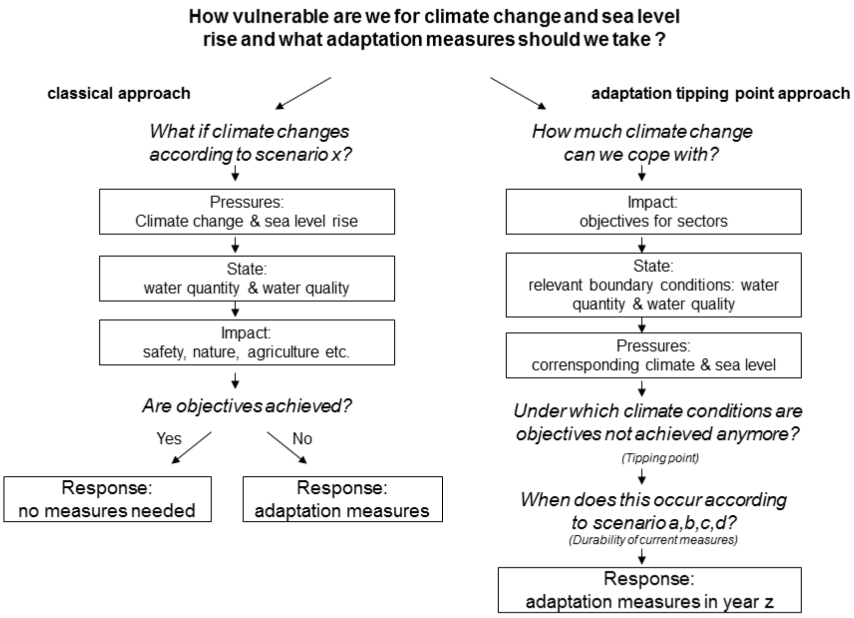


Figure 7. Examination of ATPs. Source: Haasnoot and Jeuken. The ATP is different from the traditional risk analyses developed in a top-down way: instead, it contains elements of bottom-up analysis of climate-related vulnerabilities and risks. The classic top-down approach focuses on question '*what if climate or sea-level changes according to a given scenario*', followed by an analysis of possible impacts and problems, and then the definition of measures to tackle such problems. The ATP approach addresses '*how much climate change / sea-level rise can the system cope with*' (Haasnoot and Jeuken).

[42] ATP was developed to answer a request from Dutch water managers to update their plans to new climatic scenarios. ATP was used in water management in Netherlands in 2011; flood-risk management in Rotterdam; risk-management in New Zealand (Walker et al. 2013) (Note 36).

1.3.4.3. Adaptation Pathways

Haasnoot et al. (2013) define Adaptation Pathways (APs) as a methodological approach '*for exploring and sequencing a set of possible actions according to external developments over time*' (Haasnoot et al. 2013, p.485). More specifically, it involves the exploration of possible sequences of actions (e.g. flood risk management actions / adaptation actions) throughout time, based on external developments and changing conditions (e.g. climate, physical, environmental, or socioeconomic changes, SLR, etc.). The APs approach, also called 'Route-map approach' or 'Decision pathways approach is an Adaptive Planning approach (Walker et al. 2013, p.963; Haasnoot et al. 2012, 2013, p.485).

The method of APs developed by Haasnoot et al. (2011, 2012, 2013) builds on the methodological approach that was used in the *Thames Estuary 2100 Project* – known as the 'Route-map approach' or 'Decision-pathways approach' (Reeder and Ranger 2011) – and on the ATPs approach (Note 37).

The APs approach serves to explore and sequence alternative management / policy actions for adapting to changing environmental and societal conditions (i.e. adaptation actions) (Haasnoot et al. 2012). The approach produces a set of alternative pathways into the future, i.e. it offers an overview of various routes that might be followed as time unfolds (Walker et al. 2013, p.963).

A pathway is a 'sequence of possible actions' over time. When the ATP of a given action is about to be reached, new / other actions are needed, and, thus, a pathway emerges. In this way, several possible pathways can be assembled. The various pathways are usually represented in a map – a 'route-map' or a 'decision tree'. Each route in the map is a pathway, and an APs' map presents various pathways (Haasnoot et al. 2013, p.487). Each adaptation pathway is composed of several sequenced adaptation actions that are available: a new measure is applied once a tipping-point is in sight, i.e. when the predecessor action reaches its *sell-by date*. The pathways (plural) correspond to the set of various pathways. Thus, an APs' map is similar to a metro-map: it contains alternative routes (from the present towards the future) to arrive at a desired state in the future according to the objectives defined – i.e. different ways to get to a specific destination, in other words, '*different ways leading to Rome*' (Haasnoot et al. 2013, p.487; Walker et al. 2013, 963).

The APs approach employs the concept of adaptation tipping-point (ATP), i.e. the point at which a given action is no longer adequate for meeting the plan's objectives, and a new action is necessary (Haasnoot et al. 2013, p.486). Actually, the APs' approach is *a logical extension* of the ATPs' approach: the reaching of an ATP requires new actions so that the plan can achieve its objectives, and, in this way, a pathway emerges (Walker et al. 2013, p.963; Haasnoot et al. 2013, p.487). In the APs approach, ATPs are '*conditions under which an action no longer meets the clearly specified objectives*'; when an ATP is in sight, additional actions are needed, and, thus, a pathway emerges (Haasnoot et al. 2013, p.487).

An APs' map is illustrated in **Figure 8**. In an APs' map, an ATP is like a 'terminal station' (vertical sticks) before which there are '*transfer stations*' (circles) to other actions / options. The Aps map shows the tipping-points and all available options (via *transfer stations*). Some pathways are only viable in some scenarios. The timing of the ATP of a given action – i.e. its *sell-by date* – depends on the scenario used and objectives defined (Haasnoot et al. 2013, p.487, 493; Walker et al. 2013, 963).

The APs' map identifies ATPs (points where an action no longer meets the predefined criteria, and where it is necessary to take an additional action, or switch to other action or pathway (Ranger et al. 2013). Each pathway consists of a set of individual adaptation measures (Ranger et al. 2010). The APs approach allows the planner to explore possible adaptation measures over time and sequence them (in pathways) and identify the timing for such measures under different scenarios (Ranger et al. 2010).

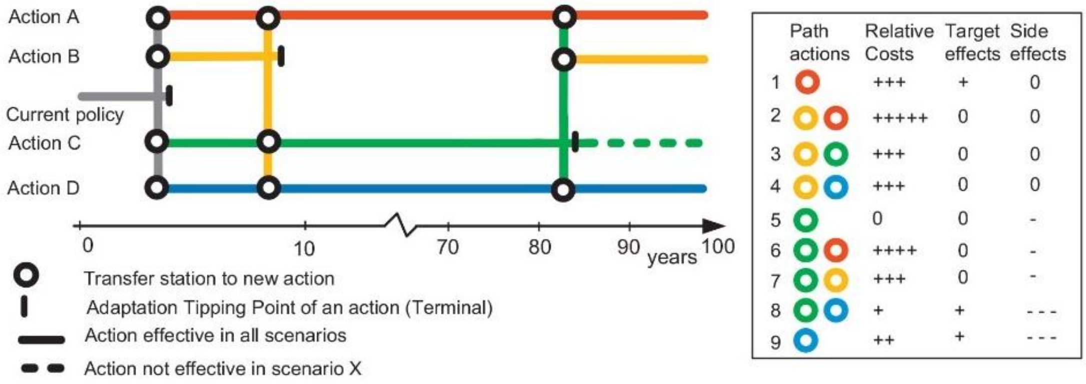


Figure 8 (left). An APs' map (left side). Figure 8 (right): scorecard of the costs and benefits of 9 possible pathways (right side). Source: Haasnoot et al. 2013, p.487. It can be observed that in the short-term it will be necessary to take actions (within 4 / 5 years). If action B is chosen, additional actions will be necessary within 8 / 9 years. If action C is chosen, additional actions may be needed within 82 / 83 years, but only if scenario X becomes real (Haasnoot et al. 2013, p. 487). The APs' map, in conjunction with a scorecard (of the costs and benefits of the diverse pathways), allow a decisionmaker to make a more informed decision (Haasnoot et al. 2013, p. 487). Departing from the current policy / situation, the objectives start to be missed after 4 years. At this point, there will four options available (A, B, C and D). Action A and action D will achieve the objectives for the next 100 years, under all scenarios considered. If action B is selected (after the first four years), it will likely reach an ATP within 5 years, which will demand a shift to another action. If action C is selected, it will require a shift to another strategy in case Scenario X occurs. Description according to Walker et al. 2013, p.964.

The APs help in the visualization of possible adaptation actions in time. Its map and the scorecard provide insights into the actions and their enchainment, and are useful for identifying: low / no-regret options, opportunities, adequate timings for actions, potential lock-ins, path-dependencies, and actions required now to keep future options open (Haasnoot et al. 2013; Walker et al. 2013; Ranger et al. 2013).

The APs approach supports, and informs, planning and decision-making in several ways, namely:

- It gives information about the sequencing of actions over time, and it considers a large range of transient scenarios. This range of transient scenarios accounts for multiple uncertainties about future changes and developments, natural variability, etc.
- It identifies the timing of ATPs under different scenarios – i.e. *sell-by date* of an action, and the moment for shifting to other actions – which contributes to the *dynamic robustness* of the Plan.
- APs give insights into available options, potential lock-ins and path-dependencies (Haasnoot et al. 2013, p.496). Hence, an APs' map can be a useful *starting point for decision-making on short-term actions, while keeping options open and avoiding lock-ins* (Haasnoot et al. 2013, p.496, 489).[43]
- The APs' map helps to identify no-regret actions, opportunities, and the appropriate timing for an action; in this way, it supports decision-making in changing contexts (Haasnoot et al. 2013, p.495-496, 487; Walker et al. 2013, p.964; Ranger et al. 2013; Haasnoot et al. 2012) (Note 38).

In the AP's approach, actions are sequenced in such a way that enable the system to be adapted over time to changing conditions (e.g. climatic, environmental or socioeconomic conditions), and options are kept open to cope with such possible conditions (Walker et al. 2013). The approach stimulates planners to reflect upon 'what if' situations and their outcomes, for example: 1) *what conditions might lead a pathway or action to fail*; 2) *what actions might be necessary to avoid this*; and 3) *what actions should be prepared now to be triggered later* (Walker et al. 2013; Ranger et al. 2013). By enabling shifts to other actions, the APs contribute to enhance the flexibility of the overall adaptation strategy / plan.

[43] A lock-in can be, for instance, 'a situation in which sub-optimal solutions persist because they have materialised in the physical, as well as the social, environment", or a situation in which the 'flexibility of a system is limited by how the system developed in the past'. Lock-ins can result from 'path dependency'. E.g. the traditional emphasis on flood control and flood protection technologies over the last century is often deemed to have led to a 'lock-in'; in these situations, changing to a different solution is often quite difficult, as flood control has 'materialised' in physical artefacts (e.g. dikes, dams, seawalls) and as 'social constructs' (e.g. water institutions) (Restemeyer et al. 2017, p.924).

Flexibility is produced via the use of: tipping-points, and shifts to other actions after tipping-points (Haasnoot et al. 2013). The flexibility of having options available for the future also drives decisions.

Overall, the APs approach is an *application-oriented approach* for designing adaptation pathways, which focusses on exploring '*actions for achieving objectives over time*' (Haasnoot et al. 2013, p.489). It explicitly considers a 'multiplicity of plausible futures' by using a wide range of 'transient scenarios' (Haasnoot et al. 2013, p.489). In this sense, it addresses multiple uncertainties. The APs approach involves the design of an APs' map, which illustrates *'sequences of possible actions'* over time, and it considers uncertainties relative to climatic, environmental and socioeconomic conditions and changes (within the scenarios used) (Haasnoot et al. 2013, p.495).

The APs is a planning approach that was devised to develop an adaptive plan / strategy, to '*address deep uncertainties in policymaking processes and to design robustness into the adaptation strategy itself*' (Isoard and Winograd 2013). It seeks to build flexibility into the adaptation plan / strategy itself (in addition to the individual measures) by sequencing diverse measures over time, *so that options are left open to deal with a range of possible different futures* (*in* Isoard and Winograd 2013).

The AP's map clearly shows when an action should be changed, and what should be the next action – and, in this way, it contributes to the flexibility of the resulting (general) plan. In its turn, the 'dynamic robustness' of the resulting plan, is (indirectly) ensured way, via: (i) the identification of the 'sell-by dates' of actions under different scenarios (which support the identification of moments for shifting to other actions), and ii) the possibility to switch to other actions (Haasnoot et al. 2013, p.489).

The APs approach is a promising approach to deal with uncertainties surrounding climate change effects, mainly due to its capacity to support the development of *robust* and *flexible* adaptation strategies. Flexibility is implicit in the so-called 'transfer stations' – the points at which a choice must be made between diverse measures – and also in the variety of measures that may be implemented when an ATP is reached (Brugge and Roosjen 2015, p.743-744).

In the light of this approach, planners facing deep uncertainties related with climate change risks and socioeconomic developments should: 1) create a strategic vision of the future, 2) commit to short- and mid-term actions, and establish a plan that can be adapted over time to meet changing conditions and ensure flexibility and adaptability in the long-term (*in* Isoard and Winograd 2013).

Process of construction of APs

Importantly, the APs approach involves a process of several steps (**Figure 9**), among them: 1) describing the current and future situation, and defining objectives; 2) assessing risks and problems; 3) exploring actions, 4) analyse various plausible future scenarios, 5) assess actions and determine the moment of the ATPs of actions (i.e. their *sell-by dates*) in the different scenarios, and identify the actions that are robust across a set of possible future, 6) develop (assemble) pathways (which may lead back to step 3). It also implies re-evaluating, and if necessary, revising decisions / choices as new information emerges or changes occur over time (Note 39).

The APs' approach implies the definition of clear goals against which the success, efficiency and performance of actions and pathways are evaluated, and which underlie the whole adaptation process (although these goals may change according to evolving climatic, environmental, or socioeconomic conditions, over time) (Haasnoot et al. 2013). Haasnoot et al. suggest that the APs' visualization works better if the basic objectives can be summed up in a single main objective (e.g. safety against flooding).

The pathways are expected to follow minimum performance levels according to the main objectives and goals predefined (Haasnoot et al. 2013). The design of the APs should involve the participation of relevant stakeholders and decision-makers; their preferences and visions are collected to identify alternative *physically* and *socially robust pathways*. The costs and benefits of each pathway, as well as the diverse preferences that stakeholders hold for each pathway, can be measured and represented in a scorecard. Moreover, this approach usually implies the application of *fast and simple* computational tools. As some pathways may be preferable than others, a group of *preferred pathways* can be selected. In discussions with decision-makers, it can be useful to simplify the APs' map, using only *preferred pathways* extracted from a more comprehensive map (Haasnoot et al. 2013).
Moreover, critical tipping-points can be subjected to sensitivity analysis and further monitored, so that the map can be adjusted. Provided that there is ongoing monitoring and learning, and that *surprises* are considered, the APs allow for planned adjustments, enhancing plan's adaptivity (Ranger et al. 2013).

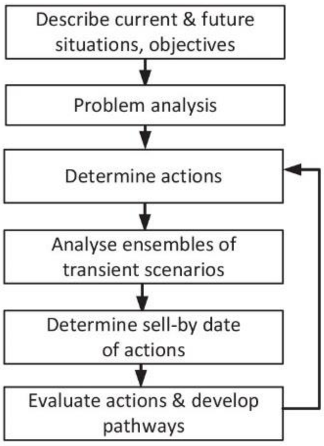


Figure 9. Steps for constructing the Adaptation Pathways. Source: Haasnoot et al. 2013, p.487.

The design of the APs should involve the participation of relevant stakeholders and decision-makers: their visions and preferences are collected to identify *physically* and *socially robust pathways*. The costs and benefits of each pathway, as well as the diverse preferences that stakeholders hold for each pathway, can be measured and represented in a scorecard. As some pathways may be preferable than others, a group of *preferred pathways* can be selected. In discussions with decision-makers, it can be useful to simplify the APs' map, using only *preferred pathways* extracted from a more comprehensive map (Haasnoot et al. 2013).

This approach presents several advantages: it supports and informs long-term planning and decision-making under deep uncertainty and in changing environments; it is robust to climate change-related uncertainties and other sources of uncertainty and risk (e.g. future socioeconomic, political, institutional changes); it does not require much time or intensive studies. The design of route-map and the definition of tipping-points can result from an assessment using experts' and stakeholders' inputs (Haasnoot et al. 2013; Walker et al. 2013; Ranger et al. 2013). The APs' approach explores *actions for achieving objectives over time*, and considers *dynamic interactions between the system and society* (Haasnoot et al. 2013)[44] (Note 40).

Nevertheless, APs may also have drawbacks: the approach offers no guidance on how the decision-map and its pathways can be translated into a real plan; its methodological, analytical and computational

[44] APs' approach considers interdependencies between climate change effects (their uncertain timing and magnitude) and adaptation responses (their features, costs, lead- and lag-times, reversibility) (Wise et al. 2014). In this respect, Wise et al. (2014) note that the approach underlines the need for a flexible and iterative management of decisions, informed by a strategic vision of the future, and a monitoring system.

tools (e.g. scenario modelling) can be too complex and demand simplification (Haasnoot et al. 2013; Walker et al. 2013; Ranger et al. 2013). The APs implies the definition of clear objectives against which the success of actions and pathways is evaluated, however, policymakers often give vague targets, which make difficult the assessment of the success and efficacy of adaptation actions and pathways (Haasnoot et al. 2013). Besides that, many adaptation actions require a lead time and triggers, which in the case of climate change can be difficult to detect due to natural climatic variability.

Still, APs proved to be useful in several contexts. This approach was applied in: flood-risk and water management in the Dutch Delta Programme in the Rhine-Meuse Delta (Haasnoot et al. 2013); the Thames Estuary 2100 Project (Ranger et al. 2013; Penning-Rowsell et al. 2013); an initiative for coastal adaptation planning in New York City (Rosenzweig et al.2011) (Note 41, and Table K, Appendix).

1.3.4.4. Dynamic Adaptive Policy Pathways

Haasnoot et al. (2013) developed a methodological approach for developing a '*dynamic adaptive plan*' and supporting decision-making under changing and uncertain future (global and regional) conditions – i.e. the 'Dynamic Adaptive Policy Pathways' (DAPP) (Haasnoot et al. 2013, p.485-486, 495, 496). DAPP results from the integration of two existing Adaptive Planning approaches (for designing *adaptive plans*): 'Adaptive Policymaking' (APM) (Kwakkel et al. 2010a; Walker et al. 2001) and 'Adaptation Pathways' (APs) (Haasnoot et al. 2012) (*in* Haasnoot et al. 2013, p.485; Walker et al. 2013, p.964). This integrated approach contains strengths of each of these approaches (Haasnoot et al. 2013, p.486).

This approach specifies a process of 10 steps to design and implement a 'dynamic *adaptive plan*' *able to deal with changing and unforeseen future conditions*', in a continuous cycle (Haasnoot et al. 2013, 496) (**Figure 10, left**).

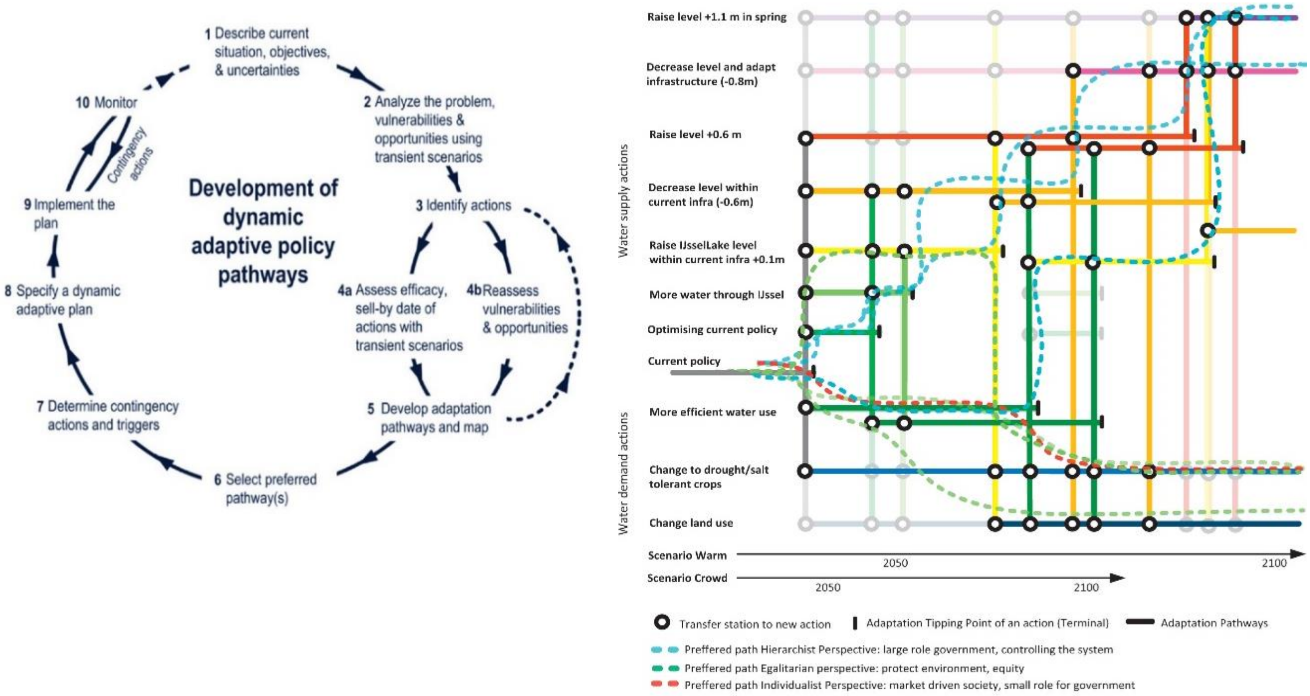


Figure 10. Dynamic Adaptive Policy Pathways' cycle (left). Example of an Adaptation Pathways' map with the preferred pathways indicated for three different perspectives (right). Source: Haasnoot et al. 2013.

The main steps of the DAPP process are the following (Haasnoot et al. 2013, p.490; Walker et al. 2013, p.964) (see Note 42):

Step 1: describe current situation, objectives and uncertainties. This step entails: (1a) describing the study area, namely the system's characteristics, and major uncertainties; (1b) defining the objectives; (1c) identifying the main constraints in the current situation and in possible future situations. Sub-step (1a) implies the identification of the main uncertainties relevant for decision-making (e.g. about the future, data or models used). Step 1 results in a 'definition of success' that specifies the 'desired outcomes' in terms of 'indicators' and 'targets' – these indicators and targets will be used in the next steps to assess the '*sell-by dates*' of the actions (i.e. the date of their ATPs), and to assess the performance and efficacy of the actions and pathways (Haasnoot et al. 2013, p.490). It is also important to identify uncertainties relevant for decision-making, and generate scenarios (considering such uncertainties) (Walker et al. 2013, p.964).

Step 2: analyse the problem, vulnerabilities and opportunities, using '*transient scenarios*'[45]. This step consists of the 'problem analysis'. In this step, the 'current situation' and the 'possible future situations' (i.e. transient scenarios) are both compared to the predefined objectives to examine whether there are any gaps. A gap indicates that actions are required. It is important to consider two types of gaps: 'vulnerabilities' (developments that can harm / hamper the achievement of the objectives), and 'opportunities' (developments that help in achieving the objectives). The identification of vulnerabilities and opportunities involves the analysis of the 'possible future situations' (Haasnoot et al. 2013, p.490). This step implies comparing the plausible future scenarios with the objectives to see if problems, vulnerabilities, or opportunities, arise (Walker et al. 2013).

Step 3: Identify actions. This step consists of the identification of actions that can be taken to meet the 'definition of success'. The identification of such actions should consider the vulnerabilities and opportunities previously identified. These actions can be categorized according to the types of actions specified in the APM method (i.e. shaping, mitigating, hedging, and seizing actions). The aim of this Step is to gather a rich set of possible actions. An identification of actions according to different 'cultural perspectives' could foster this (Haasnoot et al. 2013, p.490). The aim is to gather a rich set of possible actions. The possible actions will be used as 'building-blocks' of the pathways in the subsequent steps (Walker et al. 2013, p.964).

Step 4: Assess the efficacy and the *sell-by date* (date of the ATP) of the actions, under the several 'transient scenarios' (4a), and then reassess vulnerabilities and opportunities (4b), in an interactive way. Sub-step (4a) consists of evaluating the effects of the individual actions on the 'outcome indicators' in each of the scenarios used (and presenting them in scorecards), and determining the *sell-by date* of each action across the various scenarios[46]. The sub-step 4b involves reassessing the vulnerabilities and opportunities, by addressing the following questions: *was the action able to reduce or remove an identified vulnerability; was the action able to use an identified opportunity; does the action create new opportunities and / or vulnerabilities*. Sub-step 4b (reassessment of the vulnerabilities and opportunities) may lead back to Step 3, in which new / additional actions are identified (in an interactive way). In this way, ineffective actions are eliminated and 'promising actions' remain. Only the 'promising actions' will be used in the next steps as the '*building blocks*' for assembling the pathways. Once the set of actions is deemed adequate, pathways can be designed. (Haasnoot et al. 2013, p.490). To assess the effects (success and efficacy) of the actions and pathways, it is important to set 'quantitative targets' (Haasnoot et al. 2013, p.496).

Step 5: Develop adaptation pathways and draw the map. This step consists of assembling the adaptation pathways. A pathway is '*a concatenation of actions where a new action is activated once its predecessor is no longer able to meet the definition of success*' – i.e. a sequence or enchainment of actions (available after the reaching of the ATP of the predecessor actions). The pathways can be constructed / assembled in different ways, e.g. by exploring all possible routes with all available actions, and then evaluating the performance of these routes. Importantly, some actions may exclude others, and some sequences may be illogical. Moreover, there are important criteria that can be used to assemble the pathways, such as: the urgency of actions, the severity of impacts, the uncertainty involved, the desire to keep options open, etc. The result of this Step – the final set of 'promising pathways' – is illustrated in an APs' map. This APs' map contains all logical potential pathways in which 'success' (as defined in Step 1) is achieved (Haasnoot et al. 2013, p.490).

---

[45] *Transient scenarios describe possible futures from today to a point in the future, including changing conditions from a sequence of developments and events*. The transient scenarios consider the uncertainties identified in Step 1 (Haasnoot et al. 2013, p.490).

[46] Sub-step 4a) Assess the performance of each action across the various scenarios and in relation to the objectives defined, and determine their *sell-by date*. Then, (4b) reassess opportunities and vulnerabilities, until an adequate set of actions is reached (Walker et al. 2013, p.964). The performance of each action is assessed in the light of the defined objectives to determine its ATP.

An action (singular) does not need be a single action, but it can be a 'portfolio of actions' (a combination of actions implemented at the same time concurrently / at the same time), constructed after iteration of steps 3–5. The result of this Step is an adaptation pathways' map (Haasnoot et al. 2013, p.490). Overall, Step 5 involves building the pathways and draw the APs map. Once an adequate set of actions is devised, the pathways (i.e. possible sequences of actions) can be built (Walker et al. 2013, p.964).

Step 6: Select preferred pathway(s). I.e choose *a manageable number of 'preferred pathways'*, namely the pathways that fit well within certain cultural perspectives. In this sense, it is useful to specify two to four pathways that reflect different perspectives. This will help in the identification of 'physically' and 'socially robust' pathways. The 'preferred pathways' will form the basic structure of the 'dynamic adaptive plan' (Haasnoot et al. 2013, p.490). Some pathways may be more attractive than others, due to their costs, benefits or side-effects. These aspects should be considered in the selection of the 'preferred pathways' (Haasnoot et al. 2013, p.496). Different stakeholders might prefer different pathways for diverse reasons. One or more pathways should be chosen, and used as input for the 'dynamic robust adaptive plan' (Walker et al. 2013, p.964).

Step 7: Determine 'contingency actions' and 'triggers'. This Step aims to improve the 'robustness' of the 'preferred pathways' through *contingency planning*. It consists of defining actions to get (or maintain) each of the pathways on the track for success. Generally, the 'contingency actions' can be: *actions to anticipate and prepare for one or more preferred pathway(s)* (e.g. actions to keep options open for the future); or *corrective actions* (to stay on track in case the future unfolds differently than expected). The 'contingency actions' can also be categorized according to the types of contingency actions of APM (i.e. corrective, defensive, or capitalizing actions). The 'contingency actions' are related with a monitoring system that specifies 'trigger-values'. Overall, this step implies the definition of a monitoring system. The monitoring system designates *what to monitor* (i.e. signposts / indicators), and the triggers indicate *when a 'contingency action' (or an new action envisioned in the plan) should be activated* (Haasnoot et al. 2013, p.490). Some indicators that might be useful are: SLR, climate and physical changes, land use changes, changes in water demands, etc. (Haasnoot et al. 2013). The Plan will seek to keep the preferred pathway(s) open for as long as possible: this requires the preparation of contingency actions and a monitoring system (including triggers) (Walker et al. 2013, p.964).

Step 8: Specify a 'dynamic adaptive plan'. This step consists of translating the results from all the previous steps into a 'dynamic adaptive plan'. The plan synthesizes the results from the prior steps, namely the targets, problems, possible and preferred pathways. (Based on the problem, objectives, and pathways of the previous steps, a dynamic adaptive plan can be specified). This plan should answer a key-question: *given the set of pathways and the uncertainties about the future, what actions / decisions should be taken now, and which actions / decisions can postponed?* Here, the challenge is to elaborate '*a plan that keeps the 'preferred pathways' open for as long as possible*'. Therefore, the plan should specify '*actions to be taken immediately*' and '*actions to be taken now to keep open future* actions and *adaptations*'. The plan should also define (and further detail) the monitoring system that will be used (Haasnoot et al. 2013, p.490). The plan for future actions needs to be ready in case an opportunity arises for adapting the system to future conditions (Haasnoot et al. 2013, p.495). For example, an opportunity emerges when infrastructures – e.g. sluices, dams, etc. – require maintenance. There might also be opportunities for mainstreaming adaptation into planning – i.e. actions that incorporate possible climate adaptation measures into ongoing strategies and plans (Haasnoot et al. 2013, p.495).

Step 9: Implement the plan. The 'actions to be taken immediately' are implemented, and the monitoring system starts to operate (Haasnoot et al. 2013, p.490). The non-immediate measures are only taken if a trigger is detected.

Step 10: Monitor (and feedback monitoring results into the plan). As time runs, the information related to the 'signposts' and 'triggers' (about external global and local changes, the plan and its effects, new knowledge), is monitored and collected. Based on this information, actions might be started, altered, stopped, or expanded. After implementation of the initial actions, activation of other actions is suspended until a 'trigger event' occurs (Haasnoot et al. 2013, p.490). Monitor the world, the plans, its actions, external developments, new knowledge, and according to the results, and if necessary, take contingency actions, or revise the plan by feedbacking lessons into step 1 (Walker et al. 2013, p.964).

The DAPP approach inspired the 'Adaptive Delta Management' approach that was later applied in the Dutch Delta Programme (according to Haasnoot et al. 2013, p.495; Haasnoot and Jeuken).

1.3.4.5. Adaptive Management and derived approaches

Adaptive Management (AM) emerged as a way of dealing with the deep uncertainty that characterizes ecosystem management, and in contexts in which it is difficult or impossible to predict results of management interventions. AM tests management hypotheses by implementing them, monitoring outcomes, learning from them, and refining future management hypotheses (Holling 1978, *in* Wong et al. 2014). It is an approach that seeks to improve management practices and policies, by learning from the outcomes of applied management strategies and their uncertainties (Van der Voorn et al. 2015).

AM has been applied in coastal management (Walters 1997; Marchand et al. 2011; Mulder et al. 2011), however, there is scarce evidence of its long-term effectiveness, and the approach may face limitations, e.g. possible high costs of experimentation, institutional barriers hindering a flexible management, etc. (Wong et al. 2014). Even though, Ford et al. (2011) note that AM has arisen as an important component of climate adaptation, being increasingly advocated in decisions with long timescales, as a means for improving the ways in which human systems deal with changing risks.

AM usually resorts to *exploratory scenario methods* and *forecasting* to study long-term issues in adaptation. Nevertheless, for Van der Voorn et al. (2015), there is still significant scope to explore and use methods of '*normative foresight'*, '*vision development'*, and '*backcasting'*, within the AM and coastal adaptation research. The authors call for further investigation of the potential of *participatory normative scenario methods* for climate adaptation planning (Van der Voorn et al. 2015). Van der Voorn et al. (2012) combined two complementary approaches for planning climate adaptation – Adaptive Management (AM) and Backcasting (BC) – into a single methodology called 'Backcasting Adaptive Management' (BCAM). While BC offers a long timeframe for realizing short- and mid-term management, AM seeks to ensure *adaptiveness* into such timeframe (Van der Voorn et al. 2012, 2015).

AM emerged in the 1990s in the US as an approach to support natural resource management and policymaking. It involves a systematic process of learning from the outcomes of management actions, accommodating change and thereby improving management (*in* Zevenbergen et al. 2018). AM is an iterative process of planning, applying and modifying strategies for managing resources in face of uncertainty and change. It adjusts its approaches and solutions in response to observations of their effect and changes in the system, e.g. feedbacks (IPCC IAV 2014). Thus, it entails a process of continuous improvement of management policies and practices, and it recognizes our limited understanding of natural system's behaviour. AM is deemed as an effective approach when: uncertainty is acknowledged and 'information gaps' are identified, and thus, when learning is needed to achieve certain management goals; there are good prospects for experimenting in order to reduce information gaps; socioeconomic and physical changes justify and warrant the adjustment of management measures / interventions, as a result of lessons learnt (*in* Zevenbergen et al. 2018). More recently, AM has been defined as a *structured iterative process of robust decision-making in the face of uncertainty, with the aim to reduce uncertainty over time via system monitoring* (*in* Marchand and Ludwig 2014, p.2, 8) (Note 43). AM implies the '*ability to change policy practices based on new experience and insights*' (Pahl-Wostl 2007, *in* Haasnoot et al. 2012; Klijn et al. 2015, *in* Bloemen et al. 2018). AM implies a thorough ex-ante policy analysis and an outlook into the future, and an examination of whether a policy transition is necessary, an assessment of alternative (flood risk management) strategies, and their (anticipatory) planning (to avoid regrets and doing too little, too late / early) (Bloemen et al. 2018).

AM has captured a growing interest in river restoration projects, e.g. river restoration projects in the US; (e.g. in Mississippi, Colorado River, Colombia River Basin), and in in flood risk management plans: the Dutch Delta Programme; Bangladesh Delta Plan 2100 (Zevenbergen et al. 2018) (Note 44).

1.3.4.6. SYNTHESIS

In sum, all Adaptive Planning approaches *aim at enhancing a plan by keeping it from failing* (Walker et al. 2013). All approaches (some more than others) focus on *what could make a plan fail.* These approaches represent uncertainties through a wide set of multiple futures (*scenarios*), and seek to enhance a plan's adaptivity and flexibility (to avoid its failure), through the assessment of conditions in which a plan or action might fail and require new actions (Walker et al. 2013). Overall, these approaches are useful for designing *adaptive plans* / *policies*, in face of various uncertainties (Note 45 and Note 46).

Adaptive Planning approaches are deemed useful for climate adaptation planning and decision-making: they provide clearer information on the timing and effectiveness of adaptation measures; they help to identify conditions under which an adaptation plan / measure might fail or perform unacceptably, and possible alternative measures; they recognize that adaptation, as a long-term ongoing process, is determined by *what is known today*, but also by *what will be learnt in future*, and thus, plans and decisions are not so dependent on the availability of future scenarios (Haasnoot et al. 2013; Walker et al. 2013; Ranger et al. 2013). However, there may also be disadvantages in these approaches, namely: their possible higher total costs; they may produce delays in more urgent public projects; their analytical methods can be too complex (e.g. *scenario modelling*), requiring simplification and explanation (ibid).

The Adaptive Planning approaches have gained prominence in several policy fields, with examples and applications in water and flood-risk management, coastal protection from SLR, shipping, environmental management, etc. (For applications in coastal climate adaptation, see Table K in the Appendix).
The Adaptation Pathways, in specific, offers a valuable approach for supporting, guiding and informing climate adaptation planning and decisions, and for enabling adaptation actions (Wise et al. 2014).

1.3.5. ADAPTATION PATHWAYS IN PRACTICE: APPLICATIONS

The various Adaptive Planning approaches have applied for developing 'dynamic adaptive plans', and for supporting planning and decision-making under deep uncertainty. Adaptive Planning approaches have captured an increasing interest in several planning / policy fields, and 'dynamic adaptive plans' have been developed in several cases worldwide (Haasnoot et al. 2013, p.496).

Among the cases in which the APs approach was applied (individually or couples with other approaches) to develop an '*adaptive plan*', are:

- The Thames Estuary 2100 Project (for developing a flood risk management plan for the Thames Estuary and London) (Lowe et al. 2009; Reeder and Ranger 2011; Sayers et al. 2012; Wilby and Keenan 2012, *in* Haasnoot et al. 2013, p.486, 496).
- Flood risk management in New York (Rosenzweig et al. 2011; Yohe and Leichenko 2010, *in* Haasnoot et al. 2013, p.486).
- Flood risk and freshwater management in the Dutch Delta Programme, particularly in the Rhine-Meuse Delta (DP 2014; Jeuken and Reeder 2011; Roosjen et al. 2012; *in* Haasnoot et al. 2013, p.486).
- Flood risk management in New Zealand (Lawrence and Manning 2012, *in* Haasnoot et al. 2013, p. 486) (see more in Note 47).

1.3.5.1. Adaptation Pathways applied in large-scale projects

The Thames Estuary 2100 Project was one of the first projects to address the issue of deep uncertainty surrounding SLR projections and water-level modelling, within its planning process (Ranger et al. 2013). The TE 2100 Project aimed to evaluate when the existing flood management system (namely the Thames Barrier, built in 1984 and planned to last until 2030) would need modifications, and to develop an 'adaptive plan' to manage flood risk in Thames Estuary until 2100, in face of increasing threats posed by climate change, rising water levels, ageing infrastructure, existence of exposed assets and population in the Estuary (Ranger et al. 2013; Penning-Roswell et al. 2013) (Note 48).

This decision-oriented planning process adopted a '*dynamic adaptive planning approach*' (similar to the Adaptive Management), in which the plan was designed to be adjusted over time as more is known about the future, and implemented iteratively. New actions and their timing could be changed over time.

Moreover, it was used the Adaptation Pathways' approach for identifying the timing and sequencing of possible adaptation measures over time under diverse scenarios (**Figure 11**). This approach aimed to ensure the flexibility of future adaptation measures, and maintain risk below acceptable levels. In addition, it was adopted a monitoring system and 'decision-points' to guide the implementation of adaptation measures in timely and cost-effective ways (**Figure 12**) (Ranger et al. 2013).

This Project sought to guarantee 'dynamic robustness' (recommended by the UK Government) by using: low-regrets measures (i.e. cost-efficient and beneficial under multiple scenarios), structural flexibility (i.e. adjustable engineering solutions), and pathways' flexibility (the plan should be managed iteratively, and its measures and their timing could be changed) (Ranger et al. 2013).

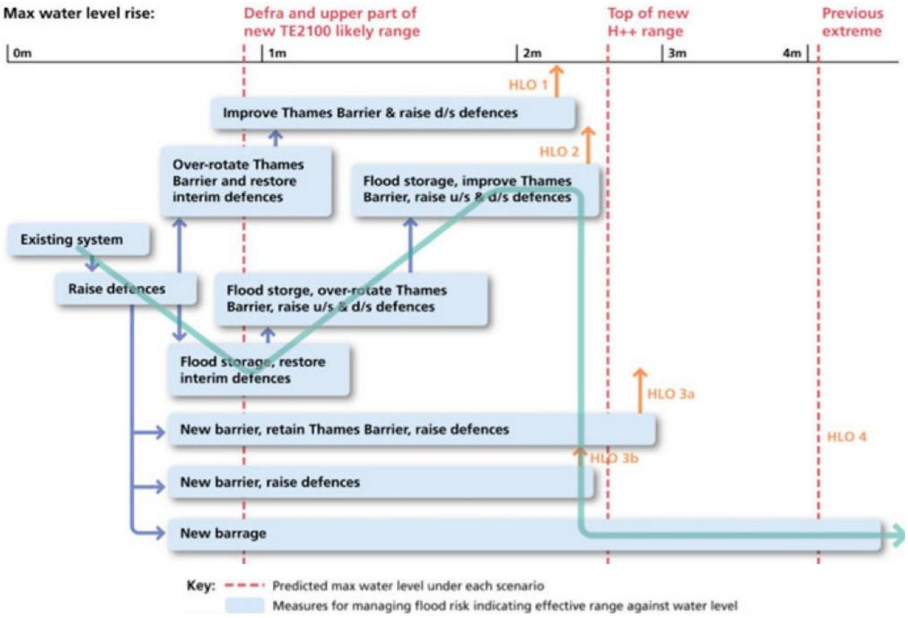


Figure 11. Adaptation Pathways' map in the TE 2100 Project, with the adaptation options (in Y axis) and thresholds in terms of extreme water levels (X axis). The blue line is a possible adaptation pathway that could be followed. The boxes contain adaptation measures available and effective for different levels of SLR (which seek to maintain risks below target levels). The blue arrows link to alternative options (applicable if an option is no longer effective). Dashed lines represent SLR scenarios predicted. Source: Ranger et al. 2013.

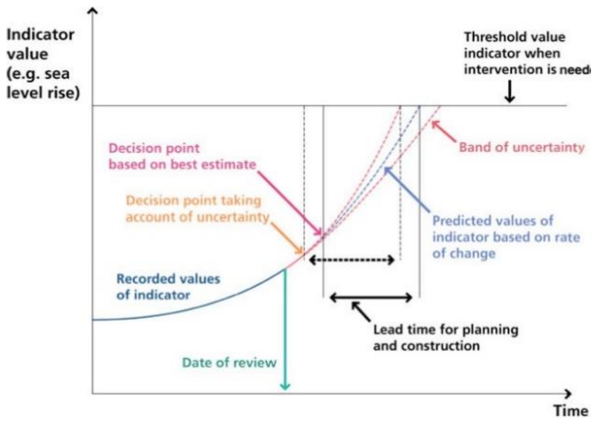


Figure 12. Decision-points, in function of indicators (in y axis), and lead time (x axis).

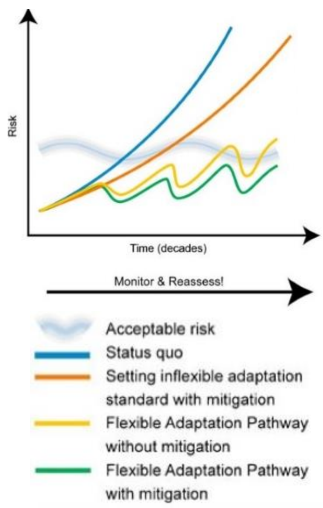
The decision-points would be identified through ongoing monitoring, observation of indicators, and definition of a lead-time for activating each option. Source: Ranger et al. 2013.

Other example of application of Adaptation Pathways is a case of coastal climate adaptation planning in New York City. This case involved: a *multi-jurisdictional stakeholder-scientist process* (for planning adaptation), state-of-art climate projections and risk-maps for critical infrastructure located on coasts, and the application of an approach called *Flexible Adaptation Pathways* (Rosenzweig et al. 2011).

The scientist-stakeholder process involved three entities: the New York City Panel on Climate Change – NPCC (which is a multi-disciplinary scientific advisory group), the Office of Long-term Planning and Sustainability – a OLPS (a Mayor's Office), and the New York City Climate Change Adaptation Task Force (composed of forty stakeholders responsible for infrastructure). The NPCC was charged of developing climate projections, downscaling projections to NY region, providing information to stakeholders. The Task Force was responsible for assessing at-risk infrastructure and assets, planning and implementing adaptation actions. This process required: inclusive participation (including actors with interdependent or overlapping jurisdictions); support from the local government (buy-in from the Mayor, and the city assuming a pioneer role in climate adaptation); the presence of a coordinating body (OLPS); and the communication of uncertainties (by the NPCC) to stakeholders. All these aspects are usually deemed key ingredients to enable successful coastal climate adaptation.

The approach developed – *Flexible Adaptation Pathways* – was partially based on the APs' approach adopted in TE 2100 Project in London. In this case, adaptation measures should be able to evolve across time as knowledge on climate change effects advanced. Thus, the adaptation process should occur as *a dynamic sequence of analysis and action, followed by evaluation, further analysis, and refinement*, in a cycle of *learning, acting, learning more* (Rosenzweig et al. 2011).[47]

Aiming to foster the development of the *flexible adaptation pathways*, the NPCC designed a process of eight steps to help stakeholders identify at-risk infrastructure and prepare adaptation strategies (**Figure 13**). This process should be integrated into the planning, risk-management, operation, maintenance and capital allocation of the involved agencies. The NPCC recommended an ongoing and longer-term monitoring of climate change effects, and of adaptation plans in the region (to assess if plans were meeting their objectives, and to identify effects of adaptation actions applied) (Rosenzweig et al. 2011).



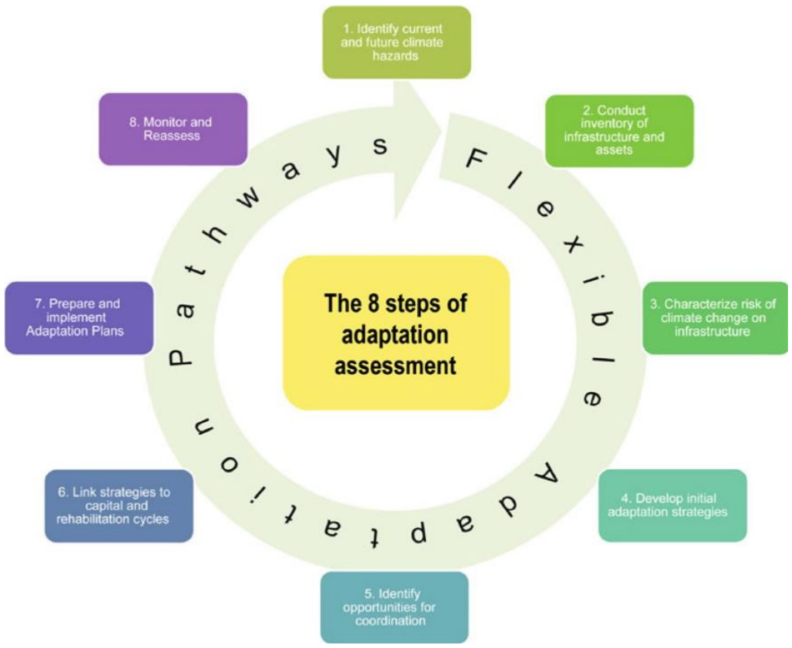


Figure 13. Flexible adaptation pathways (left). Process for adaptation assessment (right). Source: Rosenzweig et al. 2011.

47 These *flexible adaptation pathways* have similarities with the APs' approach and with Holling's work on Adaptive Management (Walker et al. 2013). Importantly, this approach was already used by the Port Authority of New York and New Jersey (Rosenzweig et al. 2011).

The APs approach was also applied in the Dutch Delta Programme (Haasnoot et al. 2013). It was used in its several sub-programmes, for decisions on sand (coastal management), flood-risk management, and freshwater supply (DP 2014) (**Figure 14**) (Note 49).

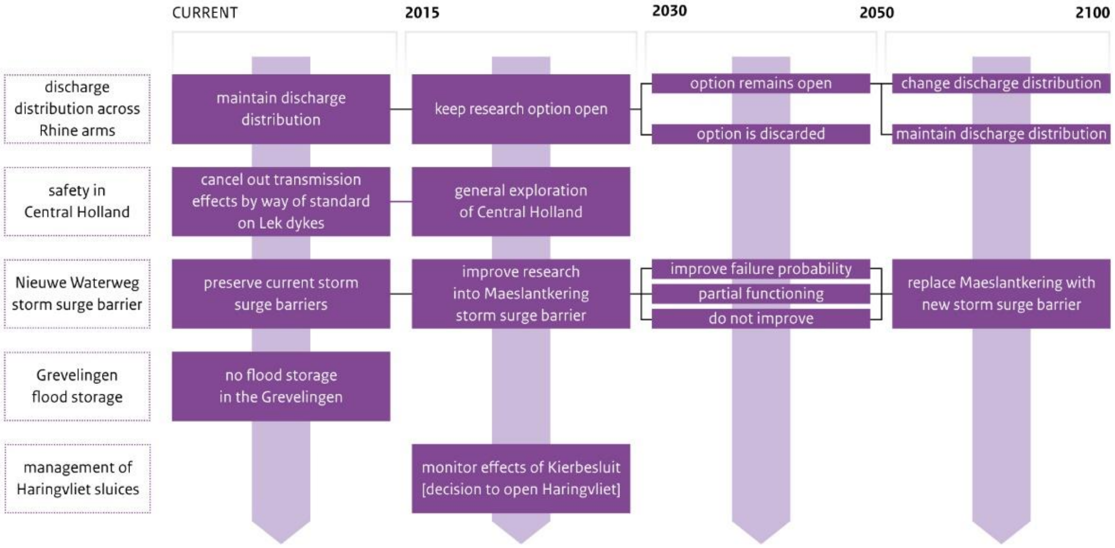


Figure 14. Adaptation pathways for flood-risk management for the Rhine-Meuse Delta. Source: Delta Programme 2014.

In sum, the three cases previously presented – i.e. the Thames Estuary 2100 Project, and the initiative for coastal climate adaptation planning in New York, the Delta Programme in Rhine-Meuse Delta – are well-documented examples of application of the APs approach for dealing with emerging coastal and flood risks. These examples are also pioneer cases in adaptation planning. From them, it is possible to extract several common features. All cases implied:

- The support or involvement of a higher-level government institution (above local government), in charge, guiding or endorsing the plan / initiative. The potential risks had national or regional significance, and the scale of threatened socio-ecological systems was large (e.g. London, Rotterdam region, New York City coast), wherefore, a higher-government agency was often involved.
- Strong commitment / initiative of local governments to address climate adaptation challenges.
- The pre-definition of clear goals for adaptation, e.g. avoiding damages from floods.
- A high technical capacity, involvement of expertise and specialized techniques for intensive modelling of possible scenarios, and assessment of adaptation options
- The anticipated identification of several possible adaptation actions in the APs' maps, which illustrate sets of possible strategies / measures for certain points in time (Barnett et al. 2014).

However, in many coastal cities these conditions may not exist, or may be difficult to gather. Frequently, local coastal governments do not have the capacity, technical skills and financial resources required to develop large-scale and comprehensive adaptation plans or initiatives for long-term coastal adaptation. Besides that, local decision-makers often lack guidance and a clear mandate from central governments for adaptation action. In addition, at local levels, decisions on adaptation are often more dependent on consensus between municipal government, community and local actors, and such consensus are quite difficult to reach, due to lack of agreement on adaptation goals and options (Barnett et al. 2014).

Nevertheless, two recent studies tested the Adaptation Pathways in small / medium-sized coastal cities, and demonstrated that APs might also be useful for enabling and guiding local adaptation processes and building the necessary local consensus (Barnett et al. 2014; Campos et al. 2016). APs seem to be a promising tool to help local governments and communities in planning and realizing adaptation (ibid).

1.3.5.2. Adaptation Pathways in research cases in medium- and small-sized coastal cities

Barnett et al. (2014) analysed the practical relevance and feasibility of Adaptation Pathways' approach for adaptation to SLR in a small coastal city in Australia (Lakes Entrance). More specifically, the authors examined if the APs could be applied in a way that was 'locally-relevant' and that fostered local ownership of adaptation measures.

In this case, adaptation pathways were interpreted as sequential interconnected steps with a strategic vision underlying them, and which are instigated by 'triggers'. The 'triggers' corresponded to thresholds important for local people (e.g. adverse impacts for communities, flood levels that residents consider unacceptable), and not necessarily moments when environmental perturbations are anticipated. Such triggers were determined in function of local 'lived values', i.e. values that people attribute to a certain area, and wish to preserve. Hence, consensus on adaptation pathways was built on the basis of consensual / shared 'lived values'. Moreover, the design of the adaptation pathways implied the definition of a vision for the threatened entity. Here, adaptation was a means for managing long-term coastal risks that threaten valued features of local places (Barnett et al. 2014) (**Figure 15**).

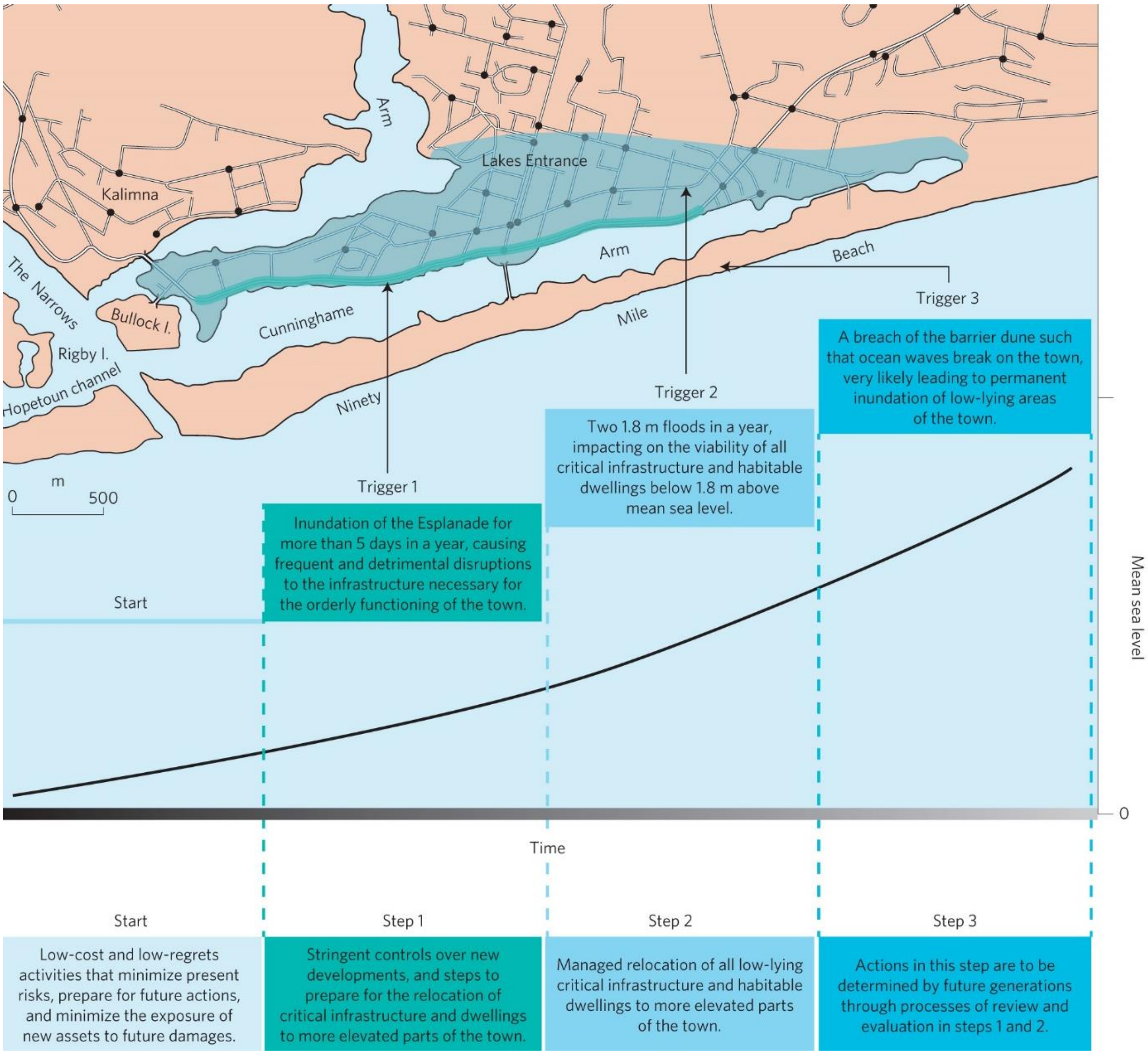


Figure 15. Local adaptation pathways for Lakes Entrance, Australia, showing triggers, areas likely to be affected, and policy steps activated by triggers. Source: Barnett et al. 2014.

Barnett et al. (2014) concluded that: 1) 'local adaptation pathways' could be applied in a small coastal city, and are a useful tool to guide long-term processes of adaptation to SLR at local level; 2) 'socially-relevant triggers' and 'locally-owned adaptation pathways' help to build consensus among multiple actors with different risk-perceptions and interests. When the APs are based on local 'lived values' and relevant for local communities – i.e. sensitive to local people's values and temporalities – they can become more feasible and facilitate the level of consensus necessary to enable adaptation to begin. This approach was considered attractive by local governments and community: it is simple and flexible; it addresses public concerns on the fairness of adaptation measures across space, time, and generations; it gives time for discussing the distribution of responsibilities, costs and benefits for adaptation decisions; it prepares local actors to timely decide on actions and investments; and it is community-sensitive.

Hence, APs seem promising as a *pragmatic way for local communities and governments to begin adapting to sea-level rise* (Barnett et al. 2014). However, and although the APs can be a valuable approach for guiding long-term coastal adaptation, further research is needed to test the implementation of the APs' approach within existing institutions (Barnett et al. 2014), namely in planning systems.

In a similar study, Campos et al. (2016) outline a process of adaptation planning activated by a group of researchers and local actors, on a small coastal port-city in Portugal (Aveiro), where there were no plans for coastal adaptation, but significant coastal risks. In this case, it was developed a Participatory Action-Research, using Qualitative Scenario Methods and the APs' approach. The authors argue that these three tools can be important catalysts of coastal adaptation processes at local level, helping to deal with key-challenges in adaptation: its long timeframes, uncertainties, complexities about adaptation options; multi-jurisdictional coordination, public inclusiveness, and interdisciplinarity.

The design of the adaptation pathways involved several actors (e.g. port authority, local residents, fishermen, surfers, etc.), and it was based on a *shared future vision*, which was possible to reach, despite the different interests of the stakeholders. This vision was shaped by two goals (**Figure 16**).

A less positive aspect identified by the participants is that the legal instruments and policies (e.g. municipal master plans, coastal management plans, land-use regulations) were not sufficiently addressed (Campos et al. 2016). Indeed, the existing legal and regulatory frameworks of spatial planning are central pieces for an effective coastal adaptation planning and implementation. The possible incorporation of APs into existing spatial planning instruments and system merits further research.

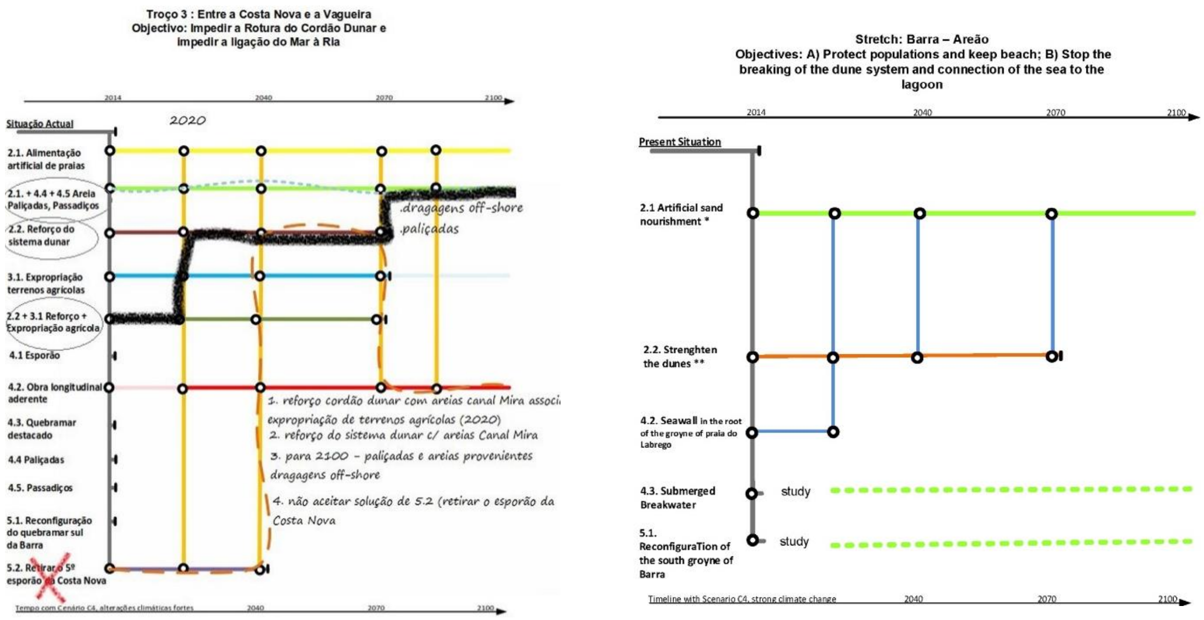


Figure 16. Adaptation pathways' map edited by participants (left); and final map (right). Source: Campos et al. 2016.

1.3.5.3. Adaptation Pathways within local policies or plans

Climate adaptation planning under uncertainty is needed, and Adaptive Planning approaches have been proposed to this end (Van der Voorn et al. 2015). In addition, the need to mainstream adaptation into long-term planning has been emphasized in adaptation research and in several policy arenas, namely for coastal regions. This implies tools to adequately integrate and deal with adaptation into spatial planning.

In a recent study, Van der Voorn et al. (2015) analysed cases in which methods of 'vision and strategy development' were applied for planning climate adaptation into plans / policies. The authors searched for contents about the envisioning of Adaptation Pathways (APs). The authors found that APs are used in two policies: the '**Rotterdam Climate Proof 2030'** and the '**Rotterdam Port Vision 2030'**. Such policies contain adaptation options, elements to deal with uncertainty, and pathways' switching.

In other case, in the **Eyre Peninsula** in Australia, in 2014, a team formed by the Eyre Peninsula Integrated Climate Change Agreement Committee (EPICCA), state and regional agencies, local governments, elaborated a regional plan for adaptation to climate change (Siebentritt et al. 2014). The plan identifies possible adaptation pathways for eight key-sectors in eight pathways' maps (namely for coastal management and port sector), and it also contains a regional adaptation pathways' map. The project's team consulted prior examples of application of APs, and found that this approach is useful, but its examples are often quite technical and expensive. Therefore, the team decided to develop a participatory and low-budget approach, which implied several interviews, conversations, and workshops with stakeholders to discuss, refine and review the pathways designed by the team. The APs' approach helped the team and local actors to understand the range of adaptation alternatives available, and to better schedule the timing, priorities, and opportunities for sequenced investment.

On their research, Gray et al. (2016) examined whether planners and decision-makers involved in coastal management in Cork Harbour (Ireland) were able to use *scenario analysis* for climate adaptation planning. *Scenario analysis* is a method for identifying alternative possible futures and evaluating of their consequences. It has gained prominence as a 'good practice' method to support climate adaptation planning and decision-making (Gray et al. 2016). In this case, *scenario analysis* facilitated various aspects of the coastal adaptation process (leading to a simple adaptation strategy), but with a less evident provision of pathways to deliver such adaptation. In addition, the gains from this method may be limited by the lack of institutional enablers of proactive adaptation planning.

More specifically, the authors found that: i) *scenario analysis* was *distant* from present-day roles, responsibilities, and problems that local planners and decision-makers usually face; ii) the planning horizons of *scenario analysis* go far beyond local governments' budgets and mandates; iii) the adoption of one or more pathways of adaptation entails time, resources and political commitment to a long-term proactive adaptation, and these factors are fragile compared to present-day pressures. Thus, for these authors, further technocratic refinement, and advancement of methodological tools (like *scenario analysis*) might not necessarily contribute to the concretization of adaptation, especially in the planning and implementation stages. In contexts characterized by lack of technical capacity, data or public participation, participants may end up in disputes around the likelihood of scenarios (Gray et al. 2016). For Gray et al. (2016), the potential applicability of more 'technocratic' approaches within the existing institutional mind-sets and frameworks, and in different contexts, especially in less developed countries, deserves further investigation, as well as the institutional barriers that hinder the integration of such approaches. Besides that, in European countries, adaptation will be strongly influenced by the quality of the process of subsidiarity of European directives to Member States, and from these to local governments, and this involves more than technical approaches (Gray et al. 2016).

1.3.6. Re-conceptualizing adaptation pathways

For Wise et al. (2014), the Adaptation Pathways' approach (APs) emphasizes the need for dynamically robust (flexible) decision-making within climate adaptation processes under deep uncertainty and inter-temporal complexity. However, the approach still needs to explicitly recognize possible tensions between incremental adaptation actions (targeted at proximate drivers of risk, and which often sustain existing governance arrangements) and transformational actions (targeted at more systemic drivers of risk, and aiming to change socio-political conditions that generate risk and vulnerability). Although the APs' approach is useful for supporting adaptation planning and decision-making, and its maps help to visualize what climate adaptation is about[48], it has been mostly applied in contexts in which goals were clearly defined, knowledge about natural and human sub-systems is well-advanced, decision-makers are easily identifiable and empowered to make decisions on adaptation, and governance structures are suitable for adaptation. However, in many contexts, such conditions do not exist: instead, there are high degrees of uncertainty in knowledge, ambiguous / ambivalent goals, unclear power distribution, etc. Thus, to Wise et al. (2014), the classical notion of adaptation pathways only gives a partial picture of the climate adaptation challenges ahead: it tends to see the pathways as *series of related incremental steps*; it does not sufficiently address the contexts and social framing in which decisions are made, e.g. complex decision-making arenas; it disregards inter-dynamics between institutions, values and knowledge, e.g. legitimate contested worldviews and goals, which influence how problems are framed and how adaptation is conceived (**Figure 17**) (Note 50).

Therefore, the authors argue that APs' design should take into account: path-dependencies; influences of values, interests, and institutions on societal responses to change; and interplays between adaptation plans, vested interests and global change. The authors propose a re-conceptualization of adaptation *as part of pathways of change and response* that continually cycle between incremental and transformative actions, mutually informative, inclusive, and complementary. In this sense, APs should combine both incremental actions (dealing with proximate drivers of risk) and transformative actions (dealing with systemic vectors of risk, impacts, problems). This notion of APs is wider than the original concept, as it includes five critical dimensions that remain under-explored in adaptation research and practice:

- Climate adaptation cannot be separated from societal, cultural, political, economic, environmental and developmental contexts, i.e. it is context-based. The contextual conditions, and systemic drivers of vulnerability, have implications for adaptation practice and research.
- There are multi-scalar changes and responses in space, time, across jurisdictions and sectors, complex dynamics in and among social and ecological sub-systems.
- There are temporal implications related with path-dependencies, feedback loops, systems' inertia (e.g. in institutions and values), lock-ins, and historical determinism, which influence the pathways.
- It is difficult, but crucial, to identify at which pathway a system is, and at which point of the pathway.
- There are interrelated rules, values and knowledge which can facilitate or hinder adaptation, and it might be necessary to change them to enable adaptation pathways' concretization (Wise et al. 2014).

This re-conceptualization of APs aims to help in the identification of: where a system is on a pathway, its current vulnerabilities and capacities to adapt, direct and indirect pathways to reach desirable futures; if an intervention can result in undesirable futures, instead of shortening the focus on proximate cause-effect links (**Figure 18**). Such APs can be useful for informing and guiding adaptation decision-making in dynamic and complex environments, namely for: detecting if transformational action is needed and what incremental changes help to reach it, and analysing interactions in knowledge, power, values, etc.

[48] Wise et al. (2014) explain that the APs' approach aims at overcoming the lack of implementation of adaptation actions, and resort to the metaphor of *pathways* to visualize what adaptation is about. It focuses on the process of decision-making (within the climate adaptation process), underlining the importance of its own adaptive nature in the face of uncertainty and inter-temporal complexity (Wise et al. 2014).

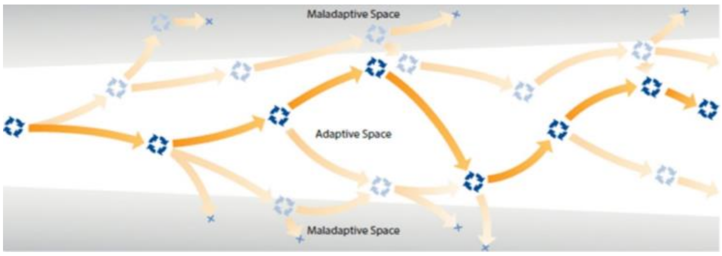


Figure 17. The 'classic' conceptualization of adaptation pathways: a series of decision cycles over time, where some chains of decisions lead to maladaptive space, but other alternatives are adaptive. Source: Wise et al. 2014.

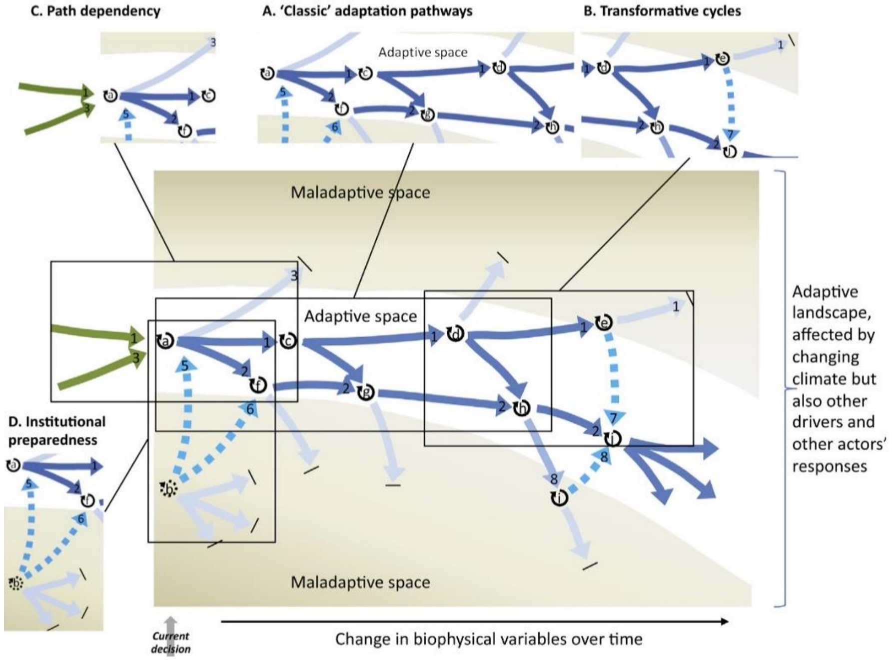


Figure 18. Re-conceptualized adaptation pathways' map. The boundaries between adaptive and maladaptive space change over time, due to biophysical, social and institutional factors (e.g. prior actions). Circle arrows are decision-points; dark blue arrows represent pathways that are contemporaneously adaptive; grey arrows lead to maladaptive dead-ends; dashed arrows represent more / less transformative segments. Green arrows are antecedent pathways (prior to current decision cycle). Boxes A, B, C, D contain differences from the traditional APs. Source: Wise et al. 2014.

Wise et al. (2014) call for further exploration of their re-conceptualization of adaptation and APs. To be operationalized their re-conceptualized APs might require: 1) moves towards longer-term and more integrated adaptation practices, and compromising multiple complementary projects; 2) social and institutional learning processes on adaptation; 3) deliberation and negotiations that enhance fairness, responsibility, local ownership and empowerment to take action; 4) participation and the 'opening-up' of policy-making, towards more inclusive and legitimate deliberation forums, in which actors with different powers can effect changes; 5) new mechanisms for testing and funding innovative policy alternatives, e.g. experimenting transformative ideas / policies, or exploring extreme events as drivers of transformational actions; 6) enhancement of reflexivity / critical consciousness, which is more than developing technical solutions, and implies changing social norms, values and behaviours that lead to vulnerability; 7) greater responsiveness of institutional structures towards more sustainable trajectories. These APs provide useful guidance for framing problems in complex contexts and interpreting uncertain projections, and offer a method more suited to the nature and level of uncertainties related with climate adaptation. They also offer practical procedures for embedding principles that have been claimed for successful climate adaptation, such as *no-regrets*, *context-based* or *flexible* measures (Wise et al. 2014). The APs offer a valuable approach for supporting, guiding and informing climate adaptation planning and decisions, and for enabling adaptation action (Wise et al. 2014) (Note 51).

For more on recent scientific developments on Adaptive Planning approaches see Note 52.

1.3.7. HOW TO DESIGN *SUSTAINABLE ADAPTIVE PLANS* FOR COASTAL CLIMATE ADAPTATION

To be sustainable, plans should 'survive' changes, and, thus, be *adaptive*. This notion of '*sustainable adaptive plans*' is linked to the Darwin conceptualization of the conditions needed for the survival of species, and to the sustainable development of the Brundtland Report, i.e. *development that meets present needs without compromising future generations' ability to meet their needs*. In face of uncertain conditions now and in the future, a sustainable plan should: 1) meet objectives related to society, economy and environment; 2) be *robust*, i.e. perform satisfactorily under numerous possible futures; 3) be *adaptive*, i.e. it can be adapted to unexpected and changing conditions over time (Walker et al. 2013).

A key-challenge is how to design such '*sustainable adaptive plans*'. Walker et al. (2013) outline some principles for developing long-term *sustainable adaptive plans* under uncertainty:

- Recognizing, understanding and managing multiple uncertainties. The disregard of uncertainties hinders corrections and can lead to problems that could have been prevented, lost opportunities, unsustainable or maladaptive outcomes. Moreover, not all uncertainties can be removed. Instead of waiting till knowledge gets available or spending excessive resources on trying to eliminate future uncertainties, planners should seek to reduce uncertainties about the performance of plans, and explore multiple uncertainties in plans' responses to external changes, natural variability, etc.
- Connecting short-term goals with long-term objectives along time, and commitment to short-term actions but keeping options open for the future. This entails the creation of a shared vision for the future, the exploration of possible adaptation pathways and measures, and the analysis of actions over time. Planners should evaluate which actions can be used to achieve their goals regardless of how future unfolds (under a broad variety of possible futures). Adaptivity implies pre-identification of alternatives available, avoidance of lock-ins, monitoring, and revision. It helps to keep plans *alive*.
- Ensuring continuous monitoring and revision of measures. Observation and reassessment are essential to evaluate the direction of adaptation processes and recognize potential negative pathways or limitations. *Monitor and adapt* is increasingly preferred as a strategy for long-term planning in face of deep uncertainties, over *predict and act* (Walker et al. 2013).

Further work is needed to assist planners and decision-makers in choosing among the Adaptive Planning approaches and using them more effectively. It is necessary to bridge the theory-practice gap in Adaptive Planning, and craft plans that adapt and *survive*, instead of *perishing* (Walker et al. 2013).

In a similar line of thought, and drawing on recent practices of coastal management in European countries, Sánchez-Arcilla et al. (2016) identify a range of conditions for designing *sustainable adaptation pathways* and *adaptive plans* for coastal climate adaptation:

- Articulation of short-term interventions with long-term planning, coordination of short-term goals with long-term needs, and balancing all relevant aspects on temporal, spatial and governance scales.
- Inclusion of *flexibilities* as well as *solid foundations*. For the authors, *an adaptive plan needs to have solid foundations (rigidities) but with flexibility enough to ensure that it will be applicable for the changing demands from climate, society and other factors*.
- Use of probabilistic projections for defining upper-limits, boundary conditions and uncertainties; and for setting referential baselines, e.g. high-end, plausible and conservative scenarios.
- Ongoing monitoring and reassessment of implemented measures (i.e. their effects, robustness, efficiency, possible revision), and continual learning;
- Follow-up of planned interventions; measures of adjustment to maximize benefits and minimize negative impacts of applied measures; observational and forecasting systems;
- Structured forums for coastal actors' participation; and education on costs and benefits of adaptation.

Given the uncertainties about the climate and physical conditions of coastal environments, Sánchez-Arcilla et al. (2016) call for *coastal adaptation pathways* as roadmaps to address adaptation at two scales: short-term (e.g. episodic storm-driven events) and long-term; and proximate and broader space. Short-term responses to coastal risks can be incompatible / conflictive with long-term goals of adaptation and sustainability, and local actions can have side-effects on wider coastal cells. Thus, adaptation demands a more careful consideration of these temporal and spatial scales. Moreover, the APs should be suited to diverse coastal setting, and enhance the natural resilience of coastal ecosystems.

1.3.8. Adaptive Planning for climate adaptation: further steps

Haasnoot et al. (2013) call for further research, testing and use of Adaptive Planning approaches, particularly of Adaptation Pathways, in diverse contexts, in 'real cases' in different countries and policy domains, and for identifying which approaches are most adequate in which context. Moreover, as the authors note, ultimately, all Adaptive Planning approaches have to *fit into a political process*, which is often a *real source of deep uncertainty* (Haasnoot et al. 2013). Thus, the Adaptive Planning approaches (individually or combined) need to be integrated into policy frameworks and policymaking [49] (Note 53).

In addition, the evaluation of the efficacy of new planning tools is difficult: it cannot be done in short-term, and implies monitoring several aspects over time. In this sense, Haasnoot et al. (2013) call for further investigation to: explore Adaptation Pathways over time; identify most promising sequences of actions from multiple combinations; detect opportunities and vulnerabilities of promising pathways and preferred actions; select candidate pathways for an ensemble of possible pathways, assess their robustness and evaluate their performance over time (e.g. their flexibility, effectiveness, etc.).

Ranger et al. (2013) suggest that Adaptive Planning approaches, in particular the Adaptation Pathways, could be applicable to a wide range of climate-related risk management fields and *long-term, climate-sensitive decisions* (e.g. spatial and land-use planning, urban development, long-lived infrastructure, buildings, natural resource management, etc.). A wider application of Adaptive Planning approaches will likely require different directions and priorities in climate adaptation research and practice, namely:

- a greater clarity from regulators and regulations; more regulatory compliance of long-term plans;
- capacity-building and training, e.g. for developing *scenarios* and *adaptive plans*;
- continuous monitoring of climate-related indicators, improvements in the physical modelling of real climatic processes; further exploration of uncertainties in climate projections and in models;
- ongoing evaluation and monitoring of indicators in plans (necessary to detect required changes);
- new services providing advice on climate adaptation and basic tools of Adaptive Planning;
- improved communication channels between scientists, local governments and communities, to better inform decision-makers, planners and those affected by decisions, and to explain current knowledge limitations and how these can be managed over time through iterative learning (Ranger et al. 2013).

Regarding the Adaptation Pathways, Van der Voorn et al. (2015) highlight that it is necessary:

- wider and effective participation of multiple actors in the co-envisioning of *futures* and *pathways*;
- more exploration of tools and methods for grasping, mediating and applying *future visions*, and for developing *normative scenarios* that balance short and long-term goals;
- enhancement of the process of *visions*' and *pathways*' development, in ways that foster stakeholders' commitment and ownership, and promote follow-up and application of outcomes;
- improvement of capacities and expertise for using *future visions* and Adaptation Pathways;

[49] As mentioned, the possible integration and application of APs into existing planning systems, institutions, and instruments merit further research (Barnett et al 2014; Campos et al. 2016).

- further integration of principles of reflexivity, flexibility and adaptivity;
- monitoring through indicators, e.g. indicators of change (signposts and milestones) and performance indicators (ongoing evaluation of adaptation plans / actions), which enables a truly adaptive planning.
- further study, testing / application of Adaptation Pathways in diverse international contexts, and exchange of experiences, learning results and knowledge on APs (Van der Voorn et al. 2015).

Van der Voorn et al. (2015) emphasize that *participatory vision development*, which entails the preparation of adaptation pathways, is a valuable tool for planning climate adaptation, applicable in diverse governance contexts. However, in many contexts, the elaboration of *visions* and Adaptation Pathways is somehow a novelty in conceptual and methodological terms, which requires resources and updated expertise that might not always be available. Importantly, for the authors, *vision development* does not necessarily imply a single shared vision for the future (Van der Voorn et al. 2015).

1.3.9. Synthesis and research needs

The Adaptive Planning paradigm provides several approaches for planning under deep uncertainty. In light of this paradigm, planners should design '*adaptive plans*' – i.e. plans that can be adapted over time to unpredicted and changing conditions, so that they can *survive* changes. The Adaptive Planning approaches aim at supporting planners in designing *adaptive plans*, and in dealing with multiple uncertainties about the future in long-term planning and decision-making. Such approaches underline the need for adaptability in plans / policies and their measures (Haasnoot et al. 2013; Walker et al. 2013). Among such approaches, there is the Adaptation Pathways (APs). APs is an approach for exploring and sequencing a set of possible alternative adaptation actions based on external changes over time. Recently, the Adaptive Planning approaches have captured an increasing interest in climate adaptation literature and research, as potentially applicable and useful approaches for guiding climate adaptation planning, decision-making and implementation. These approaches are deemed valuable for supporting and informing the planning and implementation of adaptation actions, under conditions of uncertainty and inter-temporal complexity related with climate change effects, changing / unexpected risks, shifting interests of at-risk populations, contested values, distinct knowledge types, etc. (Wise et al. 2014). The APs, in specific, have been applied in research cases, and in a few 'real' cases (Note 54).

Coastal climate adaptation is a process, and the Adaptive Planning approaches can help to grasp how such process should unfold. APs, in particular, seem promising as *a way to guide adaptation decisions into the future*, through sequences of steps manageable over time towards a desirable state (Barnett et al. 2014). However, further research is needed to apply the existing knowledge on Adaptive Planning to climate adaptation (Ranger et al. 2013), namely in coastal regions. There are still few examples of application of the Adaptive Planning approaches to coastal climate adaptation (Barnett et al. 2014). As there is no *one-size-fits-all* approach for planning coastal adaptation, a key-step will be to examine what approaches should be applied and might succeed in different contexts (Hurlimann and March 2012).

Adaptive Planning approaches require further *on-the-ground* exploration in distinct contexts. Importantly, further research is necessary to test the possible incorporation and applicability of Adaptive Planning approaches, namely of the APs, into existing planning systems, institutions, and instruments. The practical feasibility of such approaches into and through plans / policies merits further analysis. Although climate adaptation is gaining prominence within several policy fields, the lack of progress and effective planning and implementation of adaptation actions is concerning. It is, therefore, pertinent to question to what extent planners and coastal managers can adopt and use approaches advocated as supportive and useful for adaptation planning, such as the Adaptive Planning approaches.

Diagram 3 contains a synthesis of the main gaps identified in the literature on Adaptive Planning.

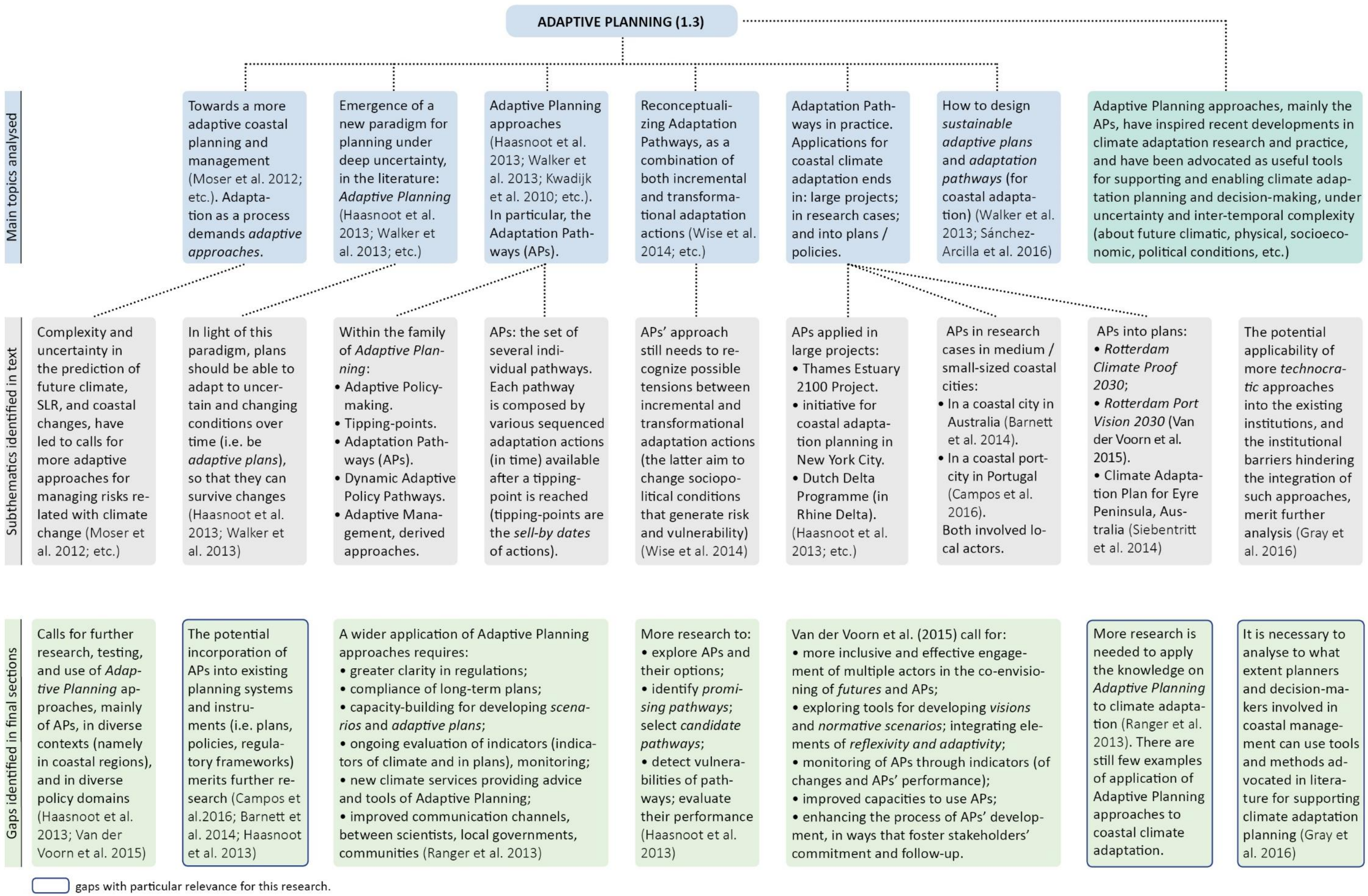


Diagram 3. Main topics analysed and gaps identified in 1.3.

1.4. Portuguese context

Most of the Portuguese coast is already subjected to several intricate problems, namely: severe and accelerated erosion and loss of beachfront areas.[50] It is also exposed to the risks of flooding, submersion of dry- and wetland areas in low-lying coastal zones. Several human-induced impacts have contributed to aggravate these problems by reducing the sediment supply to coasts: human alterations in river flows estuaries, construction of river dams, sand extraction, deployment of buildings, infrastructures and hard defences along coasts, which in some cases have led to coastal squeeze, or aggravated erosion in adjacent coastal zones (Veloso-Gomes 2007). These problems and risks will likely be aggravated by climate change effects, namely SLR and potential changes in storm patterns (Note 55).

Several authors have identified dysfunctional characteristics in the Portuguese coastal governance, and limitations that have hindered a more effective coastal management, namely: a) the confusing legal and planning framework for coasts and institutional complexity, with an excess of laws and institutions with jurisdiction or management roles over the coast, constant creation of new management bodies / models with no integration with existing legacy; lack of continuity in coastal policies (Veloso-Gomes and Taveira-Pinto 2003); b) weak public participation in coastal management issues (Veloso-Gomes 2007); c) lack of clarity in coastal policies; d) poor coordination between institutions, disconnected efforts and actions; e) existing scientific knowledge is not translated into coastal management policies; f) locally, coastal governance is influenced by immediate pressures, powerful economic interests on coasts, short electoral cycles, strong emphasis on cultural meanings of urban occupation of coasts (Schmidt et al. 2013) (Note 56 and Note 57).

In Portugal, traditionally, spatial planning instruments in coastal areas, namely coastal management plans, have sought to ensure stability, and to a certain extent, they have been *static*, expecting that reality converges to their regulations. Generally, the regulatory frameworks and policies / plans used in coasts were designed to be durable, evidencing a relative *rigidity* / *stability*. Therefore, they may ultimately counteract, or diverge from, the notions of *adaptability* or *adaptive plans*, and from the principles subjacent to Adaptive Planning, which have been claimed for long-term adaptation planning.[51] In this sense, the main challenge seems to be in articulating *static* planning instruments with the changing reality of coastlines that are facing new or exacerbated coastal risks (**Figure 19**).

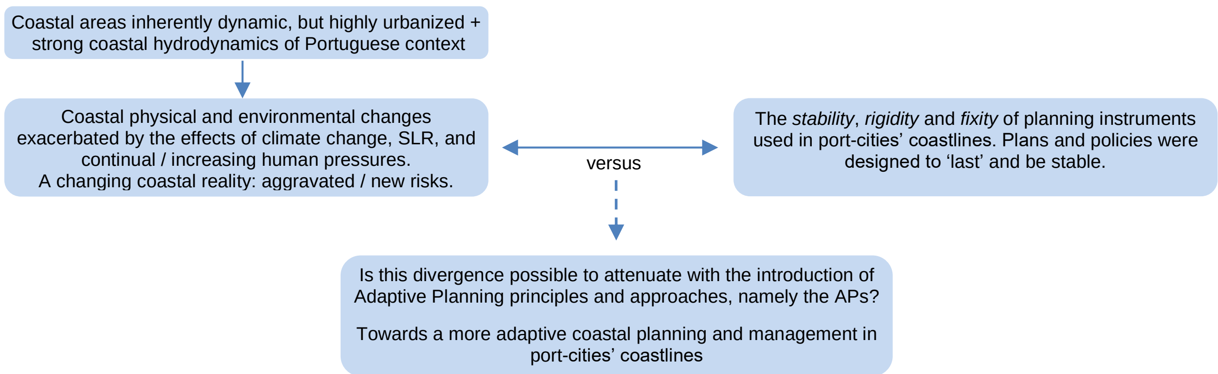


Figure 19. The confrontation of a highly dynamic coastal environment that is subjected to the effects of climate change and large human impacts, with 'static' planning instruments. It leads to the need for a more *adaptive planning / management*, in the Portuguese context. Source: own elaboration.

[50] Moreover, most of the sandy coastline of the Western continental coast is characterized by highly energetic wave regime.

[51] For example, the Portuguese Coastal Zone Management Plans (POOCs), now under revision as POCs (*Programas da Orla Costeira*) may not be adequately dealing with uncertainty dimensions when they rely on predictions of 100-year floods to define a flood-line. In this flood-line there might be discrepancies of hundreds of meters that might generate controversy. Moreover, POOCs should have been reviewed from ten to ten years, but that did not happen. (For more on POOCs, see Note 58).

In face of such problems, some authors have called for an *adaptive coastal planning and management* (Veloso-Gomes 2007), or an *adaptive coastal governance model* (Schmidt et al. 2013, 2014; O' Riordan et al. 2014).

Regarding the Portuguese Coastal Management Plans (now under revision as POCs – *Programas da Orla Costeira*), Veloso-Gomes (2007) underlines that such plans, and other spatial plans for coastal zones, need to become more 'adaptive' and consider longer temporal horizons, SLR and probable changes in storm patterns and disruptive events. It is important to develop methods for evaluating, revising and adapting POOCs (and other coastal plans) in an ongoing way, and define *action-programs* for more urgent interventions. It is also essential to develop appropriate tools for dealing with uncertainty in projections and coastal physical modelling, and further monitoring is needed on environmental, physical and biological indicators, on spatial planning instruments (POOCs and their compliance), and on projects and actions in terms of fulfilment of coastal management goals. In addition, POOCs should include estuarine zones and areas under port jurisdiction (Veloso-Gomes 2007) (Note 59).

For Schmidt et al. (2013, 2014), a *progressive adaptive coastal governance model* might require:

- *Cooperative science*, i.e. a knowledge-basis created by mutual understanding between scientific community and affected coastal communities, which implies participatory approaches and joint-learning. Cooperative science should generate meaningful and policy-relevant knowledge, e.g. through assessments of risks and adaptation options, sensitive to local interests. The definition of common visions, shared goals and agreed adaptation solutions, requires an interplay between science, policymaking, decision-making, involving all relevant actors, whose support in planning and financing is essential to increase compliance.
- Policy clarity, continuity and follow-up of plans / policies for coastal zones. This implies more long-term arrangements, risk-averse planning; further input of information from coastal modelling into coastal planning frameworks; existence of clear goals for identifying and defining the courses of action at several management scales, and accountable coastal management procedures.
- Stronger political will, commitment to coastal management, coordinated and responsive institutions. This implies flexible evolution of institutions with policy and managerial roles, e.g. offering time for progressive institutional learning, enhancement of policy coordination, communication between local and national governments, more integrative management schemes.
- Effective participation and trust-building. This implies: educational programs, awareness-raising[52], building public support for proactive preparedness, discussion and mediation of interests, more inclusive ways of coastal management, i.e. effective ways to engage local communities in coastal management in earlier and more credible ways, and taking into account different values, interests, needs and expectations of diverse actors and sectors; increasing public commitment to adaptation.
- Innovative / more adequate funding mechanisms for coastal adaptation. Dialogue on future financial resources for adaptation considering social justice issues. Creation of appropriate means for the recognition of emotional and economic costs to vulnerable actors and property-owners, and mechanisms for ensuring fairer outcomes for diverse actors, e.g. tools to improve accountability and ensure social justice, proactive insurance cover, compensation schemes, fairer financing arrangements, *path-breaking initiatives* to coastal adaptation. Coastal adaptation responses need to be sensitive to local socio-cultural, political, economic, physical and environmental circumstances.

[52] In Portugal, O'Riordan et al. (2014) found that, despite the increasing awareness of climate change-related risks in coastal areas, *the actual practice of landscape adjustment through policy shifts is being very difficult*. Building awareness and public interest in adaptation depends on the creative use of images of possible coastal futures, and on a sensitive understanding of existing cultural values and social interests, and establishing more inclusive *coastal adaptation forums*, taking advantage of momentums, e.g. disruptive storms, or revisions of POOCs.

1.5. FINAL SYNTHESIS OF KNOWLEDGE GAPS AND RESEARCH NEEDS

The theoretical debate presented in this chapter enabled the identification of a set of gaps and deficiencies in each of the four domains reviewed (**Figure 20**).

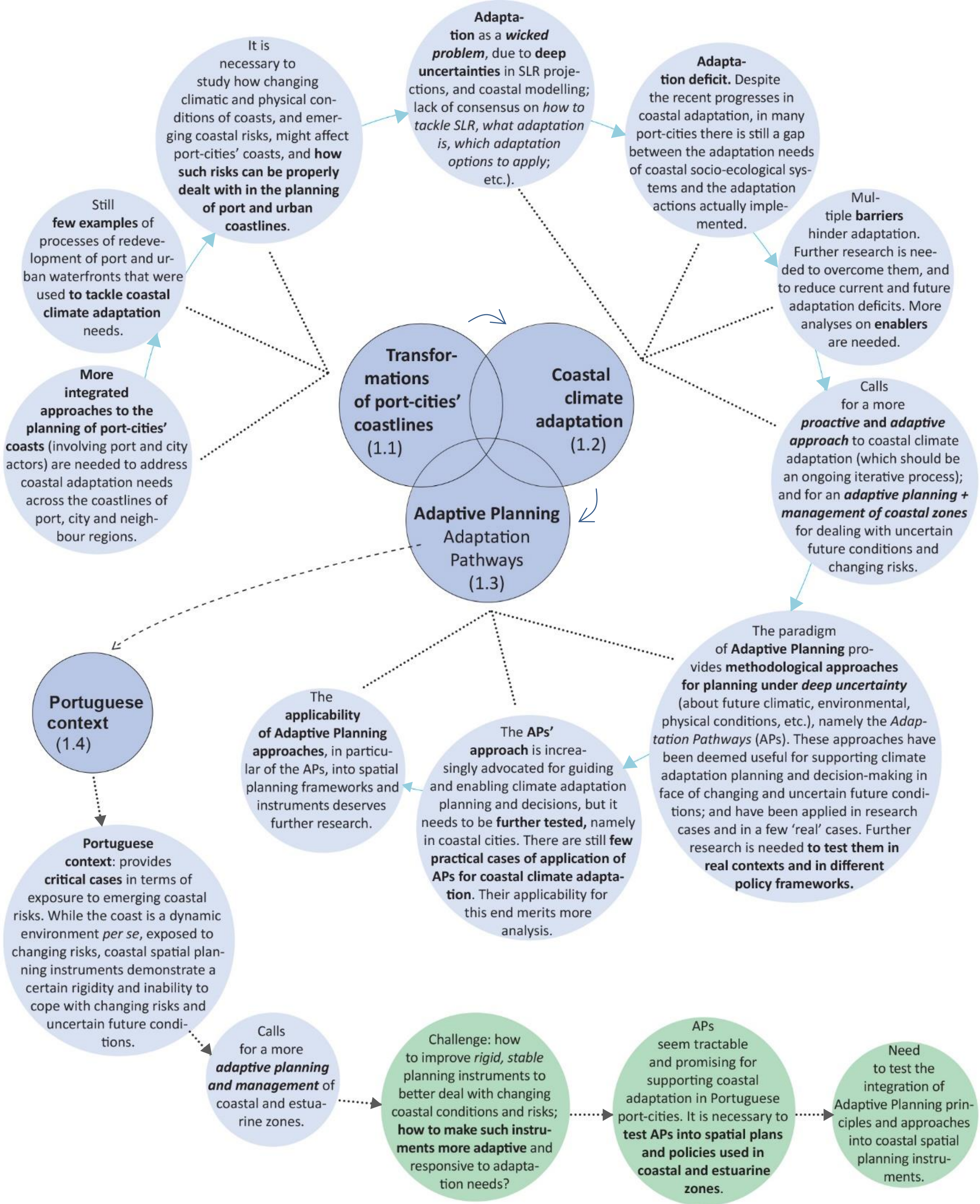


Figure 20. Final synthesis of key gaps and research needs identified in the theoretical framework (on the four main themes analysed). The three latter circles (in green) contain the gaps that this research has sought to address. Source: own elaboration.

This research sought to address the latter gaps (indicated in green), by analysing the applicability of Adaptive Planning approaches, especially of the Adaptation Pathways, into planning instruments used in port-cities' coastlines, for coastal climate adaptation planning, namely in the Portuguese context.

2. Research Proposal: Objectives and Methodology

INTRODUCTORY NOTE

This chapter presents the Objectives and Methodology of this research. It is structured in two sections. Section 2.1 (Objectives) includes the research problem, the main research question, the specific research questions, and the hypothesis. Section 2.2 (Methodology) explains the research methodology and its design.

The theoretical framework presented in the previous chapter led to the identification of the research problem and to the formulation of the main research question, from which the Objectives and Methodology were built. As mentioned, the theoretical framework has been focused on three key-topics and their intersection: a) the transformations of port-cities' coastlines; b) coastal climate adaptation; and c) Adaptive Planning (i.e. the family of conceptual and methodological approaches for planning under deep uncertainty), namely the Adaptation Pathways' approach. In each of the three main domains reviewed, the main gaps were identified and progressively intersected, leading to the research problem and research question(s). Thus, the main research question emerges from the intersection of the three main themes addressed in the theoretical framework (as well as the fourth section relative to the Portuguese context) (**Figure 21**).

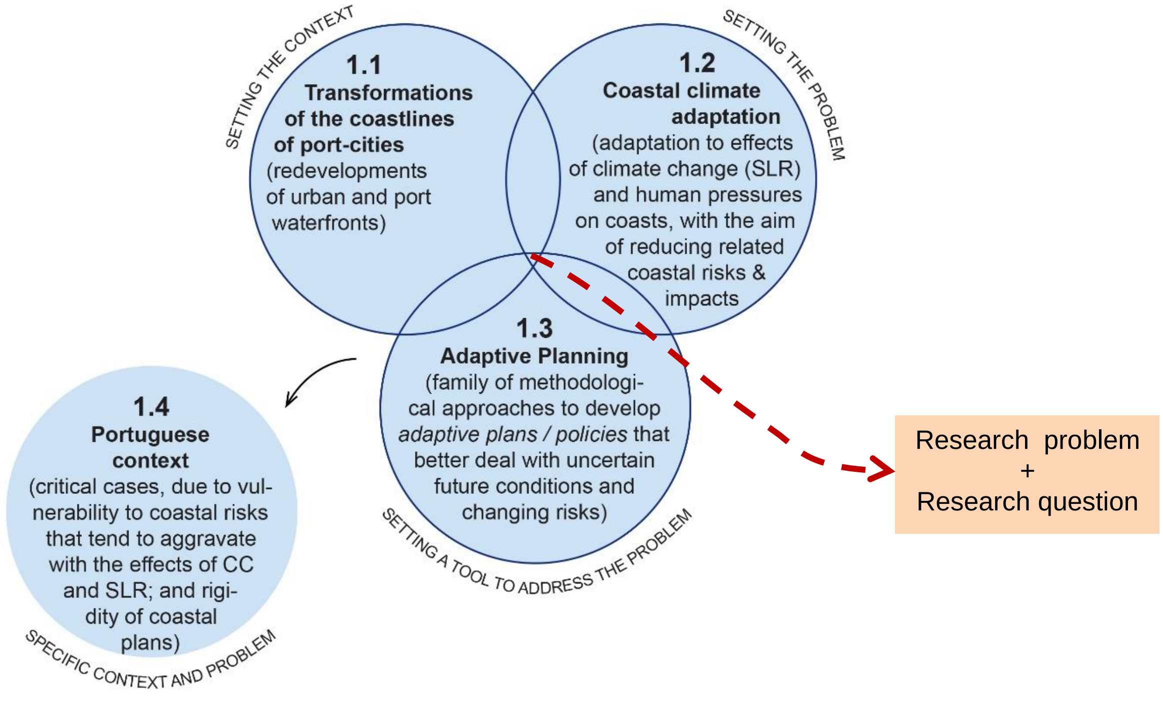


Figure 21. The four main domains addressed in the theoretical framework. The theme, the research problem and the research question were based on the intersection of these domains. Source: Own elaboration.

2.1. OBJECTIVES

2.1.1. RESEARCH PROBLEM

The research problem corresponds to an issue of concern that needs to be addressed, for instance, a difficulty in current practices which leads to the necessity for research (Creswell 2003). In the theoretical debate presented in the previous chapter, several gaps and deficiencies were identified for each of the three main domains reviewed.

Despite the increasing knowledge and experience in coastal climate adaptation, and despite the recent progresses in adaptation research, in many coastal port-cities across the world, it is possible to identify an adaptation deficit – i.e. a deficit of effective planning and / or implementation of adaptation measures, plans / policies, and actions, compared the real adaptation needs of coastal socio-ecological systems in the short-, medium- and long-term. Coastal climate adaptation and coastal management are often considered *wicked problems*, characterized by:

- deep uncertainties in climate and SLR projections and in the physical modelling of coastal changes, and complexities in the prediction of short, medium- and long-term coastal risks;
- lack of agreement on how to tackle SLR, what exactly coastal climate adaptation is, how to best implement it, what adaptation measures should be applied, and who will pay and benefit from it;
- complexities related with the presence of multiple stakeholders with different and often conflicting interests, goals and visions, diverse risk perceptions and diverse preferences for adaptation options;
- the overlapping or fragmentation of responsibilities, powers, jurisdictions, and planning instruments on urban coastal zones, especially in port-cities;
- contradictory goals, for example, aims of environmental sustainability – i.e. maintaining ecosystem's integrity and services – in contexts where such functions are already largely compromised;
- difficulties and intricacies in ensuring social equity in coastal adaptation and coastal management processes, namely intra- and inter-generational equity.

In addition, there are multiple barriers that preclude coastal adaptation planning and implementation in port-cities, namely: the common inertia in institutions and in societal systems, and resistance to change; the disarticulation between agencies with distinct jurisdictions and responsibilities on coasts, the lack of a truly *integrated coastal management*; the *rigidity* and *stability* of the regulatory frameworks and planning instruments in some coastal zones, and their difficulty in coping with uncertainty about future conditions and changes related with climate change effects, and multi-scalar complexity.

These problems, barriers and deficiencies are particularly concerning and challenging when overlapped, and interacting at the scale of port-cities' coastal zones. On their whole, they contribute to aggravate the main gap identified: the deficit of planning and implementation of coastal adaptation processes and responses, in more proactive, ongoing, feasible, *adaptive* and *sustainable* ways – *sustainable* both in social, economic and environmental terms, as well as over time, i.e. capable of *surviving* changes – in many port-cities' coastal zones. To reduce this gap, it is required further investigation of approaches, tools and means to enable, support, and operationalize the planning and implementation of coastal climate adaptation processes, in the face of uncertain future conditions and changing risks.

Recently, the Adaptive Planning paradigm, and its several approaches for planning under uncertainty, have been deemed promising for and applicable to climate adaptation planning and decision-making, under deeply uncertain, changing, and complex conditions. Nevertheless, further research is required to explore their practical applicability and usefulness in *real* contexts. The Adaptation Pathways approach, in particular, seems promising for enabling, supporting, informing and guiding the planning and implementation of adaptation processes, decisions and actions over time, but this assumption requires further exploration, in diverse contexts (different coastal biophysical and socioeconomic settings).

Moreover, the potential absorption of Adaptive Planning approaches, especially of Adaptation Pathways, into spatial plans has remained under-explored. There are still few practical cases reporting if and how Adaptation Pathways can be incorporated into planning instruments of urban and port planning, and coastal management. Thus, it is necessary to investigate the integration and application of Adaptive Planning approaches – especially of Adaptation Pathways – into planning instruments used in port-cities' coastal zones, and understand whether and how these approaches support coastal climate adaptation processes in the face of uncertain future conditions and change (research problem).

Considering this need, this project seeks to explore Adaptive Planning approaches, especially Adaptation Pathways: firstly, by analysing cases in which these have been applied, and then, examining their potential applicability into two planning instruments of two Portuguese coastal port-cities which seek to adopt a new model of adaptive planning and management of coastal zones.

2.1.2. Main Research Question

The research question is an interrogative statement that the researcher aims to answer, in order to understand, explain, or contribute to solve the research problem (Creswell 2003). Considering the theoretical debate and the research problem presented, the main research question is:

To what extent can an Adaptive Planning approach – including the Adaptation Pathways' method – be integrated and applied into the planning instruments used in the coastal zones of port-cities, namely in their port and adjacent urban coastal zones?

More specifically, the objective is to analyse to what extent and how an approach of Adaptive Planning and Management – including within it the Adaptation Pathways' approach – can be introduced and implemented in the planning instruments of port-cities' coastal zones (namely their port, contiguous urban seafront and estuarine zones), in order to enable, support and operationalize the planning and implementation of coastal climate adaptation processes, in more proactive, ongoing, feasible, adaptive and sustainable ways, and as a means to develop a *dynamic adaptive plan* that is able to deal with uncertain future conditions and changes, and thus, is more *sustainable* (able to 'survive' change).

This work addressed the research question firstly in two cases in which Adaptive Planning approaches, including the method of Adaptation Pathways (APs), were applied to plan for coastal climate adaptation / coastal risk management in the face of deep uncertainty about future conditions and changes (Part A – research on two Reference Cases in the European context); and, secondly, in cases that claim to have adopted an approach of adaptive planning and management and which have sought to introduce it (Part B – research on two Study Cases in Portugal).

In Part A, the research has sought to analyse the application of two different Adaptive Planning approaches into the planning instruments (that contain the method of Adaptation Pathways) used in coastal zones of port-cities (including estuarine zones), as useful tools for supporting and enabling the planning and implementation of coastal climate adaptation processes in the face of deep uncertainties about future conditions and changes and evolving risks, and as a means for developing *adaptive plans / programmes* (that are *dynamically robust* and *adaptable*). In Part B, the research focused on two planning instruments that advocate the adoption of a model of adaptive planning and management of coastal zones, and in which it would be useful to introduce and apply a truly 'Adaptive Planning approach' and its main elements – including the APs' method – to support the planning and implementation of coastal climate adaptation processes and improve coastal risk management under uncertain future changes and evolving risks.

2.1.3. Specific Research Questions

The main research question was subdivided into five specific research questions, which are instrumental, i.e. they served to gather information to answer the main research question, and shaped the focus of this work. These specific questions were addressed through different (methodological) tasks. This research sought to answer the following specific research questions:

Regarding the Reference Cases in Europe (Part A):

I. How are Adaptive Planning approaches, including the method of Adaptation Pathways, being developed and applied into the planning instruments used in coastal and estuarine zones of two port-cities (*TE2100 Plan* in London, and *Delta Programme* 2014 in Rotterdam area), for planning for coastal climate adaptation / coastal risk management under uncertainty about future conditions and changes? What did the application of an Adaptive Planning approach involve?

II. What are the key elements essential in an Adaptive Planning and Management approach and required to develop a '*dynamic adaptive plan*'? What requisites should a plan meet to be *adaptive*? What are the main elements / ingredients required to ensure the *dynamic robustness*, *flexibility*. and *adaptability* of the plan?

Regarding the Study-Cases in Portugal (Part B):

III. Is an Adaptive Planning approach being introduced and applied in the Portuguese cases, to address coastal adaptation / coastal risk management? Have the selected cases applied approaches of Adaptive Planning, and how? How do the selected cases conceptualize and define their approach of adaptive planning and management? Were the principles of *dynamic robustness*, *flexibility*, and *adaptability* assumed as guiding principles for the Plan or planning approach?

IV. Whether, and how, the key-elements of an Adaptive Planning and Management approach (identified in Part A) are being used in the two cases? Are the key-elements essential to develop an '*adaptive plan*' present in each case?

V. What barriers can be found in the cases that hinder a truly *Adaptive Planning and Management*, and a *more adaptive* approach to coastal climate adaptation (its planning, implementation, and monitoring)?

Importantly, the Research Proposal has suffered some adjustments since the moment of publication of the Thesis Project – for example, the specific research questions have been reformulated as the investigation progressed from Part A to Part B, and in function of the initial findings of the case-studies of Part B. Thus, methodological tasks that were associated to each of the specific research question have also been adjusted (according to the new questions that were posed).

2.1.4. Reference Cases and Study-Cases

The selected cases were:

- In Part A (research on two Reference Cases), two cases of application of Adaptive Planning approaches that include the Adaptation Pathways' method, into two planning instruments used in coastal and estuarine areas of port-cities, for planning for coastal climate adaptation / coastal risk management: i) the Thames Estuary Project 2100 (TE2100 Project and Plan in London region); and ii) the Dutch Delta Programme, namely in the area of the Rhine-Meuse Delta (DP 2014).[1]

- Part B (empirical research focused on two Study-Cases in Portugal): two coastal spatial planning and management instruments recently developed. The analysis was specifically focussed on the coastal zones of the two major port-cities in Portugal (the coastal of the metropolitan area of Porto, including the Port of Leixões, and the coastal and estuarine zone of Lisbon metropolitan area, including the Port of Lisbon). The cases selected consist of two Programmes for the Coastal Zone – *Programas da Orla Costeira* – which claim to have adopted a new model of adaptive planning and management.

While the Reference Cases offer experiences / examples in which Adaptive Planning approaches were already used into plans / programmes for coastal risk management / adaptation planning purposes, in the Portuguese context, the introduction and application of such planning approaches could substantially benefit coastal planning and management practices in the face of uncertain future conditions and changing risks. In Portugal, the possibility of implementing a more *adaptive planning* of coastal zones, through the application of a methodological approach of Adaptive Planning (including the method of Adaptation Pathways) into planning instruments used in coastal zones of port-cities, and as a tool to manage emerging coastal risks and address coastal climate adaptation needs, deserved further research.

Thus, in Part B, the cases selected correspond to two coastal planning and management instruments used in the coastal zones of the two major Portuguese port-cities, which claim that they have launched and adopted a novel approach of *adaptive planning and management* of coastal zones. Thus, it was necessary to assess to what extent is a real approach of Adaptive Planning and Management (APM) being implemented in such cases – namely whether and how the key-elements of an APM have been applied.

- **Case I** is the new Programme for the Coastal Zone Caminha-Espinho (*POC-CE*), with a specific focus on the coastal zone of the cities of Matosinhos and Porto, including the Port of Leixões[2].
- **Case II** is the Programme for the Coastal Zone Alcobaça-Cabo Espichel (*POC-ACE*), with the specific focus on the coastal stretch of the Municipalities of Lisbon, Oeiras, Cascais, Almada and Seixal, including the Port of Lisbon and the estuarine zones.

The case studies focused planning instruments used in the coastal zones of port-cities. The study was anchored in one specific type of plans – coastal zone management plans – and focused on specific spaces – the coastal zones of port-cities. The use of planning instruments (coastal planning and management instruments) targeted at coastal zones of port-cities as the object of analysis in Part B has helped to set boundaries for this research. Unlike other coastal uses, ports are usually located in areas particularly vulnerable to the effects of climate change and SLR. On their turn, port-cities' communities and economies are highly dependent on waterfront locations, like seafronts or estuaries, which put heavier pressures on coastal ecosystems and tend to aggravate the vulnerability and exposure to coastal risks.

[1] The selection of cases that would be studied in Part A was based on a prior systematization (carried in the phase of elaboration of the Thesis Project) of: coastal planning instruments used in European countries (**Table F**, Appendix), of strategies adopted by some European countries to address climate adaptation (**Table G**, Appendix), and of cases of in which Adaptive Planning approaches, especially the Adaptation Pathways (APs) were already applied to deal with coastal climate adaptation issues in the face of uncertain future changes (**Table K**, Appendix).

[2] The Port of Leixões is expected to undergo future works for the expansion of the western areas of the container terminal towards west, the reconversion of the fishing port area, as well as a possible extension of the exterior west breakwater towards south. The new container terminal will be designed to receive Post-Panamax ships (Dias et al. 2012). These projected works will have repercussions on the vulnerability and exposure of nearby beaches, especially at south of the port. Thus, it seems pertinent to address coastal climate adaptation issues in this context.

2.1.5. HYPOTHESIS

Hypotheses are *predictions that the researcher holds about the relationship among variables* (Creswell 2003), for example, about the relationship between independent and dependent variables. Researchers usually have certain expectations about the relationship among variables and predicted outcomes, thus, they test hypotheses and draw inferences from them (Creswell 2003). Ultimately, hypotheses are provisory answers to the research question, which the researcher predicts based on information and clues provided by the literature reviewed. In this sense, the following hypothesis was initially advanced:

> The integration and application of Adaptive Planning approach (including the Adaptation Pathways' method) into the planning instruments used in the coastal zones of port-cities, is possible, provided that such planning instruments meet several requisites – key-elements / ingredients necessary to develop a dynamic adaptive plan and to operationalize a truly process of Adaptive Planning and Management (which is associated to an ongoing process of coastal climate adaptation). Moreover, the adoption of such Adaptive Planning and Management approach can contribute to enable and support the planning and implementation of coastal climate adaptation processes, and lead to more *adaptive* and *sustainable* plans (that 'survive' change and are better prepared to cope with uncertain future conditions and changing risks), provided that such plans (and their pathways) ensure and comply with important criteria (namely dynamic robustness, flexibility, *adaptivity*, low-/no-regrets' properties such as *revisability*, *correctability*, *reversibility*, *easiness to be changed*, *etc.*).

2.2. METHODOLOGY

The methodology is the strategy or plan that links the research questions to outcomes, and it guides the choice and use of methods (Creswell 2003). On their turn, the methods correspond to techniques or procedures that will be used to answer the research questions.

2.2.1. A MIXED-METHODS APPROACH

In this work, the main area of research– i.e. spatial planning – intersects with the emerging knowledge on climate change, coastal adaptation science and coastal risk management (thus, it crosses social, applied and natural sciences), wherefore it was adopted a mixed-methodology (that mixes quantitative and qualitative methods, in a mixed method). This methodology was applied on a case study-based approach. The case studies were carried in Part B.

2.2.2. METHODOLOGICAL DESIGN: STAGES OF THE RESEARCH PROCESS

The structure and organization proposed for this research is presented **Figure 22**. The research was structured in **three main parts: A, B and C**. Each part involved several tasks. Such tasks sought to answer specific research questions and, thus, resorted to different methods.

Part A | research on two cases in the European context in which Adaptive Planning approaches, including the Adaptation Pathways' method, were used into planning instruments of coastal and estuarine zones of port-cities, for coastal climate adaptation planning purposes and / or coastal risk management, under deep uncertainties about future conditions and changes.

Task 1: Analysis of two planning instruments (plans / programmes) that developed and applied Adaptive Planning approaches, including the Adaptation Pathways' approach (APs), to plan for coastal climate adaptation / coastal risk management and to deal with deep uncertainties about future conditions and changes (e.g. changing risks associated with climate change effects).

Task 2: Identification and systematization of the key elements of the Adaptive Planning approaches applied, namely the main elements / ingredients that were essential to develop *dynamic adaptive plans* and which are necessary to ensure and operationalize an Adaptive Planning and Management.

↓

Part B | case-studies. Research on two Portuguese coastal spatial planning and management instruments that have sought to introduce and adopt a new approach of 'adaptive planning and management' of coastal zones, in order to assess whether, and how, a real Adaptive Planning approach was used, and evaluate the extent to which such an approach and its key-elements were met and ensured.

Task 3: Analysis of two coastal plans (programmes) that advocate the adoption of a new model of adaptive planning and management of coastal zones, and which have sought introduce a new approach of 'adaptive planning and / or management'. Examine if the selected cases have applied an Adaptive Planning approach, and how an 'adaptive planning and management' has been conceptualized and defined.

Task 4: Assessment of whether and how the key elements of the Adaptive Planning approaches (identified in Task 2) – i.e. the main elements essential to develop a *dynamic adaptive plan* and to deliver an Adaptive Planning and Management – are present (met) in the Portuguese cases. Evaluate the selected cases against each key-element.

Task 5: Identification of barriers to the introduction and application of a real Adaptive Planning and Management approach (including the APs' method), and to a more *adaptive* approach to coastal climate adaptation / coastal risk management, existent in the selected cases.

↓

Part C | Answering the main research question; drawing of conclusions; and elaboration of recommendations (for the Portuguese cases).

Task 6: Synthesis and confrontation of the main findings of Part A and Part B. Answer the main research question.

Task 7: Discussion on the potential feasibility of applying an Adaptive Planning and Management approach, including the APs' method, in the Portuguese study cases in the future. Drawing recommendations for the Portuguese cases.

Figure 22. Main parts of the research and their respective tasks. Own elaboration.

PART A (research on two Reference Cases in the European context). The focus will be on cases in which Adaptive Planning approaches, including the Adaptation Pathways' approach, were developed and applied into two new planning instruments (that address coastal and estuarine zones of port-cities) to plan for coastal climate adaptation / coastal risk management. Part A includes task 1 and task 2.

TASK 1 seeks to answer the specific research question I.

Task 1: analyse two cases in which Adaptive Planning approaches, including the Adaptation Pathways' method (APs), were applied in planning instruments used in coastal and estuarine zones of port-cities, as tools to support coastal climate adaptation planning and / or coastal risks management, in the face of deep uncertainties about future changes and conditions (namely uncertainty associated with the effects of climate change on emerging and changing coastal risks).

Essentially, this task focused on examining the development and application of two different Adaptive Planning approaches – including the Adaptation Pathways' method (APS) – into two planning instruments that address coastal zones of port-cities, as a means (methodological tool) for planning for coastal climate adaptation / coastal risk management. Each of the Reference Cases should be examined in terms of: a) Adaptive Planning approach developed and applied (input), and b) process of development and application of such approach into the new planning instruments.

Thus, this task should concentrate on the following dimensions of analysis:
- Type and main characteristics of the Adaptive Planning approach used, i.e. tools, methods and principles created and introduced;
- How such approach was developed and applied (process / procedures, main steps and phases, context of application, actors involved, time required, etc.);
- Motivators and drivers, i.e. factors driving to the development of Adaptive Planning approaches.
- Main pre-requisites that the plan should meet (pre-defined requirements) and requirements for the Adaptive Planning approaches;
- Main attributes of the Adaptive Planning approaches created, namely of the APs, which allowed the development of a *dynamic adaptive plan / programme*.
- Types of adaptation options foreseen; timeframe considered; spatial scale addressed; climate and SLR scenarios considered, pre-defined objectives (vision of the desired futures).
- Identifiable outcomes / effects of the application of Adaptive Planning approaches; evolution after the application of Adaptive Planning approaches (and publication of the plan / programme), main contributes of the Adaptive Planning approaches used.

In terms of **methods**, Task 1 involved: an in-depth analysis of the selected planning instruments; scanning of topics regarding 'Adaptive Planning and Management', 'Adaptation Pathways', 'uncertainty', 'coastal climate adaptation'; interpretation of qualitative and quantitative data (APs' maps, tipping-points, future scenarios); a systematization and organization of information according to the dimensions of analysis mentioned; a comparative analysis and synthesis of the Reference Cases.

TASK 2 seeks to answer the specific research question II.

Task 2: Identify and systematize the main elements of the Adaptive Planning and Management approaches developed in each Reference Case (which contained the APs method), namely the key requisites / ingredients that were essential to develop a *dynamic adaptive plan / programme*, i.e. a *dynamic robust* and *flexible* plan – that is able to deal with uncertain future changes (and evolving risks) – and which are required to deliver a process of adaptive planning and management.

Firstly, this task involved identifying and organizing the main elements / requisites of the Adaptive Planning approaches that were developed and applied in the Reference Cases, and which were essential to develop a dynamic adaptive plan (or adaptive strategies, in the case of the Delta Programme). Secondly, it was conducted a review of scientific literature on the main elements of the Adaptive Planning approaches and the main requisites to build a '*dynamic adaptive plan / policy programme*' that contains adaptation pathways. Thirdly, based on the results of the two prior operations, the key-elements required to develop a *dynamic adaptive plan* and indispensable in an Adaptive Planning and Management approach were systematized. This task also allowed the identification of the main 'ingredients' (components) that a plan should meet to be *dynamically robust* and *adaptable* (which were derived from the analysis of the two Reference Cases and from studies on these Cases) – i.e. it also implied analysing what are the main elements / ingredients necessary to ensure the *dynamic robustness*, *flexibility* and *adaptability* of the plan / programme (and its strategies).

Ultimately, the purpose of this task was to identify the elements that are essential to develop a *dynamic adaptive plan* that is able to deal with uncertain future conditions and changes over time, and, thus, able to 'survive' change, and more 'sustainable'. The list of the key-elements should have an instrumental/ operational character: it should sum up the elements characteristic of Adaptive Planning approaches that must be met to construct a *dynamic adaptive plan*, and it show allow for future comparisons of other cases (worldwide) with these key-elements. With the final list of key-elements, it should be possible to confront other cases against the key-elements, and check / verify whether each element is met (and thus, to which extent a truly Adaptive Planning and Management approach is applied and concretized).

In terms of **methods**, Task 2 involved: a) the search for (identification of) the main elements that were necessary to develop a *dynamic adaptive plan / strategies* in the two Reference Cases and of the main requisites and ingredients of the Adaptive Planning approaches devised, b) the review of literature on the elements fundamental in Adaptive Planning approaches and indispensable to develop dynamic adaptive plans; c) the systematization of the key-elements required to design an adaptive plan and to operationalize an Adaptive Planning and Management. In addition, this task involved the identification of ingredients that make the plan / strategies developed in the Reference Cases *dynamically robust* and *adaptable* (i.e. which confer *dynamic robustness* and *adaptability* to the plan / strategies devised).

PART B consisted of a case-study based research focused on two cases in Portugal. The aim was to assess if and how Adaptive Planning and Management approaches were applied into two different coastal planning and management instruments that claim to have adopted a novel approach of adaptive planning and / or management of coastal zones. Part B includes the tasks 3, 4, and 5.

Task 3 seeks to answer the specific research question III.

Task 3: Analyse two Programmes for the Coastal Zone (POCs) that have sought to introduce and launch a new approach of adaptive planning and management of coastal zones, and examine if such programmes have applied an Adaptive Planning approach, and how each POC defines and conceptualizes its approach / model of 'adaptative (coastal) planning and management'.

This task required an analysis of the two selected POCs (their contents and process of elaboration) to detect whether each case developed and applied a truly approach of Adaptive Planning and Management. It also was necessary to examine how each Programme has framed and defined the concept of 'adaptive planning and / or management' and what such an approach entail / imply.

The two coastal programmes selected advocate the adoption of a new model / approach of adaptive planning and management of coastal zones, and have sought introduce such novel approach (in the face of the inherent dynamism of coastal zones and uncertain future conditions and changing coastal risks associated with climate change and ongoing anthropic pressures). Thus, it was pertinent to examine if these cases have applied an Adaptive Planning and Management approach (APM), and how an 'adaptive planning and management' was conceptualized and defined. Moreover, this task involved checking if the principles of *dynamic robustness, flexibility* and *adaptability* (which underlie the paradigm / family of Adaptive Planning approaches) had been assumed as guiding principles for the Programme or its planning / management approach.

This task also involved an analysis of diverse guidance and strategic policy / planning documents to search for specific references to, or recommendations for the use of, an adaptive management / planning approach and to any contents related with the key-elements identified in Task 2. It was important to understand whether there were already guidance and reference information available when the elaboration of the new POCs was initiated, and if such guidance was absorbed in the POCs.

Moreover, this task required an analysis of other issues (related with APM approaches and principles):
- How are the selected POCs addressing coastal climate adaptation needs and challenges, namely the existence of deep uncertainties around the projection of future coastal risks (and the effects of climate change and socioeconomic development)?
- Do these programmes have mechanisms to properly deal with / handle uncertainty about future conditions and changes and complexity (associated to natural variability, dynamic environments, emerging coastal risks associated with climate change effects, namely SLR)? Do these programmes have proper tools to manage changing risks over time?
- What is the lifespan (shelf life) expected for the POCs? Were the POCs devised as long-term plans?
- Do the POCs contain specific guidelines for the development of an *adaptive plan / strategies* (for coastal climate adaptation), or are these guidelines absent? Did the POCs set prerequisites for the planning approach or for the Programme related with *robustness*, *flexibility*, or *adaptability*?
- What are the main objectives of the POCs?
- How are the POCs' contents devised and structured, namely its strategies of coastal adaptation?

The **methods** used in Task 3 were: content analysis of the selected POCs, search for references to 'Adaptive Planning', 'Adaptive Management', 'pathways' 'uncertainty', 'coastal climate adaptation'; 'robustness', 'flexibility', 'adaptability'; and analysis of guidance documents and reference information that served as a basis to the elaboration of POCs to check if they mentioned aspects of adaptive planning and / or management.

It also is worth mentioning that, in the scope of the research of Part B, several entities were asked to participate in individual interviews to discuss the potential applicability of an Adaptive Planning approach (including APs) in their own planning instruments – namely APA (Portuguese Environment Agency, responsible for the leadership and supervision of the elaboration of the new POCs), coastal municipalities of the Metropolitan Area of Porto and of the Metropolitan Area of Lisbon, the Administration of the Lisbon Port and the Administration of the Leixões Port. Most of these entities answered to this request and showed interest in using such a methodology. However, APA did not reply. Notwithstanding, it is at the POCs that an eventual application of an approach of Adaptive Planning and Management could be more useful and valuable – the POCs work at diverse geographical scales (along the coast), cross several municipalities, have a strategic role in addition to a normative role (while the municipal plans lack such strategic scope), and one of their main objectives is the prevention and reduction of coastal risks (coastal risk management). Thus, POCs seemed the most appropriate planning instruments for introducing an approach of APM. Moreover, APA claimed that the new POCs have sought to adopt such an approach (a positive signal of the intention of launching an adaptive approach).

Task 4 seeks to answer the specific research question IV.

Task 4: Assess whether, and how, the key-elements of an Adaptive Planning approach (including APs) identified in Task 2 – i.e. the main elements essential to develop a *dynamic adaptive plan / programme* and to deliver a process of Adaptive Planning and Management – are present (met) in the Portuguese cases. Confront and evaluate the selected POCs against the key-elements of Adaptive Planning.

This task involved a confrontation and assessment of the selected plans against (in relation to / on) the key-elements of an Adaptive Planning and Management approach. More specifically, Task 4 required an assessment (evaluation) of the selected POCs against each of the key-elements that were systematized in Task 2. It was necessary to analyse the POCs' contents and verify if each key-element was met, and how. The two POCs were discussed in the light of the main elements of an Adaptive Planning approach that are necessary to develop an *adaptive plan*. More specifically, by using the list of key-elements that were derived from the Reference Cases (and scientific literature on Adaptive Planning approaches), it was possible to compare each key-element with the response given by each POC to such aspect (i.e. assess the ways through which each POC has answered and addressed each key-element).

This task implied an in-depth analysis of the following issues:
- Did the POCs use various plausible future scenarios? Which scenarios were developed and how?
- Did the POC examine critical thresholds / Adaptation Tipping-points?
- Was the APs' method applied to devise strategies of coastal adaptation / coastal risk management?
- Did the POCs contain and define a monitoring and reassessment system?
- Were the dynamic robustness and adaptability of each POC, and of its strategies, safeguarded?
- Did the POC specify any process of adaptive planning and management, and the steps involved?
- If the ingredients that ensure the dynamic robustness and adaptability of the plan itself (and its strategies) can be found in the selected POCs and in their adaptation strategies?

To answer the specific research question IV, this task required confronting: the selected POCs, and the ways through which they currently cope with changing coastal risks, deep uncertainties about future conditions and changes (and *wicked problems* associated to the expected effects of climate change, SLR and human pressures on coasts), on one hand, with the main ingredients and elements of Adaptive Planning approaches and their ways of planning for coastal climate adaptation / coastal risk management and ways of dealing with uncertain future changes and changing risks – which had been deduced from the Reference Cases and which have been advocated and proposed in the scientific literature on the paradigm of Adaptive Planning approaches, on the other hand. It was necessary to analyse the current status of the POCs in terms of responsiveness to coastal climate adaptation challenges (and preparedness to deal with uncertain future change), in terms of achievement of requisites for an Adaptive Planning and Management; and, in this way, identify the main gaps in these planning instruments in terms of *dynamic robustness* and *adaptability* (of the POCs and their strategies).

In terms of **methods**, Task 4 involved: an analysis of the selected cases to search for contents and keywords related with the key-elements identified in Task 2, an evaluation of the POCs' contents against such key-elements (confrontation and comparative assessment to verify the presence of each key-element in the POCs). This assessment allowed grasping whether there are significant gaps between the POCs and the elements essential for an Adaptive Planning approach. It allowed discussing the level of development and concretization of the approach of adaptive planning and management advocated by the POCs, and, in this way, assessing the extent to which a real Adaptive Planning and Management approach is being delivered in the POCs (thus, Task 4 helped to answer the main research question).

In the scope of Task 4, and in the sequence of the analysis of the strategies of adaptation proposed by the POCs, it was developed a type-map of adaptation pathways that could be developed in each POC.

Such map is an example of a possible map of pathways that could be designed and presented in each POC. It does not aim to provide any concrete solution – what is at stake it the method of developing pathways to be included in the future in the POCs, and not the contents of the maps (or their adequacy).

At the end of Task 4, the main findings / results obtained from the two Portuguese study cases (regarding the specific research questions III and IV) were synthesized and presented in comparative tables. This involved a systematization and comparison of results of the two Portuguese case studies.

Task 5 seeks to answer the specific research question V.

Task 5: Identify barriers to the application of an Adaptive Planning and Management approach, and, in a broader sense, to an *adaptive planning and management* of coastal zones and a more adaptive approach to long-term coastal climate adaptation / coastal risk management), in the selected planning instruments.

This task consists of diagnosing barriers that hampered the application of an approach of Adaptive Planning in the selected POCs and of obstacles and difficulties that preclude a more adaptive approach to coastal climate adaptation – its planning and implementation – in the studied cases, namely of hindrances or shortcomings in the POCs themselves. Thus, the following issues will be analysed:

a) What problems can be identified in these instruments in terms of Adaptive Planning principles and assumptions, and in terms of principles for ensuring a sustainable and ongoing process of coastal climate adaptation? Do the selected POCs show signals of policy / plan's *stability* and *rigidity* (an inherent lack of adaptability, flexibility or dynamic robustness; overload of regulations on coastal zones and the difficulty of changing them in function of changing conditions and evolving risks)?
b) Have the new POCs brought significant improvements in relation to the first POOCs in terms of preparedness to address coastal climate adaptation needs and capacity to deal with deep uncertain future conditions and changes? Are the new POCs more 'adaptive' that the 1st POOCs?
c) What were the main difficulties in and hindrances to a truly introduction and adoption of approaches of Adaptive Planning and Management in the selected cases?

The **methods** used in Task 5 were: content analysis of the selected plans to search for gaps in their current planning and management approach for coastal climate adaptation and for hindrances arising in the current planning system and regulatory framework; interviews for the identification of barriers to key-actors (e.g. port authorities, municipalities, municipal spatial planning staff, consultants); and analysis of articles and scientific literature that already outline barriers to an adaptive planning and management approach and to the concretization of coastal climate adaptation in the Portuguese context.

PART C consists of a final synthesis and confrontation of the main findings of Part A and B, in order to draw the main conclusions (and answer the main research question and the specific research questions), and recommendations for the Portuguese cases. Part C includes the tasks 6 and 7.

Task 6: sum up and confront the findings of Parts A and B; answer the main research question.

Task 6 sends back to the main research question. To answer it, the main findings of Part B must be confronted and contextualized with the findings of Part A. This task implies verifying the applicability of Adaptive Planning approaches (including APs) into plans, and their relevance for supporting the planning of coastal climate adaptation / coastal risk management in coastal zones of port-cities, under deeply uncertain future conditions and changes. It was important to reflect on the potential application of the knowledge core on Adaptive Planning approaches (including APs) for coastal climate adaptation planning purposes in different coastal port-urban contexts.

In terms of **methods**, Task 6 involved: drawing inferences, conclusions; systematization and articulation of results of Part A and B. The answers to the research questions are presented in the Conclusions.

Task 7: Discuss the potential future applicability of an Adaptive Planning approach, including the method of Adaptation Pathways, and draw up recommendations for the Portuguese cases.

Task 7 will consist of a final discussion on the potential feasibility / viability of applying an Adaptive Planning and Management approach, including APs, in the Portuguese cases, in the future. This task will seek to summarize the necessary conditions for a more *adaptive coastal planning model* in the Portuguese cases. Therefore, the following issues will be addressed:

- What adjustments and modifications would be necessary to integrate and apply an Adaptive Planning and Management approach, including the APs' method, into the selected planning instruments? How to introduce elements of 'adaptive plans' (e.g. adaptivity) into plans that have been *static*?
- How can an Adaptive Planning approach, including the method of APs, be integrated and applied into the selected planning instruments, as a means to support and operationalize long-term coastal climate adaptation processes (their planning and implementation) under uncertainty about future conditions and changes? How could the APs be applied and managed over time, in such plans?
- What scope is there for taking an *adaptive coastal planning* forward in the selected cases; would it be viable to apply an Adaptive Planning and the APs into these planning instruments?
- How to overcome the barriers and impediments identified in Task; what enablers can help to overcome such barriers (for example found within the Adaptive Planning paradigm).

Task 7 will imply exploring the possibilities of introducing and applying Adaptive Planning approaches – including APs – and their key-elements, into the selected planning instruments. In the recommendations, it will be important to highlight the importance such approaches to improve current coastal planning and management practices in the face of uncertain future conditions and change, and to better manage changing coastal risks, and as methodological tools to support and operationalize the planning and implementation of long-term coastal climate adaptation processes, and in this way, justify why Adaptive Planning approaches should be applied in the POCs.

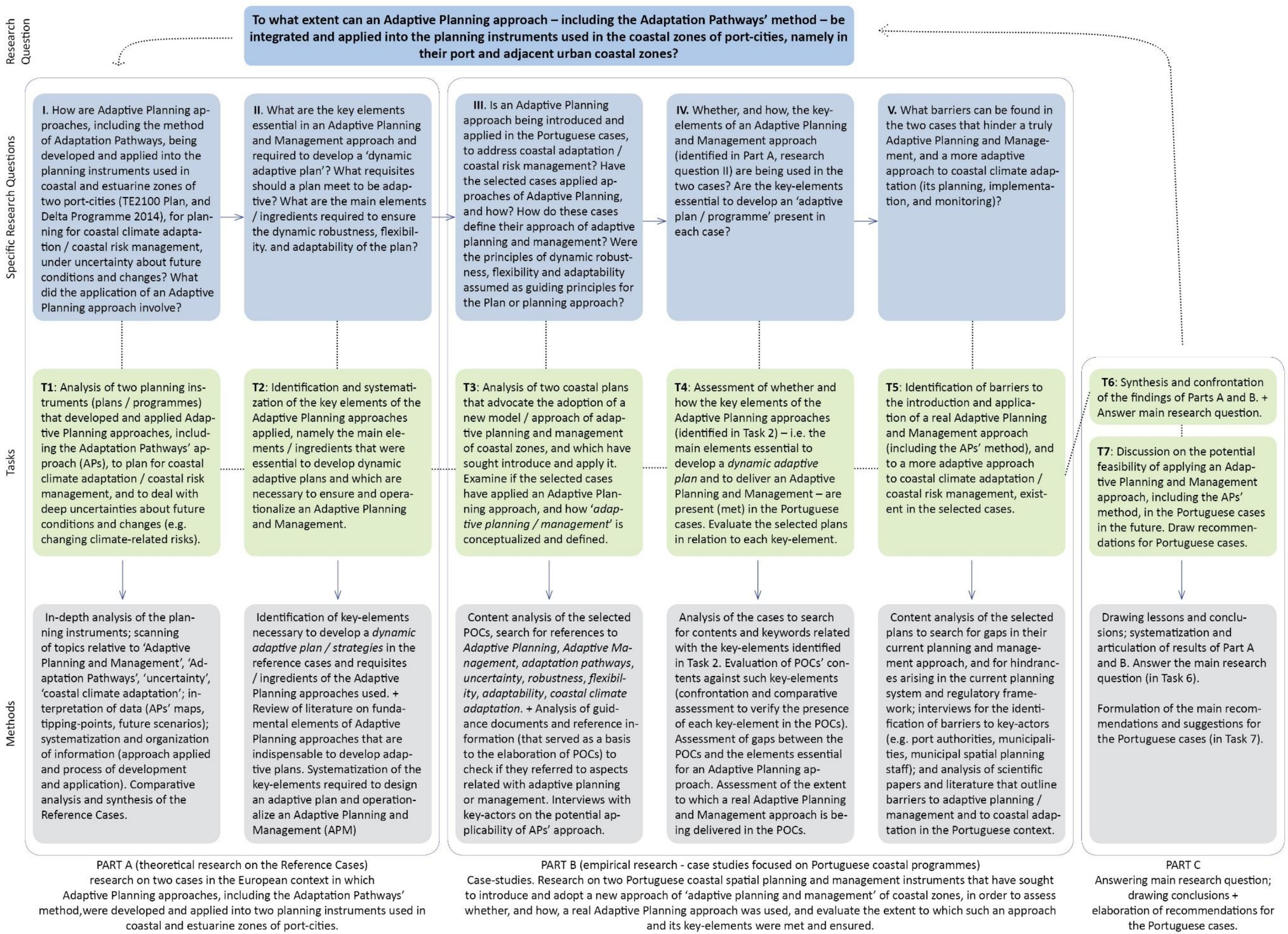
In terms of **methods**, Task 7 required the formulation of the main recommendations and suggestions for the Portuguese cases. In broad terms, this task seeks discuss the potential applicability of an Adaptive Planning approach into the studied planning instruments, as a means to achieve an end: enable a more *sustainable* planning for coastal climate adaptation / coastal risk management, and more adaptive coastal planning and management practices, under deep uncertainty about future changes and evolving risks.

Furthermore, this section will also identify issues for further investigation, such as:

- What does the application of Adaptive Planning approaches (including the APs method) into the POCs might imply (what implications and repercussions might this have, e.g. adjustments needed to incorporate and implement the Adaptation Pathways into the studied POCs)?
- To which extent the current regulatory framework and planning instruments analysed would need to be transformed to integrate APs (that could be iteratively planned, managed or evaluated over time)?
- Could the application of Adaptive Planning approaches into planning instruments used in coastal port-cities support coastal climate adaptation planning in the face of uncertain future changes?

In the future, it will be important to assess if the application of an Adaptive Planning approach into the studied planning instruments could contribute to streamline and operationalize ongoing and more *sustainable* coastal climate adaptation processes in the Portuguese cases, considering the deep uncertainties about future conditions and changes, and the current existence of adaptation deficits (which will tend to aggravate with the effects of climate change and ongoing anthropic pressures).

The previously mentioned research questions, tasks, and methods are synthesized in **Organigram 1**.



Organigram 1. Research framework. It identifies the main research question, specific research questions, parts, tasks, and methods, proposed for this research.

Part A: Reference Cases

ANSWERING THE SPECIFIC RESEARCH QUESTIONS I AND II

INTRODUCTORY NOTE

The two major applications of Adaptive Planning approaches – including the Adaptation Pathways' approach (APs approach) – in the field of flood risk management and coastal climate adaptation are the TE2100 Project and the Delta Programme. The Adaptation Pathways' approach was first applied in the TE2100 Project and, subsequently, in the Dutch Delta Programme.

This research focussed on these two cases, in order to analyse:

I. How are Adaptive Planning approaches, including the method of Adaptation Pathways, being developed and applied into the planning instruments used in coastal and estuarine zones of two port-cities (*TE2100 Plan* in London, and *Delta Programme* 2014 in Rotterdam area), for planning for coastal climate adaptation / coastal risk management under uncertainty about future conditions and changes? What did the application of an Adaptive Planning approach involve? (**specific research question I**)

II. What are the key elements essential in an Adaptive Planning and Management approach and required to develop a '*dynamic adaptive plan*'? What requisites should a plan meet to be *adaptive*? What are the main elements / ingredients required to ensure the *dynamic robustness* and *adaptability* of the plan? (**specific research question II**)

This chapter answers these two research questions, first in relation to the TE2100 case, then in relation to the Delta Programme (DP) case, and then it provides a synthesis drawing on both cases. In each case, this chapter is structured as follows:

- Section 1 introduces the pre-existent flood risk management (FRM) system when the Project / Programme was initiated.
- Section 2 presents the TE2100 Project / DP, and its main characteristics (objectives, drivers, requisites, etc.)
- Section 3 describes the Adaptive Planning approach devised and used to develop an adaptive plan.
- Section 4 explains how this Adaptive Planning approach was applied (the process of application).
- Section 5 highlights some of the main contents of the Plan.
- Section 6 identifies the main elements and ingredients of the Adaptive Planning approach adopted that are essential to develop an '*adaptive plan*'.
- Section 7 provides a brief overview of the current status of the Plan / Programme.
- Section 8 sums up some of the main effects and outcomes of the Plan / Programme, focussing on positive outcomes and advantages of using an Adaptive Planning approach, as well as on barriers to and difficulties in applying it.

CASE I – THAMES ESTUARY 2100 PLAN (TE2100)

1. EXISTING FLOOD RISK MANAGEMENT SYSTEM AT THE BEGINNING OF THE TE2100 PROJECT

This section presents a brief description of the existent flood risk management (FRM) system in the Thames Estuary when the TE2100 Project was initiated.

The historical background of flood risk management (FRM) in the Thames Estuary and London, and the status of FRM by the time when the TE2100 Project was initiated, are briefly outlined in Figure 1.

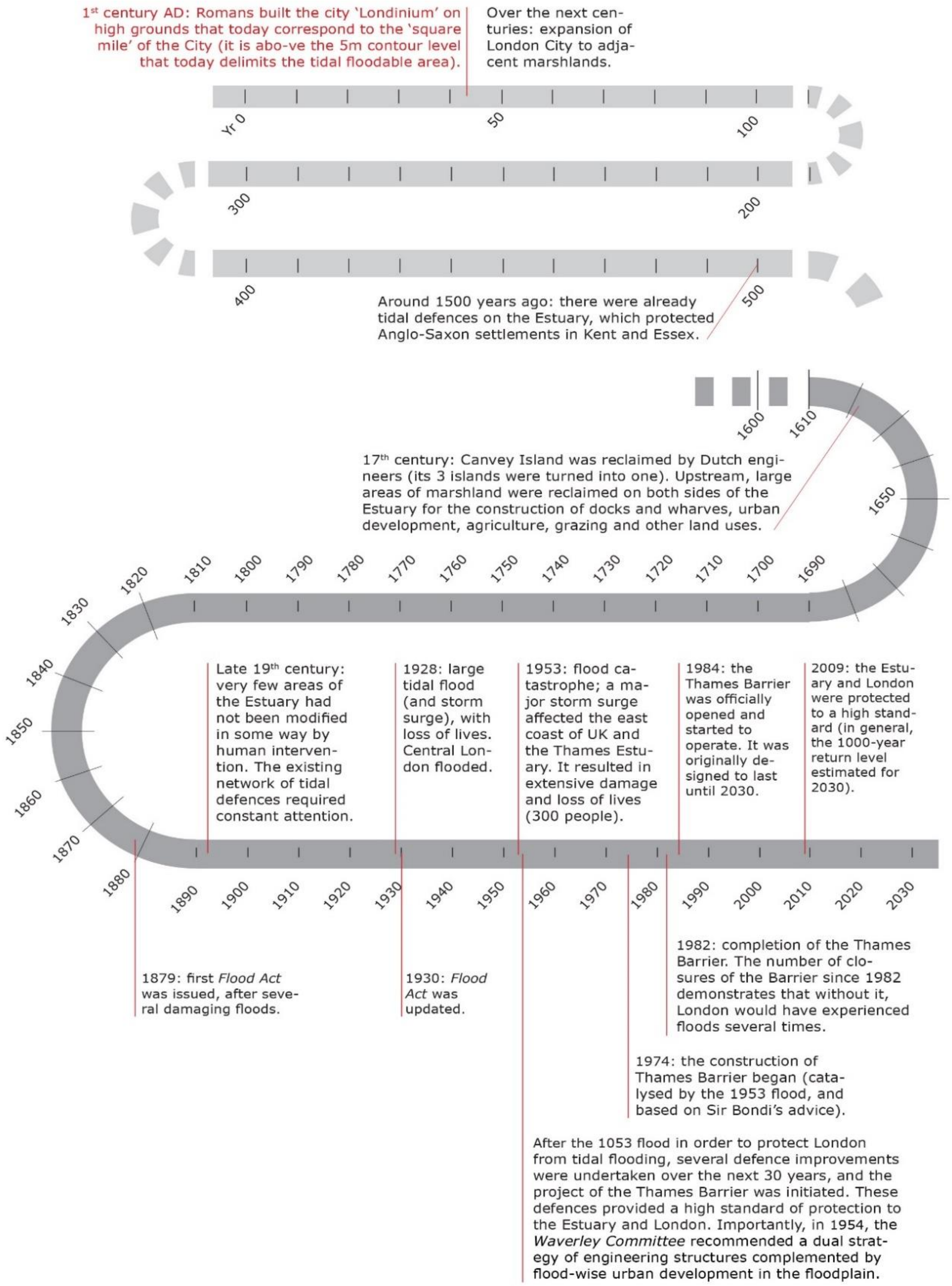


Figure 1. Historic background of flood risk management activities in the Thames Estuary and London. Source: Own elaboration, based on several authors (e.g. EA 2012, Penning-Rowsell et al. 2013, Ranger et al. 2013, Lowe et al. 2009).

The Thames Estuary's tidal floodplain corresponds to a corridor which passes through London, North Kent, and South Essex (in the east), which concentrates numerous assets at risk of flooding (namely in London), and a large number of people living and working there (Figure 2). In specific, it concentrates: 1.25 million people living (plus commuters, tourists, visitors), nearly 500000 homes, 40000 commercial and industrial properties (e.g. the Canary Wharf Business District, Docklands area, Port of London[1]), Government buildings (Houses of Parliament, Greater London Authority's City Hall, Westminster City Hall, government offices, etc.), 400 schools, 16 hospitals, 8 power stations, over 1000 electricity substations, 4 World Heritage sites, art galleries and historic buildings (e.g. Tower of London), 167 km of railway, 51 rail stations (one international), 35 underground railway stations, over 300 km of roads, 55 km^2 of designated habitat sites (e.g. 3100 ha of sensitive heritage sites). It encompasses 350 km^2 of land area, and £200 billion property value (EA 2012; Penning-Rowsell et al. 2013; HM Treasury 2009). All these assets are at risk of tidal flooding, especially, if the existing defences fail or are overtopped, and this risk is increasing (Penning-Rowsell et al. 2013, p.1384).

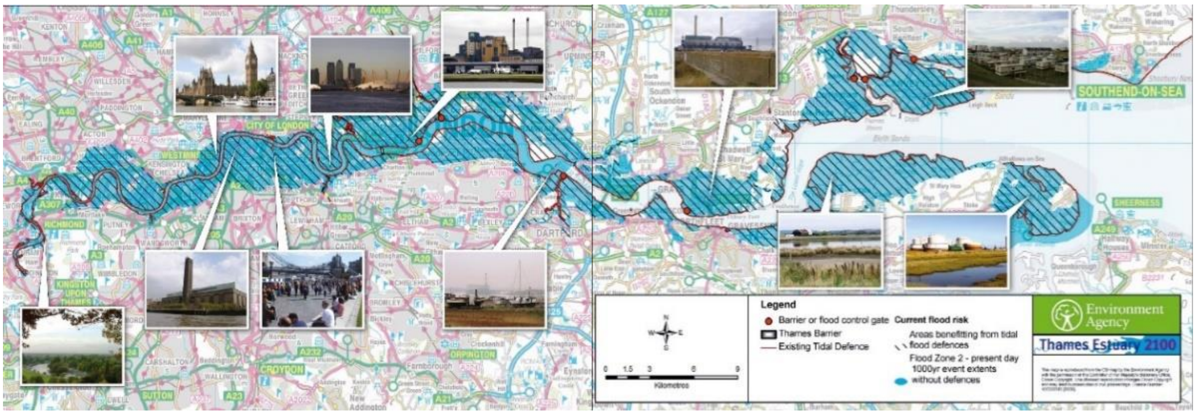


Figure 2. The blue area represents the floodplain – i.e. the area that can be flooded due to a combination of tidal waters and freshwater flows. Source: EA 2012, p.10-11.

The main sources of flooding in the Thames Estuary (TE) are, in order of importance: tidal flooding from sea tides and tidal waters, river flooding, pluvial/drainage flooding, and flooding from the tributaries of Thames River (EA 2012, p.12) (Note 100). Tidal flooding is related to daily tides and potential increases in water levels caused by storm surges[2] from the North Sea (EA 2012, p.12). The TE is prone to floods and rises in water levels caused by storm surges, and daily tides and strong northerly winds which can increase the height of surges (Penning-Rowsell et al. 2013, p.1384).

Existing flood defence system in the Thames Estuary in 2002

The Thames Estuary and London are protected from floods by a 'top-level' tidal flood defence system. The 2002-existent flood defence system encompassed: the Thames Barrier, other 8 flood barriers (owned and operated by the Environment Agency), 330 km of floodwalls and embankments / banks (under 3000 different ownerships), 36 floodgates, 400 smaller movable structures, and 104 pumping stations (EA 2012, p.21-22; EA 2016; Met Office 2012; Ramsbottom and Sheppard 2017, p.3, 6).

[1] The Port of London will host, in the near-term, the 'Thames Gateway': the largest regeneration program in UK, which will create thousands of houses and businesses and a new port facility. Some houses and businesses will be located in the floodplain (at-risk of flooding). To sustain the investment, local authorities must ensure that their areas will provide a high standard of flood protection, and that FRM measures are adopted in new urban development (EA 2012, p.18-19) (see more in Note 101).

[2] Storm surge tides occur when a band of low-pressure moves across the Atlantic towards the British Islands, causing the sea to rise above the normal level and generating a 'hump' of water which becomes higher as it gets squeezed between the UK coastline and mainland Europe and funnels up the Estuary. A surge tide entering the Estuary can increase water levels by 1 - 3 m (Ranger et al. 2013; Penning-Rowsell et al. 2013).

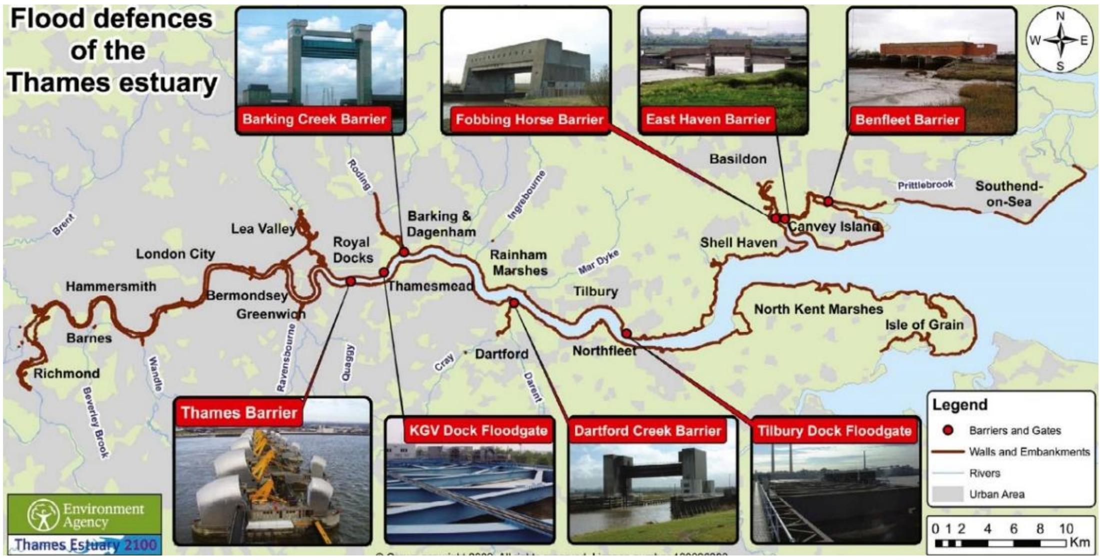


Figure 3. The 2002-existing flood defences (within the FRM system) in the Thames Estuary. Source: EA 2012, p.21.

Figure 4. The flood defence system in the Thames Estuary. Source: Ramsbottom and Sheppard 2017.

The Thames Barrier (TB) is a defence structure with 500m located across the River Thames, which protects Central London from floods and storm surges coming from the North Sea. It was built in response to the 1953 flood and designed to last until 2030 (Ranger et al. 2013; Reeder and Ranger 2011). Its construction started in 1974, and it started to operate in 1984 (EA 2012).[3] It provides a very reliable protection level, and, when it is not closed, river-walls protect low-lying areas (EA 2012, p.107).

Figure 5 left. The Thames Barrier protects Central London from flooding associated with surge tides (Ramsbottom and Sheppard 2017, p.3). **Figure 5 right**. Surge tide at the Thames Barrier (EA 2012, p.13).

[3] The decision to construct it was based on the advice of Sir Hermann Bondi (a Government Chief Scientific Advisor during the 1960s) (EA 2012; Penning-Rowsell et al. 2013). The project of the TB took into consideration early historical rates of sea level rise projected for 2030, which were largely driven by natural subsidence rather than climate change (Ranger et al. 2013; Ramsbottom and Sheppard 2017). Although the design of the TB took into account some potential rise in water level, it did not specifically consider changes in sea level and fluvial flows due to climate change, neither changes in the size of storm surges (Lowe et al. 2009, p. 86). When the TB was designed, engineers accounted for a rise in sea level of 8 mm per year; by 2012 sea level was rising 6 mm per year (Met Office 2012). During its construction (1974-1982), interim defences were operating (EA 2012). The number of closures of the Barrier since its completion demonstrates that, without it, London would have experienced floods several times (Penning-Rowsell et al. 2013).

The standard of protection provided at the beginning of the TE2100 Project

In 2002, the existing defence system provided a high standard of flood protection to the Estuary: a 1/1000-year flood in most of the Estuary (including London metropolitan area) (Jeuken et al. 2014, p.6; Lowe et al. 2009, p.86). The TB, in specific, offers a very high standard of protection from floods, i.e. a 1-in-1000 year, but such standard will decrease as sea levels rise (Ranger et al. 2013; Met Office 2012; Reeder and Ranger 2011) (Note 102).

In 2002, the broader flood defence system was deteriorating, and it was expected that many of the existing defences would reach the end of their design lives (lifespan) between 2030 and 2060 /2070 (Ranger et al. 2013; Met Office 2012).[4] The 2002-existent system of tidal flood defences had been designed and built over the prior 50 years (most after the 1953 flood) and the design standard of many defences was expected to be reached between 2030 and 2070 (Jeuken and Reeder 2011). Moreover, although the Estuary is protected by a '*robust and well-organized*' flood defence system, flood risk has been increasing due to multiple factors associated (mainly the effects of climate change, SLR and socioeconomic development) (EA 2012, p.1; Penning-Rowsell et al. 2013).

Flood risk management (FRM): actors, policy and spatial planning instruments

In the Estuary, several actors and organizations are responsible for flood risk management (FRM) (for planning and managing FRM solutions) namely: the UK's Environment Agency (EA); the Department for Environment, Food and Rural Affairs (Defra); Regional and local authorities; communities and businesses; and the charity 'National Flood Forum' (EA 2012, p.22-23) (Note 103).

The framework of spatial planning instruments, and of flood and water policy, is illustrated in Figure 6. It shows the relation between the various spatial planning instruments (e.g. *high-level plans*, *strategies*, *planning initiatives*) and flood and water policies / plans, and where the TE2100 fits in this hierarchy.

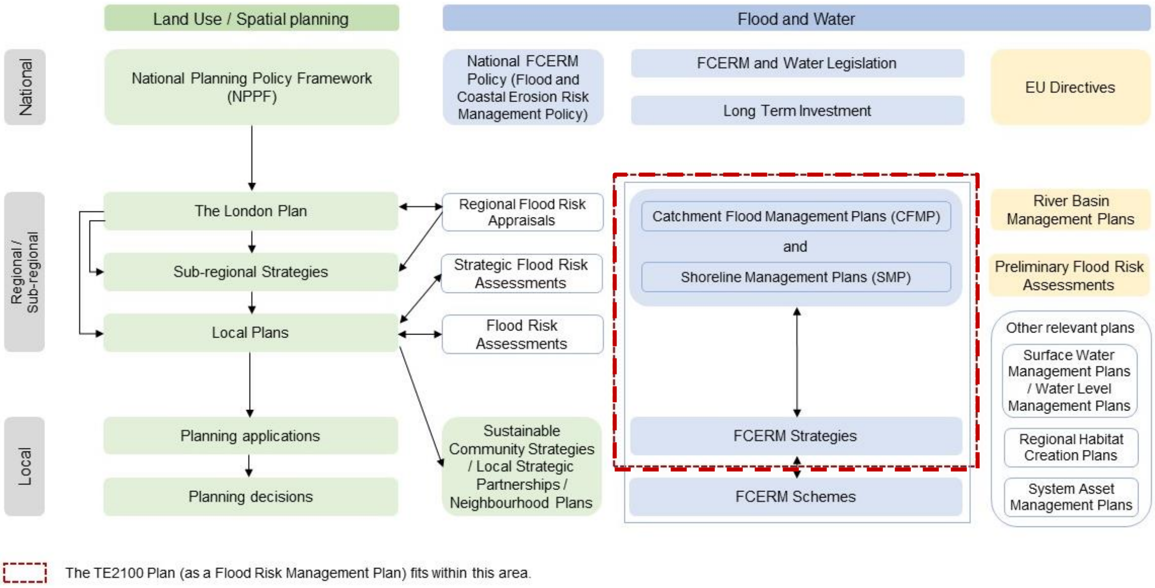


Figure 6. The planning framework and flood and water policy existent in the Estuary, and the location of the TE2100 Plan within it. The TE2100 Plan fits within the framing of plans on 'Flood and Coastal Erosion Risk Management', like CFMPs, SMPs and local FCERM Strategies. Source: own elaboration based on EA 2012.

[4] Many of the existing flood defences (which were built after the 1953 flood) are expected to reach the end of their design lives until 2060 / 2070. The TB is expected to continue to provide its standard of protection (the highest in the country) up to 2070. However, its maintenance must be continued to ensure its reliability and reduce greater future costs. Upstream defences and plans also need to be adapted, in order to deal with increased water run-off from winter rains (which are projected to increase with climate change) (Met Office 2012).

The TE2100 Plan fits within the frame and purpose of 'high-level plans' like *Shoreline Management Plans* (SMPs) and *Catchment Flood Management Plans* (CFMPs), but also offers a more detailed strategy (as the FCERM strategies). Moreover, the TE2100 Plan should inform and be informed by the other relevant planning instruments (e.g. the London Plan, Local Plans, etc.) (EA 2012, p.23). CFMPs and SMPs set strategic directions for future flood risk and erosion risk management in areas adjacent to the Thames Estuary. It was important that the TE2100 Plan, the CFMPs and SMPs supported each other and worked well together (in an integrated way) (EA 2012, p.5) (Note 104).

Importantly, prior to the TE2100, in the UK, there were already several policy documents and governmental guidance addressing climate change effects and related risks. For example:

- The *Green Book*, *Orange Book* and *Magenta Book* (HM Treasury 2009, p.3). These documents (provided by central government) explain how to consider (*incorporate*) climate change effects and related changing risks into the development, appraisal and evaluation of policies, programmes and projects (HM Treasury 2009, p.3)[5] (Note 105).
- The DEFRA provided 'Guidelines for Environmental Risk Assessment and Management', and the 'Flood and Coastal Erosion Risk Management guidance' and conducted a cross-government climate adaptation programme.
- The UK Climate Impacts Programme (UKCIP), i.e. a government-funded programme to develop information on climate change impacts, climate projections and scenarios for the UK, and tools to help users understand these, namely: the *Adaptation Wizard* (www.ukcip.org.uk/wizard, a web-based tool to scope climate change effects and support the assessment of the vulnerability to current and future climate, the identification of options to address risks, and the development of a plan to manage risks) (HM Treasury 2009, p.6, 20).
- the Report of Willows and Connell 2003, which explains how to consider climate risk and uncertainty into decision-making (HM Treasury 2009, p.6, 20).

1.1. Factors that led to the development of the TE2100 Project

This section outlines the main factors and changes that drove the EA to develop the TE2100 Plan (and review its approach to FRM). Over the last decades, several drivers have contributed to increase flood risk in the Estuary floodplain, namely: climate change effects (e.g. SLR), socioeconomic and urban development and environmental changes (EA 2012, p.1; Penning-Rowsell et al. 2013). At the beginning of the TE2100, the main drivers of increasing flood risk in the Estuary were:

- Climate change and its effects, particularly SLR. This brought the biggest challenge in terms of uncertainty, e.g. uncertainty about the possible rise in sea levels, rate of SLR, peak surge tide levels, wave heights, changes in rainfall and freshwater flood flows (EA 2012, p.5, 25, 26; Jeuken et al. 2014, p.6; Ranger et al. 2013; Lowe et al. 2009, p. 86). Climate change was expected to have effects on global sea levels, regional sea levels and river levels. In the Thames Estuary (TE), in particular, climate change would likely have effects on the average sea and tide levels (which affect the river level), the frequency and severity of storm surges coming from the North Sea, and fluvial flows coming down the River and its tributaries (Lowe et al. 2009, p.87; Met Office 2012; TE2100 Appendix L 2009; London Councils' TEC 2007). It was recognised that climate was already having effects on the marine environment, alongside with the need to further investigate how climate change

[5] The Green, Orange and Magenta Books are government guidance on: the appraisal and evaluation of policies, programmes and projects; the management of risk; and policy evaluation; respectively. These guidance books explain why and how climate change effects and associated risks should be accounted for in policy, programmes, or projects (directly or indirectly affected by climate change).

might impact flood safety and habitat conservation (Lowe et al. 2009, p.5). In the beginning of the TE2100, several studies reported, and there was a growing evidence of, changes in the climate which affect flood risk in UK, e.g. increasing winter precipitation, greater multi-day rainfall totals, higher contributions from intense daily rain events since the 1960s; global mean sea level has risen 2mm/yr during the last century, and 3mm/yr since the 1990s. Global projections indicated that this current trend will increase (TE2100 Appendix L 2009).[6] It was expected that climate change would increase the risk of flooding, due to rises in sea levels, changes in storm surge patterns, rainfall, and river flows, which were expected to increase 'flood probability' (Ramsbottom and Sheppard 2017, p.4). Climate change was expected to drive changes in sea levels, storm surge patterns, and river flows (Met Office 2012; Ramsbottom and Sheppard 2017).

- Socioeconomic and urban development. There has been an extensive and rapidly increasing urban development in the floodplain (associated to socioeconomic and technological changes) over the last decades (EA 2012, p.25). This has translated into more properties placed in flood-prone (at-risk) areas in the floodplain (London Councils' TEC 2007), a dramatic increase in the value of buildings and assets, and in their vulnerability to floods (the potential damages per property has increased) (EA 2012, p.25). Much of the urban development in the TE floodplain, especially in London, *paid little heed to the possibility of a flood, relying wholly upon the defences to manage the risk* (EA 2012, p.25). Historically, spatial planning paid scarce attention to how to manage the consequences of floods; but the *'National Planning Policy Framework*' has sought to change this by recommending that FRM must be reflected in future spatial planning (EA 2012, p.5, 25, 26; Jeuken et al. 2014, p.6; Ranger et al. 2013; Lowe et al. 2009, p.86). It was recognized that the Estuary is changing, not only due to climate change-related factors, but also due to population growth and property development on the floodplain, namely in area of the Thames Gateway (Met Office 2012).
- Changing physical and environmental conditions. The land levels in the Estuary have slowly sunk (land subsidence). Furthermore, over the centuries, the Estuary morphology of has been altered, the original river channel narrowed as urban development unfolded, and urban pressures and the attractiveness of the Estuary for new urban development have encroached the river space (EA 2012, p.5, 25, 26; Jeuken et al. 2014, p.6; Ranger et al. 2013; Lowe et al. 2009, p. 86).
- Ageing flood defence infrastructures. Many of the 2002-existing defence structures were built in the 1970's and early 1980's, and some were expected to reach the end of the useful life between 2030 (or until 2070), requiring repair or replacement. Moreover, in 2002, many floodwalls, embankments and barriers were deteriorating or getting older, and they would need to be raised or replaced as the water levels rise. Besides, the riverside and its land uses have changed over the years, thus, the form and position of some existing defences may no longer be suited to current and future conditions of the Estuary (EA 2012, p.5, 25, 26; Jeuken et al. 2014, p.6; Ranger et al. 2013; Lowe et al. 2009, p. 86).

By 2002, it was expected that the design standard of some existing flood defences would be reached around 2030, thus, it was necessary to start planning the next generation of defences (Jeuken and Reeder 2011).[7] By the beginning of the TE2100 Project, the Team expected that it would be necessary

[6] The 2009 projections of climate change for the UK (of the *UK Climate Impacts Programme*, UKCIP) predicted changes for several climate-related variables in land, coastal and marine regions of UK, namely: higher temperatures, rising sea levels, changing precipitation patterns, changes in extreme events (e.g. more frequent and larger storm surges) (*in* HM Treasury 2009, p.3, 5; TE2100 Appendix L 2009).

[7] By the beginning of the TE2100, it was thought that by 2030, the standard of protection offered by the existing defences – the design standard offered by most of the existing defence system (including the TB) was 1-in-1000 years annual chance of flooding – would be reached. Though these defences might continue to provide a high standard of protection beyond that date, the TE2100 Project was launched to plan the next generation of FRM measures to tackle the increasing flood risk (London Councils' TEC 2007).

to make a major investment in the Thames Barrier and associated defences at some point in this century (TE2100 Appendix L 2009). Given the increasing flood risk (associated with the effects of climate change, socioeconomic development and other factors), it was expected that around 2030 new arrangements would be needed to maintain the flood protection standards at the then-existing levels during this century (Lowe et al. 2009, p. 86, 90).

As flood risk will deeply influence the future sustainability of the highly developed Thames corridor and London, there was a '*compelling case for production of a long-term strategy without delay*' (Jeuken and Reeder 2011). The fear that there was insufficient time for replacing the TB and other defences (because major engineering projects can take 25 / 30 years to plan and implement, and SLR was accelerating) was an important motivation for the TE2100; the TE2100 Project was developed to provide a FRM plan that considered the need to replace or upgrade the Thames Barrier in the future (according to Ramsbottom and Sheppard 2017, p.3).

- Low public and institutional awareness of flood risk. There is a weak awareness of flood risk in the Estuary, in part due to the low probability of flooding (given the high standard of protection provided), as well as a low awareness of the responsibilities for FRM action (*who does what*) (EA 2012, p.5, 25, 26; Jeuken et al. 2014, p.6; Ranger et al. 2013; Lowe et al. 2009, p. 86).

The above-mentioned drivers of change and increasing flood risk led to the need to develop the TE2100 Project (EA 2012, p.36). The increasing flood risk, and the need to manage it, and especially, the need for 'adaptation', were key drivers for developing the Plan. Managing climate change effects was considered an important requisite for planning future FRM (Ramsbottom and Sheppard 2017, p.3).

2. PRESENTING THE TE2100 PROJECT

2.1. OBJECTIVES AND AREA COVERED

The UK's Environment Agency (EA) initiated the Thames Estuary 2100 Project (TE2100 Project) in 2002, with the objective of developing a long-term *'flood risk management plan'* for the Thames Estuary (including London) – i.e. a plan to manage flood risk[8] in the Estuary until the end of the century (EA 2012, p.5, 29).

Moreover, the TE2100 was the first major project in the UK to address climate adaptation (i.e. the reduction of climate change-related risks) as a central issue (EA 2012, p.27; TE2100 Appendix L 2009; EA 2016). Furthermore, a specific goal of the Project was to analyse if, and when, the existing flood defence system (including the TB that protects Central London) would need to be modified, and to develop a forward plan until 2100 (Reeder and Ranger 2011; Ranger et al. 2013).

The Project started in 2002 and the final Plan was published in November 2012 (Ranger et al. 2013; EA 2016; Ramsbottom and Sheppard 2017, p.1, 3).[9] The final Plan lays down the EA's recommendations for managing flood risk in the TE and London over this century, i.e. the Options (pathways) and recommended actions to manage tidal flood risk in the next 100 years (EA 2012, p.1, 6).

The TE2100 Plan covers the Thames Estuary and its tidal floodplain, from Teddington (in west) to Sheerness and Shoeburyness (in east) (EA 2012, p.5; London Councils' TEC 2007) (Figure 7). The Estuary floodplain has nearly 350 km^2; it includes central London, towns, industrial sites, port facilities and grazing marshes (Ramsbottom and Sheppard 2017, p.2).

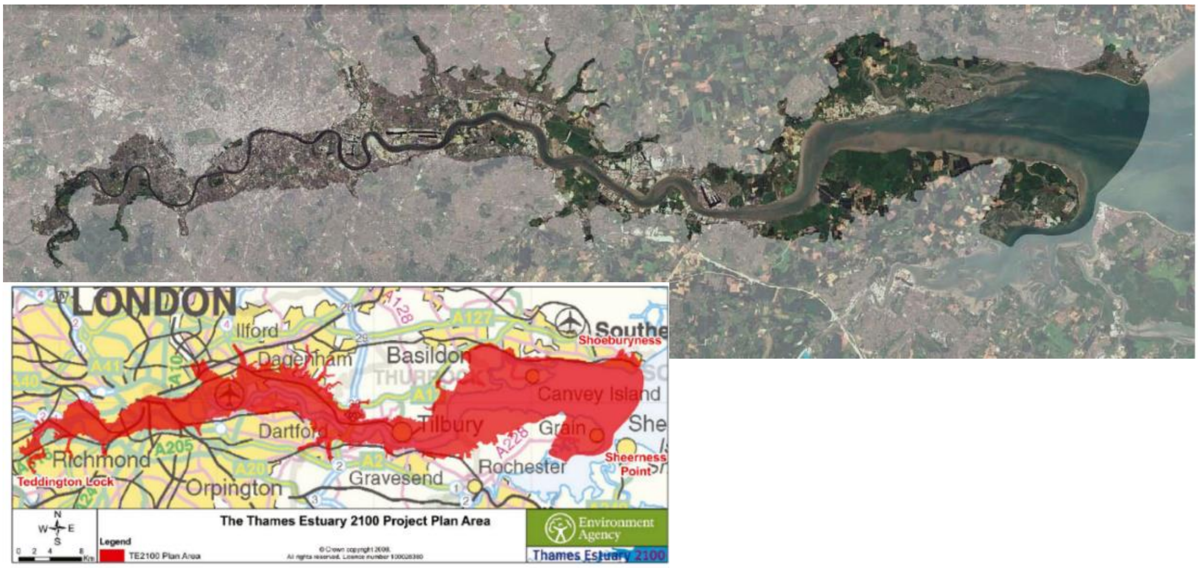


Figure 7. Area covered by the TE2100 Project (EA 2012, p.5). The EA consists of the area of the lower 100 km of the River Thames which is influenced by tides, between Teddington and the sea (Ramsbottom and Sheppard 2017, p.2). The Plan's area contains nearly 54% of the area proposed for 'Thames Gateway development' – a zone of high flood risk due to high potential impacts of flooding, which is low-lying and densely populated, and has critical importance to the economic well-being of the UK – and also areas of conservation protected under EU Legislation (London Councils' TEC 2007).

[8] In the TE2100, flood risk is expressed by combining information on probability (likelihood) and consequence (impact). Flood Risk Management (FRM) involves solutions to reduce the risk of flooding from the sea and rivers, to people, property and natural environment. The Plan addresses primarily tidal flood risk (sea tides are the main driver of flood risk in the Estuary), but also other sources of flooding, e.g. high river flows, pluvial flooding (rainfall), surface water, drainage (EA 2012, p.1).

[9] In 2009, a draft plan was released for consultation (Ranger et al. 2013; Ramsbottom and Sheppard 2017, p.1, 3), and data collection and detailed studies finished by 2010 (EA 2016). The TE2100 was a resource-intensive project that costed nearly £16 million (Ranger et al. 2013).

The area covered by the Plan is divided into **23 'policy units'** with similar flooding characteristics and assets at-risk (EA 2012, p.6). The 'policy units' requiring similar types of actions were grouped into **eight 'action zones'** (EA 2012, p.50) (Figure 8). In addition, there is one 'estuary-wide zone' denominated 'Action zone 0'.

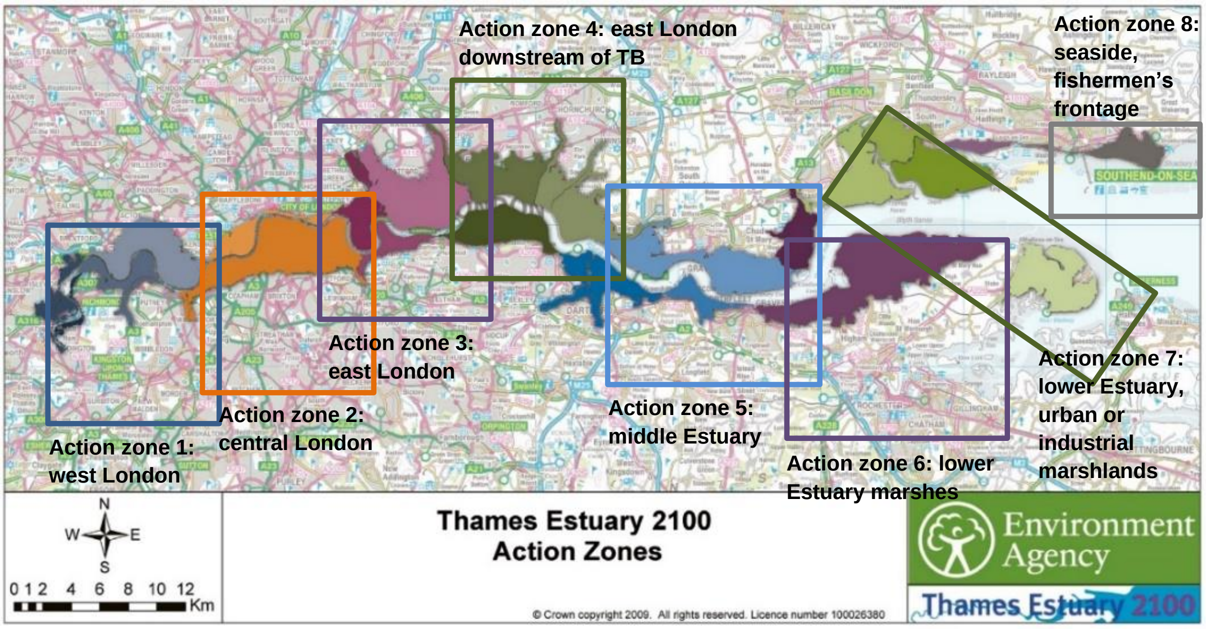


Figure 8. The eight 'action zones' (rectangles), and their diverse 'policy units' (coloured solid hatches). See Note 106. Action Zone 0 corresponds to the whole Plan's area – the estuary-wide area

2.2. Drivers of the need to develop an *Adaptive Plan* and motivators for devising an Adaptive Planning approach

In the case of the TE2100, there were two main drivers of the need to devise an adaptable plan, which led to the development and use of Adaptive Planning approach. These are outlined next.

'Deep uncertainties' about future conditions and changes

In the beginning of the TE2100 (2002), there were deep uncertainties about the possible future increases in extreme water levels in the Estuary (Ranger et al. 2013; Lowe et al. 2009; TE2100 Appendix L 2009). There were deep uncertainties about the scale and rate of climate change effects and climate-related risks (e.g. about how global warming is affecting storm routes in the North Atlantic and high water levels in the TE during extreme events), and uncertainties around the projection of future water levels (which involved the use of models about which there is much uncertainty) (Reeder and Ranger 2011).

For example, different studies projected different trends in the height of storm surges in 2080 in the Estuary (e.g. some studies predicted an increase while others predicted decreases) (Figure 9); this range of uncertainty could lead to large differences in the future FRM measures and their costs, making their planning quite difficult (Lowe et al. 2009, p. 88, 7; TE2100 Appendix L 2009). While in 2002 various studies already reported (and there was a growing evidence of) climate change effects that affect flood risk (namely SLR), these effects were highly uncertain when extrapolated to the local scale (ibid).[10]

[10] Moreover, the IPCC AR4 shows that existing GCM-based projections were possibly underestimating global SLR, due to missing processes in models, e.g. ice sheets' dynamics, uncertainties about the North Atlantic storm tracks due to global warming (Lowe et al. 2009).

Alongside uncertainties related with climate change and its effects, there were uncertainties related to potential socioeconomic changes, and lack of information (Reeder and Ranger 2011, p.3, 11). There were uncertainties about the plausible future increases in extreme water levels in the Estuary, but also about the valuation of non-monetary impacts and property values (Ranger et al. 2013). These uncertainties presented important challenges to the TE2100 Project (Reeder and Ranger 2011).

A key issue (which challenged the development of the Project) was '*how tidal flood risk was likely to change in response to future changes in climate and people and property in the floodplain*'; the Plan should '*make recommendations on what actions were needed to adapt to a changing estuary*' (EA 2012, p.5), thus, it should plan in advance for changing and uncertain future conditions.

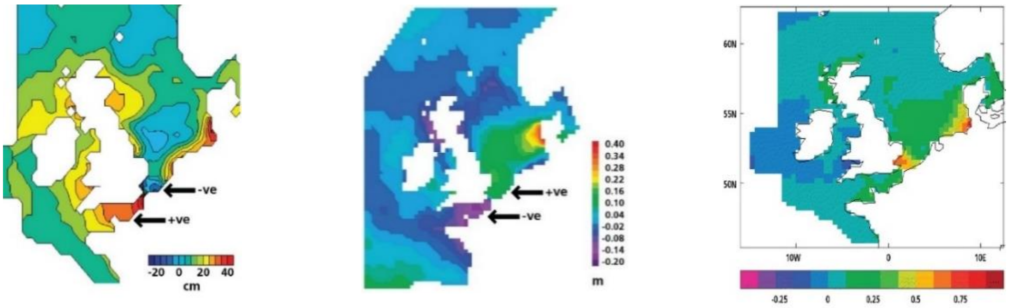


Figure 9. Changes projected by three different climate models in a 50-year storm surge height for the 21st century, due to changes in storminess. This shows the great uncertainty that existed about possible changes in extreme water levels in the TE when TE2100 Project was initiated. Source: Lowe et al. 2009, p.87.

Since an early stage, the TE2100 Team decided that the uncertainties about climate change should be 'incorporated' in decision-making. The Team felt the need to better understand and quantify the uncertainties about the effects of climate change on flood risk in the TE (and their rate) and about future projections of climate change. For this reason, the Team commissioned several organizations (namely the Met Office) to conduct research on the uncertainties about storm surge, relative SLR and river flows (Note 107). This research work showed that flood risk is already increasing in the TE (due to the effects of climate change and socioeconomic development) and will increase significantly over this century, which justified the TE2100 Plan (TE2100 Appendix L 2009).

The TE2100 was one of the first major infrastructure projects to explicitly deal with the issue of deep uncertainty that surrounds future climate projections, during its planning process (Ranger et al. 2013; Bloemen et al. 2018, p.7). It is deemed a real example of (adaptation) planning and decision-making under uncertainty, here, focused on long-lived flood defence infrastructures (Reeder and Ranger 2011). A central issue for managing future flood risk was dealing with, and adapting to, uncertain future effects of climate change; the Project had to devise a plan that was able to deal with the uncertainties associated with multiple possible climate change and socioeconomic futures (Lowe et al. 2009, p.85). The management of future flood risk required adaptation to changing and uncertain future conditions (Met Office 2012; Ramsbottom and Sheppard 2017).

The Project had to explicitly consider climate change effects on flood risk, and the uncertainties about them, which had implications for developing the Plan: '*because of uncertainty in future effects, TE2100 has developed an* ***adaptive approach*** *to future flood risk management*' (HM Treasury 2009, p.13, 22). The TE2100 Plan must deal with uncertainties about future effects of climate change and socioeconomic developments, and multiple plausible futures. The Project devised an approach for developing the Plan that explicitly addresses uncertainties around the projection of future climate, physical and socioeconomic conditions and changes in the TE (Lowe et al. 2009, p.86). The need to manage the increasing risk of flooding and adapt the TE floodplain to uncertain future changes and conditions led to the need to develop a *dynamic robust adaptive plan*.

Existence of high stakes involved, and the need to avoid maladaptation

As a long-term FRM plan, the TE2100 Plan could entail large-scale irreversible investments in the flood defence system, decisions with long lifetimes and lead times, or high risks in case of failure (Ranger et al. 2013). Any investment in the flood defence system would be highly sensitive to the effects of climate change, and there was a great potential for maladaptive outcomes, since such investments usually imply long-lived or large-scale investments with long lead-times, and which might result in potential irreversible outcomes or high risks in case of failure (Reeder and Ranger 2011). Thus, it was necessary to consider the increasing risks and hazards associated with the effects of climate change and urban pressures, and the uncertainties about climate and human drivers of risk (ibid).

It was recognized that a failure to account for plausible changes in climate and physical conditions could result in significant future costs or missed opportunities, or a poor performance of measures in the future, the need for retrofitting them, or their early abandonment (HM Treasury 2009, p.7-8). In a broad sense, the lack of (or inadequate) consideration of uncertainties about future projections in FRM planning could lead to maladaptation (too much, too little, too late, too early, or wrong type of actions, leading to greater risks, wasted investments or unnecessary retrofit costs) (Ranger et al. 2013; Reeder and Ranger 2011).

In synthesis, the need to deal with deep uncertainties about future changes and conditions, and the need to avoid 'maladaptation' were two important drivers for developing a 'robust and adaptive plan', and for devising and using an Adaptive Planning approach (for elaborating such plan). The following section outlines some of the **main requisites** that the Team decided that the Plan should meet.

2.3. Requisites for the plan: a long-term *sustainable adaptable plan*

- A long-term and proactive plan
  Given the long timescales involved in planning for adaptation to climate change effects, the EA decided to set up a long-term (FRM) plan: for the next 100 years (Lowe et al. 2009, p.86). Besides, one of the main purposes of the TE2100 Plan was '*to plan proactively for the future rather than waiting for the next flood catastrophe to provoke society into action*' (EA 2012, p.1). The need to plan in advance was emphasized by the presence and value of numerous assets at risk of flooding, and by the long lead-times required to design and build FRM solutions (HM Treasury 2009, p.13).

- A '*risk-based'* and *'sustainable*' plan
  From a strategic point of view, the TE2100 Project aimed to develop a long-term FRM plan for the TE that was: *'risk-based' and 'sustainable'*, i.e. the plan must address flood risk and problems *in the context of a changing climate and varying socio-economic conditions that may develop over the next 100 years*, and take into consideration the existing and future assets at-risk (EA 2012, p.29; London Councils' TEC 2007). The Plan must address the current and future risks to people and built assets and be able to deal with potential future risk, under different plausible future scenarios over the next 100 years (climate and socioeconomic scenarios) (Jeuken and Reeder 2011). Moreover, to be sustainable, the Plan should account for the needs of various stakeholders (EA 2012, p.29; London Councils' TEC 2007)[11], being inclusive of all relevant stakeholders in the TE (Jeuken and Reeder 2011). The Plan should be 'climate-resilient' and contribute to increase the resilience of communities and infrastructures to flood risk (ibid).

[11] The Plan would steer the actions needed from multiple agencies to manage tidal flood risk over the next years (EA 2012, p. 29, 35).

In specific, the Team defined that, to be successful, the TE2100 Plan should be: 1) *technically feasible and adaptable to change*; 2) *environmentally sustainable*; 3) *economically justifiable*; and 4) *socially and politically acceptable* (EA 2012, p.29).
To manage the emerging risk and deal with uncertain future conditions and changes, the Project aimed to develop a FRM system that was '*adaptable to the changes*' faced over time, '*maintainable*' and did '*not threaten the ecological balance of the Estuary*' (EA 2012, p.27). Since many of the actions and decisions that could be taken in the short-term might affect the ability to adapt in the future, it was necessary to look ahead to the end of the century, and use '*sustainable approaches to flood and coastal risk management*' that prevented the increase of flood risk (EA 2012, p.27).

- A '*robust* and *adaptable*' plan
The main objective the TE2100 was develop a plan to manage flood risk in the TE over the next 100 years. Such plan would have to manage the increasing flood risk throughout the next years, but also take into account multiple uncertainties about future changes and conditions (e.g. about the future plausible rises in extreme water levels in the TE). A FRM plan up to 2100 would tend to be highly sensitive to then-current assumptions about future extreme water levels (Ranger et al. 2013). Considering this, the Team decided that the TE2100 Plan must be *'adaptable to change and remain fit for purpose throughout its 100-year life*' (EA 2012, p.36, 38); therefore, the Team decided to design a plan that was '*as robust as possible*' and '*adaptable to change'* (Ranger et al. 2013, p.239).[12]
'*Adaptability to future change'* is at the core of the Plan (EA 2012, p.1). The Plan was devised to be *adaptable* and able '*to cope with a changing climate'* and changing socioeconomic and physical conditions (EA 2012, p.28). The Plan is *'adaptable to future climate change*' (EA 2012, p.1).

  As a long-term FRM plan, the TE2100 Plan should be *'sustainable, adaptable and responsive*' to changing climatic and socioeconomic conditions throughout the next 100 years. The Plan is *adaptable* to change (namely to a *changing climate*) '*to ensure that the actions that are taken are right and adequate, taken at the right time and will not waste money on over-engineered solutions* (EA 2012, p. 29, 35). As mentioned in the Plan itself, *'a long-term plan such as the TE2100 strategy needs to be flexible enough to incorporate changes to climate projections and the scientific evidence base, while at the same time, provide decision-makers with the evidence needed to take important investment decisions now'* (Association of British Insurers, *in* EA 2012, p.55).

  According to Ramsbottom and Sheppard, the TE2100 was the first major FRM plan in the UK *'to place adaptability as a fundamental requirement, in recognition of the uncertainty of pace and scale of changes that might occur with climate change*', and this resulted an *adaptive flood risk management plan* (Ramsbottom and Sheppard 2017, p.1).

In synthesis, the need to design a long-term sustainable adaptable plan that took into consideration the changing and uncertain future conditions of the Estuary was a key driver of the TE2100 Project and its planning approach (Jeuken et al. 2014, p.6).

[12] In the face of uncertain future changes and conditions, and the challenges they pose to the elaboration and implementation of the Plan, the Team decided that the TE2100 Plan '*must be adaptable to change and remain fit for purpose throughout its 100 year life*' (EA 2012, p.36; 38).

3. The '*Dynamic Adaptive Planning approach*' devised in the TE2100

In the TE2100 Project, the uncertainties around the projection of future conditions and changes, and the existence of high stakes involved, led the Team to adopt a new approach to plan for FRM based on the concept of ***Dynamic Robustness*** (Ranger et al. 2013, p.247-248).[13] *Dynamic Robustness* aims at building a plan / strategy that is '*robust*' and '*flexible / adaptive*': a *robust* plan / strategy is one that '*performs adequately well against a set of decision criteria under a wide range of possible future states of the world*' (instead of the more traditional approach that optimizes a strategy for a particular risk level), and a *flexible* plan / strategy is one that '*can be changed over time as more is learnt or as conditions change*', i.e. it is *adaptable* (Ranger et al. 2013, p. 247, 233). The TE2100 placed the concept of *Dynamic Robustness* at the heart of its Plan and planning approach (Ranger et al. 2013, p.254; 258).

Under deep uncertainty about future conditions and changes (e.g. about the plausible future increases in water levels in the TE), the Team decided that the TE2100 Plan must be '*as robust as possible'*, *'adaptable to change and remain fit for purpose throughout its 100 year life*' (EA 2012, p.36, 38; Ranger et al. 2013, p.239). As a long-term plan for FRM (up to 2100), the TE2100 Plan should be *robust* to uncertainties surrounding the projection of future extreme water levels (Ranger et al. 2013, p.254) and *adaptable* to changing conditions (EA 2012, p.35).

Drawing on the concept of 'Dynamic Robustness', the TE2100 developed and applied a '***Dynamic Adaptive Planning approach'***, also called '*managed adaptive approach*' or '*iterative risk management approach*' (Ranger et al. 2013, p.249-250, 254, 257; Jeuken et al. 2014, p.1, 3, 23; Ramsbottom and Sheppard 2017, p.1, 18). In this *Dynamic Adaptive Planning approach*, a plan (and its strategies) is '*implemented iteratively*' and is '*designed to be adjusted over time as more is learnt about the future*' or as changes occur (Ranger et al. 2013, p.249). In this approach, the timing of new measures (*interventions*), and the measures themselves, can be changed over time – in this way, flexibility is built-in into the long-term strategy itself (Ranger et al. 2013, p.249). The TE2100's *Dynamic Adaptive Planning approach* contained an innovative methodological approach to design a *dynamic robust adaptive plan / strategy*: the '***Adaptation Pathways approach***' **(APs)**, also called '*Route-map approach*' or '*Decision Pathways approach*' (Ranger et al. 2013, p.249).

In the *Dynamic Adaptive Planning approach*, and particularly in the **APs approach**, measures are implemented iteratively over time to keep risk below a target level, *while keeping open options to manage future risk* (Ranger et al. 2013, 249, 248, 247, 239; Reeder and Ranger 2011, p.13). A pathway is a *package* of several measures sequenced and implemented over time (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8; Jeuken and Reeder 2011, p.4). The TE2100 devised the Route-map / APs approach as a methodological approach to design a plan that was able to deal with uncertainties about the future effects of climate change and socioeconomic developments in the Estuary and changing flood risk (TE2100 Appendix L 2009, p.3-4).

The TE2100's approach resulted in a plan that is *adaptable* to change; the Project elaborated an *adaptable plan*, i.e. a plan that can be adapted to changing (climatic, physical and socioeconomic) conditions (EA 2012, p.1, 29, 35-36, 39; TE2100 Appendix L 2009, p.4; Ranger et al. 2013, p. 239; Bloemen et al. 2018, p.12; Jeuken et al. 2014, p.2,4,19,21).

[13] *Dynamic Robustness* (also called *flexibility*) is an approach for dealing with deep uncertainty in planning (Walker et al. 2013); it produces a *dynamic robust (adaptive) plan*. Dynamic Robustness was recommended in UK Government guidance documents for domains where there is 'unquantifiable uncertainty' (which called for a *flexible* and *adaptive* planning approach) (Defra 2006; *in* Ranger et al. 2013, p. 248). The TE2100 Team recognized the need to develop robust methods to elaborate a long-term FRM plan: it should be robust to uncertainty about climate change and other changes (TE2100 Appendix L 2009, p.199).

In sum, under deep uncertainties about future changes, the TE2100 Team decided to adopt an ***adaptive approach*** (TE2100 Appendix L 2009; EA 2012, p.34; Jeuken and Reeder 2011, p.5, 9; Reeder and Ranger 2011, p. 13; Lowe et al. 2009, p.85; HM Treasury 2009, p.22). As noted in the Technical Report, '*to continue to manage flood risk from the tidal Thames will require substantial investment over the next 50 years and it will be essential that adaptability and flexibility are key parts of the plan* (TE2100 Appendix L 2009, p.2). The TE2100 devised and applied a new method for designing a Plan that is *flexible* and *adaptable* to an uncertain future and change (TE2100 Appendix L 2009, p.4) – i.e. an 'adaptive plan' for FRM (Ramsbottom and Sheppard 2017, p.19).

BOX 1: the Dynamic Robustness approach aims at building a plan (or strategy) that is '*robust*' (i.e. that *performs adequately well against a set of criteria under a wide range of possible future states of the world*') and '*flexible*' (i.e. that *can be changed over time as more is learnt or as conditions change*) – i.e. a dynamic adaptive plan (Ranger et al. 2013, p.233, 247). Under uncertain future change, the Team decided to develop a plan that was as *robust* as possible and *adaptable* to change (changing climatic and socioeconomic conditions) and that remained *'fit for purpose' throughout its 100 year life*' (EA 2012, p.35-36, 38; Ranger et al. 2013, p.239, 254).
Based on the concept of *Dynamic Robustness*, the TE2100 Project devised a new planning approach (to plan for FRM): a *Dynamic Adaptive Planning approach* (also called '*managed adaptive approach*' or '*iterative risk management approach*') which encompasses an innovative method for designing a **dynamic adaptive plan**: the *Adaptation Pathways approach* (Ranger et al. 2013, p.247-249, 254, 258). In this 'Dynamic Adaptive Planning approach', plans / strategies are *designed to be adjusted over time as more is learnt about the future* or as changes occur, and are implemented iteratively over time. The timing of new measures, and the measures themselves, can be changed (adjusted / adapted) over time; hence, flexibility is built into the long-term strategy itself. This approach seeks to manage (reduce) risks iteratively: it defines short-term actions and lays out possible future actions, which fosters flexibility (Ranger et al. 2013, p.248-249). This approach is reflected in the way of managing flood risk so-called '*managed adaptive approach*'.

3.1. The 'Managed Adaptive approach' for FRM

The *Dynamic Adaptive Planning approach*, also called '*managed adaptive approach*', is reflected in the way of managing flood risk (EA 2012, p.34; HM Treasury 2009, p.22). The *Dynamic Adaptive Planning approach* (*managed adaptive approach*) seeks to manage (reduce) risk iteratively over time: it defines short-term measures and, at the same time, lays out possible future measures, which fosters flexibility (Ranger et al. 2013, p.248). Under uncertain future changes and conditions, flood risk management required an adaptive approach where *'measures are introduced at different times to limit the increase in flood risk* (*due to climate change*) *to acceptable values*' (Ramsbottom and Sheppard 2017, p.1, 3).

Figure 10 illustrates the 'managed adaptive approach' in relation to other conventional approaches that could have been used (e.g. a *precautionary approach*). It can be observed that flood risk increases in case of *no active intervention* (blue dashed line). The level of flood risk acceptable in a given area (horizontal blue line) is defined in a policy (which sets the level of FRM investment that is justifiable in such area). The *precautionary approach* (dashed black line) involves a single measure that lasts over the plan's life (until it exceeds the acceptable level of risk). Studies conducted in the TE2100 showed that the precautionary approach could be expensive and environmentally damaging or generate a 'white elephant' if flood risk increased at a slower rate than predicted. Therefore, the TE2100 devised a different approach: the *managed adaptive approach* (red toothed line). The '*managed adaptive approach*' involves planning several measures to manage (reduce) flood risk over time (EA 2012, p.34). To manage flood risk, the TE2100 followed the *managed adaptive approach*. Firstly, the Project Team assigned a FRM policy to different areas of the Estuary (a policy sets the level of FRM investment or activity necessary in such area); then the Team explored several possible measures to achieve the policy defined, and, in this way, developed (assembled) various '*estuary-wide Options*' (pathways) to manage flood risk over this century (EA 2012, p.34, 38). An *Option* (pathway) is a package of measures (actions) implemented over time to achieve the policy recommended throughout the century. The *managed adaptive approach* is realized by sequencing several measures over time. It was also necessary to determine critical conditions under which each measure will be needed (EA 2012, p.34).

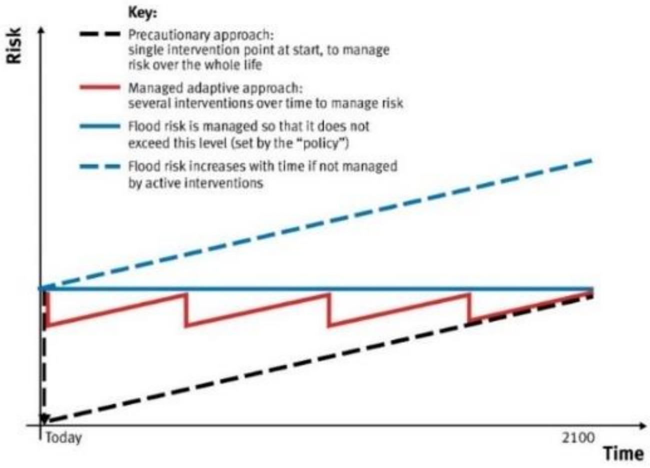


Figure 10. The '*managed adaptive approach*' of the TE2100 (also called 'iterative risk management approach', or *Dynamic Adaptive Planning*, which is based on 'dynamic robustness') (red saw-tooth line), compared with other approaches for managing flood risk. Source: EA 2012, p.34. Flood risk (dashed blue line) will increase over time if it is not managed with actions. The precautionary approach (black dashed line) involves a single measure that lasts over time. The blue horizontal line shows a FRM policy (*the level of FRM activity* that is justified in a certain area) (EA 2012, p.34). In the *managed adaptive approach*, various measures are implemented iteratively over time to keep risk below the target level cost-effectively and options are kept open to manage future risk (instead of optimizing a solution for a particular risk level) (Ranger et al. 2013, 247-249).

The TE2100 was one of the first projects to propose an adaptive approach to manage flood risk, (an *adaptive FRM approach*) in the world (Zevenbergen et al. 2018; Ramsbottom and Sheppard 2017, p.1).

3.2. The 'Route-map approach' or 'Adaptation Pathways' approach'

As part of its 'Dynamic Adaptive Planning approach', the TE2100 Project developed and used an innovative methodological approach for designing a *dynamic adaptive plan*: the '**Route-map approach'** (also called 'Decision pathways approach', and later named 'Adaptation Pathways approach') (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.5, 8).[14]

The 'Route-map approach' consisted of the development of a route-map of pathways, so-called *High-Level Options* (HLOs) (Reeder and Ranger 2011, p.2-3). Each *HLO* is a pathway, i.e. a *package* of FRM measures sequenced and implemented over time (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8; Jeuken and Reeder 2011, p.4; TE2100 Appendix L 2009, p.3-4, 1, 10; Ramsbottom and Sheppard 2017, p.4; EA 2012, p.34, 38).[15]

Using the 'Route-map approach', the Team identified the timing for and sequencing of possible measures over time under different future scenarios, and developed various possible pathways (Ranger et al. 2013, p.233, 239). In the 'Route-map approach', measures are implemented iteratively over time to keep risk below acceptable levels cost-effectively, while keeping open options (alternative measures) to manage future risk, thus, maintaining *flexibility* (Ranger et al. 2013, p.249, 239).

The Route-map method involved sequencing the implementation of diverse FRM measures over time in a way that allows the system considered (FRM system) to be adapted to changing climatic conditions over time, and in which alternative measures are left open to cope with multiple plausible future

[14] Hence, the 'Dynamic Adaptive Planning approach' of the TE2100 encompasses the 'Route-map approach' as a sub-method. The Route-map approach of the TE2100 was largely based on the '*Risk, Uncertainty and Decision-Making Technical Report*' produced by the EA for the UKCIP (Willows and Connell 2003) and other tools and assessment guidance (TE2100 Appendix L 2009; Reeder and Ranger 2011, p.8; Lowe et al. 2009, p.86); and on prior work developed in the EA's collaboration in the 'European Spatial Planning Adapting to Climate Events Project (ESPACE) (Ranger et al. 2013), where partners from UK, Holland, Germany, etc. worked on transnational methods.

[15] A pathway is a 'package' of measures (individual or in portfolios) sequenced and implemented over time to manage risk stepwise (Bloemen et al. 2018, p.7; Jeuken et al. 2014, p.18; Ramsbottom and Sheppard 2017, p.5).

conditions (Reeder and Ranger 2011, p.3). The idea underlying the Route-map approach is *to design packages of adaptation measures that can be implemented over time* (Reeder and Ranger 2011, p.8). The Team designed a series of adaptation pathways (in a route-map) that are appropriate to cope with the plausible range of climatic changes that might occur until 2100 (Reeder and Ranger 2011, p.5).

Each HLO is *a pathway or route through the century* that can be *adapted to the rate of change* that is experienced over time (TE2100 Appendix L 2009, p.3; Reeder and Ranger 2011, p.9; Ranger et al. 2013, p.250; Lowe et al. 2009, p.89; Jeuken and Reeder 2011, p.5). The route-map produced (Figure 11) shows five possible HLOs against three SLR scenarios considered.

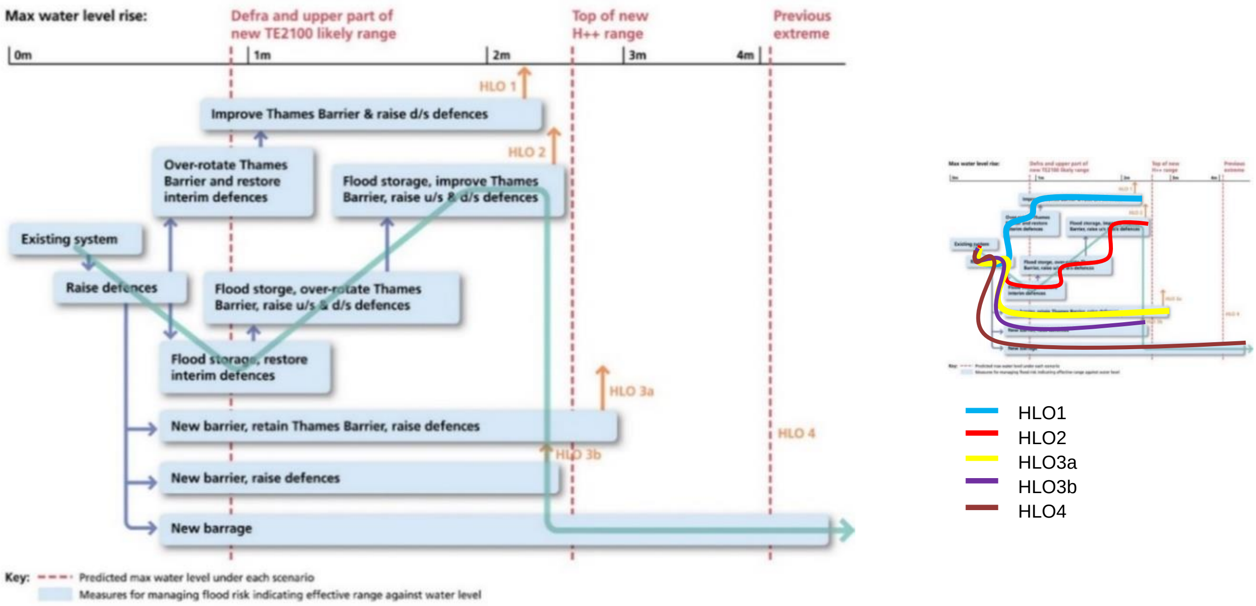


Figure 11. The ‘route-map’ of the TE2100 with the *High-Level Options* developed (HLO1, HLO2, HLO3a, HLO3b, and HLO4). Each HLO is a pathway / route, i.e. a ***package*** of measures sequenced over time. The HLOs are shown (in the Y axis, orange arrows) in relation to future water level rise (in the X axis). Three plausible future scenarios of water level rise are illustrated (dashed vertical lines). The fat green line represents a possible route that could be used to manage flood risk in case of more extreme change, which would initially follow HLO2 and then shift to HLO4 if sea level increased more than 2,7m. Source: TE2100 Appendix L 2009, p.4; Lowe et al. 2009, p.88; Reeder and Ranger 2011, p.8; Ranger et al. 2013, p.249; Jeuken et al. 2014, p.16; Jeuken and Reeder 2011, p.5). The blue boxes show available measures (individual measures, or ‘portfolios, combinations of measures’) to manage flood risk. Each box finishes at the level of SLR at which such measure ceases to be effective (the threshold level for such measure). The blue arrows link to other measures that might be implemented once a measure is no longer effective. The dashed red lines represent three different scenarios of water level rise that were considered: DEFRA (0,9m), initial H++ (4,2m), and revised H++ (2,7m).

Interpreting the route-map

In the Route-map approach used, the following terminology is employed:

- a ‘**response / measure**’ is an individual FRM measure (e.g. building a new barrier, raising defences).
- a ‘**portfolio of responses**’ is a number of measures combined, a combination of measures, which provides a solution for a particular level of water level rise.
- an ‘**Option**’ (HLO) is a pathway, a package (number) of measures (individual measures or portfolios of measures) implemented in sequence over time, which provides a complete FRM solution during the Plan’s lifespan (according to Bloemen et al. 2018, p.8; Ramsbottom and Sheppard 2017, p.2).

Each measure (within a pathway) can be adopted according to the rate of change that occurs. For example, in HLO1: a SLR of 20-30 cm would require raising small defences around the TB; if SLR reached 60-70 cm, it would be necessary to over-rotate the TB and restore interim defences; and a SLR of 89-90 cm would require improving the TB and raise downstream defences (Ranger et al. 2013, p.250).

As a whole, the HLOs were designed to span the estimated range of plausible increases in extreme water levels in the TE until 2100 (up to 4,2m) (Reeder and Ranger 2011, p.8; Ranger et al. 2013, p.250; Jeuken and Reeder 2011, p.4). For instance, HLO1 (which involves *improving the TB and raising defences*) is adequate for up to 2,3m SLR, a level which corresponds to the 2009-current 'most probable' SLR scenario, but under an extreme scenario of 4,2m SLR, the only option available would be HLO4 (which involves building *a new barrage*) (Reeder and Ranger 2011, p.9; Jeuken and Reeder 2011, p.4). The HLOs illustrated in the route-map provide various possible routes throughout the next 100 years – i.e. various *Options* (which are represented in the final Plan) to manage flood risk in the Estuary under all plausible SLR scenarios considered, throughout the next 100 years (Lowe et al. 2009, p.90).

The Route-map / APs approach resulted in an *adaptive plan* that provides a suite of pathways (sequences of measures to manage risk) that maintain *the flexibility to cope with the range of possible future sea level rise* (Reeder and Ranger 2011, p.13, 8). The 'Route-map approach' sought to ensure that the strategies (pathways) *cost-effectively reduce risk while being flexible and adaptable to an uncertain future*, and that *'adaptation decisions made today are resilient to a fast-changing and uncertain climate*' (Reeder and Ranger 2011, p.13, 2). In the 'Route-map approach', a planner envisions measures to cost-effectively reduce risk now, while avoiding foreclosing future options (Ranger et al. 2013, p. 258).

The *Dynamic Adaptive Planning approach* of the TE2100 implied an iterative and learning-oriented planning and decision process, where measures to reduce risk are applied over time while *avoiding foreclosing future options* (Ranger et al. 2013, p.258).

With the Route-map / APs approach, the TE2100 Project has developed an *adaptive plan* for managing flood risk iteratively over the next 100 years. The final TE2100 Plan is an *adaptable plan* (EA 2016, p.18), which contains various *Options* (pathways) to cope with the possible future increases in water levels in the Estuary (from the current level until a 'worst-case scenario' in 2100) (EA 2012).

In the Route-map / APs approach, the timing of new measures, and measures themselves, can be changed (adjusted, adapted) over time – in this way, *flexibility* is built-in in the long-term strategy (pathway) (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.9). Not only are the HLOs (pathways) flexible (for example, it is possible to move from a given measure to a new one), but it is also possible to move from one pathway (HLO) to another depending on the actual rate of change that occurs (TE2100 Appendix L 2009, p.3; Lowe et al. 2009, p.89; Reeder and Ranger 2011, p.9).

The TE2100 developed an 'adaptive plan' for FRM. The plan can be adapted to changes over time: it is possible to adjust the timing of measures, as well as the measures themselves (to shift to one measure to another within a pathway, or review the measures planned), or switch from a pathway to another (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.9; Ramsbottom and Sheppard 2017, p.19; TE2100 Appendix L 2009, p.3; Lowe et al. 2009, p.89).

Route-map method: characteristics

The 'Route-map approach' is a method for developing several possible pathways, also called 'routes', *High-Level Options* (HLOs) or *Options*. In this method, several FRM measures are identified and tested on their effectiveness and lifetime under different future (climatic and socioeconomic) scenarios in order to detect thresholds (points where a measure ceases to be effective and a new measure is required), and, in this way, develop (assemble) possible pathways. The suitability of diverse measures is tested under different scenarios, to identify the timing of thresholds, and inform the development of pathways. Thus, the 'Route-map method' implies a 'thresholds analysis' (TE2100 Appendix L 2009, p.3-5, 12).

In the TE2100, the pathways (*Options*) were developed in an iterative process: different FRM measures were tested, and then used to develop (assemble) pathways, and such pathways were progressively refined. This process resulted in a set of pathways that are robust (*resilient*) and adaptable to uncertain future conditions and changes. The Route-map method led to the development of *flexible and adaptable Options* – i.e. pathways (TE2100 Appendix L 2009, p.1, 2, 12).

The 'Route-map approach' involves identifying the timing for and sequencing of possible FRM / adaptation measures over time under different scenarios, and, in this way, developing various possible pathways. To design the pathways, it was necessary to identify conditions under which a measure no longer meets the specified objectives and another measure is needed (Ranger et al. 2013, p.249-250). In the Route-map method, a planner uses several FRM measures and tests their effectiveness (e.g. under different scenarios of SLR): when a measure ceases to be effective, a new measure is required, and, in this way, develops possible pathways that are progressively iterated and refined (Lowe et al. 2009, p.86). This implies the definition of thresholds that are critical to the diverse measures used (e.g. a SLR level). The pathways designed can then be appraised against various decision-criteria (cost-benefit, performance, etc.) under diverse plausible future scenarios, and the most cost-beneficial pathway can be identified (ibid).

As mentioned, in the adaptive approach of the TE2100, *measures are introduced at different times to limit the increase in flood risk* (*due to climate change*) *to acceptable values* (Ramsbottom and Sheppard 2017, p.1,3). In each *Option* (pathway), measures are implemented in a staged way (as conditions change) to prevent that flood probability (or flood risk)[16] increases above a pre-specified level (ibid). Figure 12 shows the way of developing an *Option* (pathway) to manage flood risk. Each *Option* (pathway) was designed so that a particular 'probability of flooding' was not exceeded. With climate change, flood probability will increase until a certain threshold level (the *maximum acceptable flood probability*, which sets the *design flood probability*)[17] is reached and a new measure to reduce this probability is necessary. After a measure is applied, flood probability decreases, but then, over time, it increases again until the threshold is almost reached and other measure (to reduce the flood probability) is needed. Thus, an *Option* is a sequence of measures (individual measures, or portfolios of measures) that are implemented over time (Ramsbottom and Sheppard 2017, p. 2, 4).

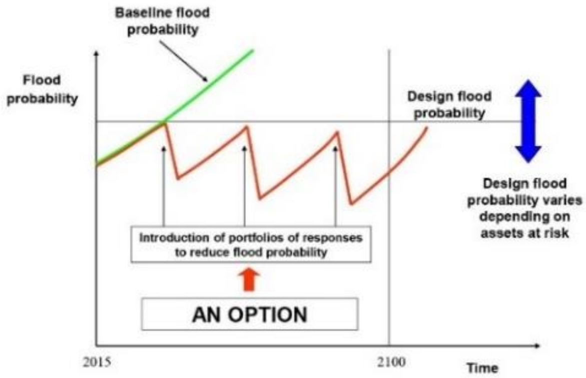


Figure 12. The way of elaborating a FRM Option in the TE2100, showing the interrelation between 'flood probability', 'portfolios of responses', and 'Options' (i.e. pathways, sequences of 'portfolios'). Source: Ramsbottom and Sheppard 2017.

16 In the TE2100, it was considered 'flood probability', but the method can be applied using 'flood risk', though its calculation is more complex (flood risk = flood probability x consequences). The design of Options was not based on flood risk, because all Options had very high benefits in terms of avoidance of consequences. Instead, a *maximum probability of flooding* was defined (Ramsbottom and Sheppard 2017, p.2-3).

17 The *maximum acceptable flood probability* determines the 'design *Standard of Protection'* (SoP), which is the level of protection that the flood defences must provide, expressed either as an annual flood probability (%) or a return period in years. The SoP sets the threshold value of acceptable flood probability for the flood defence system, which should not be exceeded (Ramsbottom and Sheppard 2017, p.4).

4. How the *Dynamic Adaptive Planning approach* was applied: process of steps

4.1. A 'Decision-centred' planning process: interpreting the steps of development of the Plan

This section describes how the *Dynamic Adaptive Planning approach* was applied in the TE2100 Project, focusing particularly on how the 'Route-map method' (i.e. Adaptation Pathways' method, APs) was used for developing an 'adaptable FRM plan'. The TE2100 Plan itself (EA 2012; TE2100 Appendix L 2009), and several authors and documents have provided a detailed description of the application of such Adaptive Planning approach (including the APs' method within it) (see e.g. Reeder and Ranger 2011, Ranger et al. 2013; Penning-Rowsell et al. 2013; Lowe et al. 2009; HM Treasury 2009; London Councils' TEC 2007; London Councils 2018; EA 2016; Ramsbottom and Sheppard 2017[18]; Bloemen et al. 2018[19]). This section builds on these descriptions.

The TE2100 Project followed a *decision-centred* planning process (also called policy-first, context-first, or bottom-up process), which is different from the more traditional *science-first* planning process (Ranger et al. 2013; Reeder and Ranger 2011).[20] In a *decision-centred process,* planners start from the adaptation problem itself (e.g. the need to reduce flood risk) rather than with climate projections, then define objectives and constraints, identify adequate measures and assess their effectiveness under a range of plausible scenarios (Reeder and Ranger 2011). Such a process stimulates decision-makers to focus on the decision problem and its characteristics (objectives, stakeholders' interests, constraints, system's vulnerability, decision criteria) and on the solutions and measures themselves; the analysis is also focused on the choice of measures (to reduce risk), and measures are planned based on in-depth understanding of the problem instead of future climate projections (Ranger et al. 2013).

The TE2100 Project is a practical example of the application of a *decision-centred process* to FRM / adaptation planning (Reeder and Ranger 2011; Ranger et al. 2013). Its planning process, which included the design of a 'route-map' of Options (pathways) within it, was based on the framework developed by Willows and Connell (2003) and refined in the ESPACE programme (European Spatial Planning Adapting to Climate Events, *in* Reeder and Ranger 2011) (see more in Note 108). Besides, the TE2100 Project is an exemplar case of an *adaptive planning approach* (for FRM). Several authors have analysed how this approach was applied to develop an 'adaptable FRM plan', especially how the pathways (and their individual measures) were devised and developed (e.g. Reeder and Ranger 2011; Ranger et al. 2013; Ramsbottom and Sheppard 2017). The next section provides a detailed description of the process of application of the Adaptive Planning approach in the TE2100 (for further details, see Note 109).

Moreover, the TE2100's planning approach is also characterized as a *multi-partner* / *multi-agency* approach (EA 2012, p.1, 7, 42; Ranger et al. 2013; London Councils' TEC 2007) (Note 110).

The stages of development of the TE2100 Plan are shown in Figure 13. The steps of the planning process followed in the Project are in line with a 'decision-centric process'.

[18] David Ramsbottom was the Environment Agency's technical leader for the development of the TE2100.

[19] Bloemen et al. 2018 were directly involved in the application of the Route-map approach in the TE2100 Project and in the DP.

[20] The decision-centric planning process is common in project appraisal but not in climate adaptation. The traditional approach to climate adaptation planning and risk management has been a 'science-first' or 'science-based' process. A science-first process starts with the 'downscaling' of global climate projections to local projections, which are then introduced into 'impact models' (e.g. hydrological models) to analyse potential risks and impacts; and then this information is used to identify and assess adaptation measures. This involves 'resource-intensive' analyses, e.g. scientific modelling, where multiple uncertainties usually arise and tend to delay or hinder the identification and assessment of measures. Conversely, in the TE2100, climate projections entered in the planning and decision process at a later stage than in a science first approach (Ranger et al. 2013, p.243). The 'decision-centric' process has been increasingly recommended in literature on climate adaptation; several arguments favour its use (in detriment of the 'science-first'), especially under deep uncertainty (Ranger et al. 2013; Reeder and Ranger 2011). A 'science-first' process usually involves the generation and interpretation of climate projections, the analysis of risks and potential impacts, and then, the design and assessment of measures to reduce risk (Reeder and Ranger 2011, p.4).

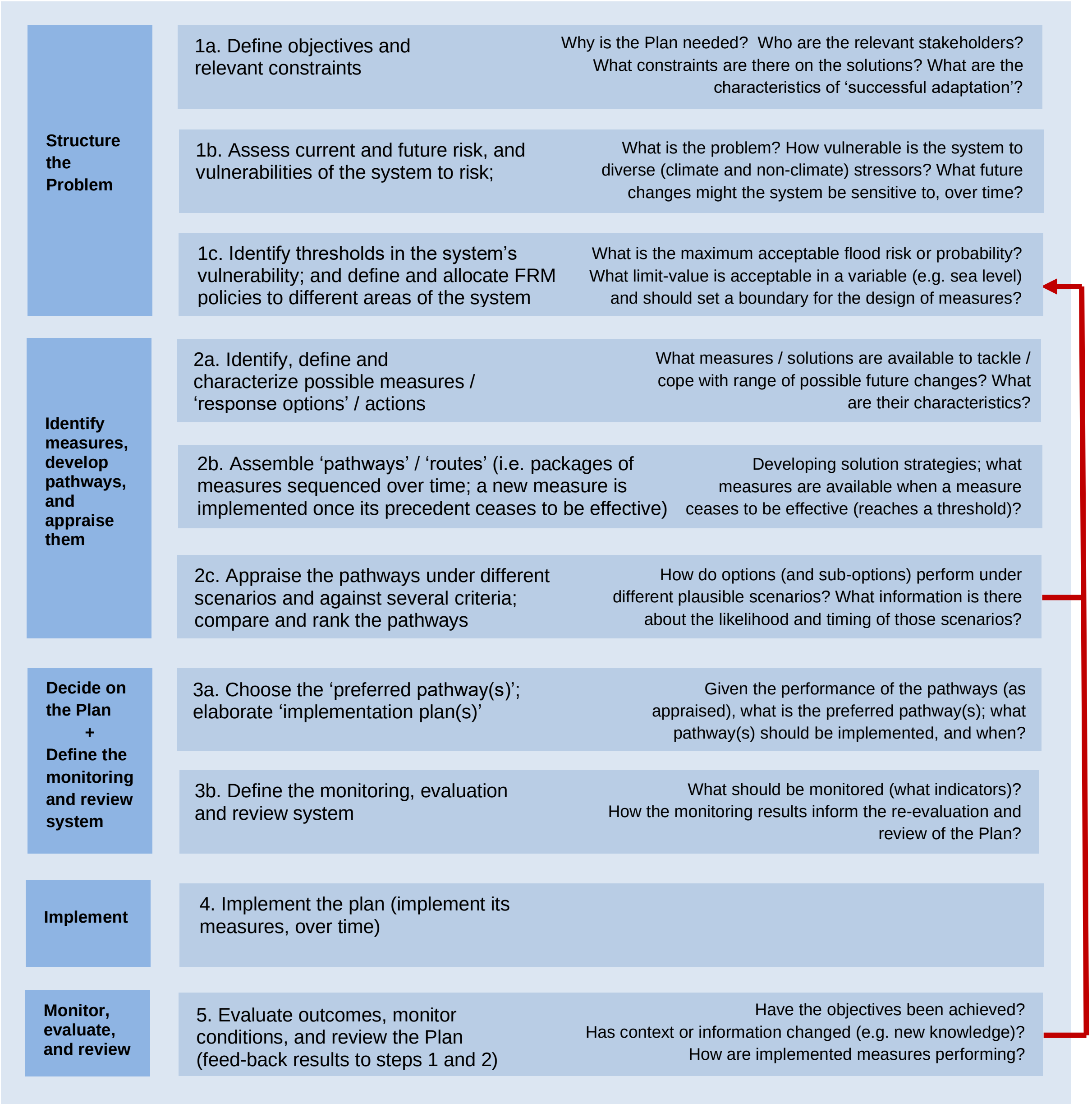


Figure 13. Stages of development of the TE2100 Plan (planning process), in line with a 'decision-centric' process. Source: own elaboration, based on information from EA 2012, p.31; Ranger et al. 2013; Reeder and Ranger 2011; Ranger et al. 2010. This process was inspired in the process of steps provided by Willows and Connell 2003 and refined by the ESPACE programme. See more in Note 108.

Each of the steps / stages of the planning process of the TE2100 Project is described in detail below (Table 2), framed within the context of the process previously illustrated.

<table>
<tr><th colspan="3">Table 2. Planning process of the TE2100 and its main steps and sub-steps</th></tr>
<tr><td rowspan="2">Structure the Problem</td><td>1a. Define objectives and relevant constraints</td><td>Definition of the main characteristics of the decision problem i.e.: objectives, values of stakeholders, constraints and decision criteria (Ranger et al. 2013, p.240).
Definition of objectives of the TE2100 (‘Setting the Vision – objectives and purpose’) (EA 2012, p.32). The main purpose of the TE2100 Project was to develop a FRM plan to manage tidal flood risk in the TE and London. The Plan’s specific objectives are:
- Managing flood risk and minimizing adverse flood impacts to people, property and environment;
- adaptation to climate change effects and related risks;
- supporting spatial planning to ensure sustainable, resilient urban development in the floodplain;
- safeguarding social, cultural and commercial values of the River and its floodplain;
- restoring and enhancing estuarine ecosystems (environmental and biodiversity targets);
- managing existent defences (EA 2012, p.32; Ramsbottom and Sheppard 2017, p.8; Ranger et al. 2013). A specific goal was to analyse when the existing FRM system might need to be modified’, and to produce a ‘forward plan’ up to 2100 (Ranger et al. 2013).
Specification of constraints and decision criteria. The plan had to be justifiable in relation to relevant policy guidance on FRM and in terms of cost-benefit. The cost-benefit ratio (i.e. ‘value for money’) was a crucial aspect the design of FRM measures – they should achieve a good ‘value for money’ (cost-benefit). Besides, the plan should satisfy economic, social, cultural and environmental objectives (which were addressed later, in a Multi-criteria Analysis and Strategic Environmental Assessment). Public consultations occurred throughout the process, to understand decision-criteria, trade-offs and interests of stakeholders (Ranger et al. 2013).
The main drivers of changing (increasing) flood risk were identified (climate change, urban development in floodplain areas, growing population, increasing economic value at risk, ageing flood defences) (Ranger et al. 2013; Marchand and Ludwig 2014, p.13; London Councils’ TEC 2007).
The Plan should consider deep uncertainties about future increase in extreme water levels in the TE, climate projections, valuation of non-monetary impacts and property values. It was decided to design a plan that was ‘as robust as possible’ and ‘adaptable to change, which remained ‘fit for purpose throughout its 100-year lifetime’ (EA 2012, in Ranger et al. 2013, p.239).</td></tr>
<tr><td>1b. Assess current and future risk, and vulnerabilities of the system to flood risk

(flood risk assessment, and vulnerability analysis)
(i.e. assessment of current and future flood risk)</td><td>‘Understanding (the current and future) flood risk in the Estuary’. The Project Team studied the current flood risk and how it might change in the future (EA 2012, p.32). A comprehensive flood risk assessment was conducted. This involved an in-depth analysis of the TE’s natural processes, area at risk of flooding, existent flood defence system (e.g. defence crest levels, dimensions and types of defences), the collection of data about and inspections of defences from the TB to the sea (EA 2012, p.32; London Councils’ TEC 2007; Ramsbottom and Sheppard 2017, p.5,16).
1b1) Assessment of current flood risk and vulnerabilities of the system
This consisted of a detailed assessment of the current level of flood risk, which implied analysing the existent ‘Standards of Protection’ in the TE, and current vulnerability of the defence system to flood risk (Ranger et al. 2013, p.242; Reeder and Ranger 2011, p.5; Bloemen et al. 2018, p.7). Firstly, flood risk was assessed without considering the existing defences to examine its magnitude and the importance of defences under the current situation, and then with the defences. To calculate the current risk, the Team estimated the ‘current flood probability’ (using hydraulic modelling) and analysed the existent ‘design Standards of Protection’ (SoPs, available or defined previous studies / projects, expressed as ‘an annual flood probability’) (Ramsbottom and Sheppard 2017, p.8, 10).
1b2) Assessment of future flood risk and potential future vulnerabilities
At this sub-step, the Team sought to better understand and assess future flood risk and potential future vulnerabilities of the defence system to flood risk (Ranger et al. 2013, p.242; Reeder and Ranger 2011, p.6; Bloemen et al. 2018, p.7). This implied analysing how flood risk might change in the TE in the future, due to climate change effects, but also due to ageing defences and socioeconomic development. Hence, at this stage, the Team commissioned research studies to better understand the effects of climate change effects on SLR, storm surge behaviour, and river flows (considering future projections and broader evidence relating to these), to analyse the plausible range of future extreme water levels in the TE, and to develop a range of plausible ‘scenarios’ of water level rise until 2100. These studies occurred in parallel with the development of options (as a ‘second track’) (Ranger et al. 2013, 243, 246; Reeder and Ranger 2011, p.7; Bloemen et al. 2018, p.7-8; HM Treasury 2009, p.22; Lowe et al. 2009; EA 2012; Ramsbottom and Sheppard 2017, p.5, 16).[21]

In the meantime, to assess future flood risk, and its plausible increase (due to climate change, SLR, changes in storm surge, rainfall and river flows), the Team developed and used four ‘interim’ scenarios</td></tr>
</table>

[21] To understand future changes in flood risk associated with climate change, it was necessary to conduct studies to collect climate information and develop projections. The projections that were developed entered in the planning process at a later phase than in a science-first process.

		of future water level rise: *High++* scenario (4,2m rise by 2100), *Defra 06 central* scenario (0,9m); *Medium-High* scenario (1,5m); and *High+* scenario (2,7m) (TE2100 Appendix L 2009, p.7; Lowe et al. 2009, p.88; HM Treasury 2009, p.22; Penning-Rowsell et al. 2013, p.1400; Ranger et al. 2013, p.243; Reeder and Ranger 2011, p.7; Ramsbottom and Sheppard 2017, p.8) (Figure 14).
	1c. Identify thresholds (in the system's vulnerability); and define and allocate FRM policies to different areas of system	• **1c1) Identification of thresholds** The Team identified *critical thresholds* in terms of vulnerability of the system to flood risk (i.e. thresholds that would be disruptive for the FRM system and that might occur between the present situation and the upper-bound scenario, and / or which would imply modifications to existent defences) (Ranger et al. 2013, p. 242, Reeder and Ranger 2011, p.6; Bloemen et al. 2018, p.7), namely: ▪ limits (of protection) of the existing flood defences (floodwalls and embankments), e.g. the level of SLR at which the existing defences would fail. ▪ engineering limits of the TB as existent and with modifications. ▪ the SLR level at which the TB (as originally designed) will fall below the target protection level (1 in 1000 years). ▪ the 'limit to adaptation' of the flood defence system, i.e. the level of SRL at which it will be quite difficult to continue to protect London in its current form, and some retreat will be necessary. This level was estimated to be 5m SLR (Ranger et al. 2013, p. 241, 255, Reeder and Ranger 2011, p.6; Bloemen et al. 2018, p.8).[22] Some of these thresholds were postulated and then subjected to more detailed modelling (Ranger et al. 2013, p.255; Reeder and Ranger 2011). All major flood defences were examined on their *robustness* (ability to last in time under different future scenarios) and *sustainability* under changing conditions (Jeuken and Reeder 2011). The thresholds identified set up limits for FRM measures and provide signals that a change of measure may be needed (Reeder and Ranger 2011, p.5).[23] • **1c2) Definition of FRM policies** Five policies were defined. Each policy sets the level / standard of FRM that is justifiable in a certain area according to the number of people, assets, and value at-risk in such area. The policies served as the basis for the design of measures (each policy sets different design criteria for measures). A policy was allocated to different parts of the TE, so-called *policy units*, based on an assessment of socioeconomic, environmental, and physical characteristics, and of how much FRM activity / investment can be justified in each unit (EA 2012, p.32,34; London Councils' TEC 2007, p.4; Penning-Rowsell et al. 2013, p.1388). The definition of the FRM policies required a detailed assessment of the existing flood risk per zone of the TE and pre-existent *Standards of Protection* (SoP), and on an analysis of whether such SoPs should be increased, maintained, or reduced (Ramsbottom and Sheppard 2017, p.9-10).
Identify measures, develop pathways, and appraise the pathways	**2a. Identify, define and characterize adaptation measures / 'response options'**	**Exploration and identification of possible FRM measures (actions, *responses*) to manage risk** This step involved the exploration and identification of possible and feasible FRM measures – also denominated '*response options*' or '*responses*' (EA 2012, p.32; Reeder and Ranger 2011, p.6; Ranger et al. 2013, p.242, 243; Ramsbottom and Sheppard 2017, p.4-6, 10-11; Bloemen et al. 2018, p.7). Firstly, various measures were identified by experts, in a conceptual analysis based on H++ scenario (first guess) (Ranger et al. 2013, p.242, 243). The measures identified are called *Early Conceptual Options* (EA 2012, p.34, 32; Ramsbottom and Sheppard 2017, p.6). The Team sought to identify all available measures – either '*individual responses*' or '*portfolios of responses'* (i.e. combinations of measures) – to manage flood risk (HM Treasury 2009, p.23; EA 2012, p.31-33), namely measures needed under extreme conditions (Ramsbottom and Sheppard 2017, p.5). Then, each measure (response) was investigated to examine its lifetime and engineering limits (effectiveness), cost, environmental implications, and potential for flexibility (for making adjustments over time) (Ranger et al. 2013, p.242; Reeder and Ranger 2011, p.6; Bloemen et al. 2018, p.7; TE2100 Appendix L 2009, p.3-5; Ramsbottom and Sheppard 2017, p.4-6, 10-11). Each measure was assessed on its effectiveness in delivering the objectives (the *strategic vision*) (EA 2012, p.35).
	2b. Design / assemble *pathways* or *routes* (i.e. packages of	**Development (design) of several pathways / routes** In this step, the Team developed several adaptation pathways, 'routes', so-called *High-Level Options* (HLOs) (Reeder and Ranger 2011, p.5, 6, 8; Ranger et al. 2013, p.242, 233, 239, 258; Ramsbottom and Sheppard 2017, p.6; Bloemen et al. 2018, p.7). By using the measures identified, and based on the engineering limits and cost-effectiveness of each measure (investigated in Step 2a), several pathways were assembled and designed in a *route-map* (Ranger et al. 2013, p.242; Reeder and Ranger 2011, p.6) (Figure 11). Each HLO is a pathway, i.e. a *package* of FRM measures sequenced and implemented over

[22] This level represents an engineering limit to continuing with upgrades and additions to the existing defences (Reeder and Ranger 2011).

[23] The term 'critical threshold' refers to the 'adaptation tipping-point' (ATP) that later emerged, and its identification implied an assessment of the useful life of existing defences (Marchand and Ludwig 2014, p.13).

	measures implemented in sequence to manage risk over time)	time (TE2100 Appendix L 2009, p.3-4, 1, 10; Reeder and Ranger 2011, p.8; Ranger et al. 2013, p.249; EA 2012, p.34, 38; Jeuken and Reeder 2011, p.4), a sequence of measures (individual or portfolios) over time (Ramsbottom and Sheppard 2017, p.4, 2). ▪ In this step (and to develop the pathways), the Team used the measures previously identified, explored their timing and sequencing over time and under different scenarios, and in this way, designed (assembled) various possible pathways (Ranger et al. 2013, p.233, 239, 258). The High++ scenario set the upper bound for the route-map (Ranger et al. 2013, p. 243). ▪ The design of pathways implied the identification of 'critical thresholds', namely thresholds of the existing flood defence system (TE2100 Appendix L 2009, p.3, 10) (e.g. useful life of existing defences), and conditions under which a measure no longer meets the specified decision criteria and it is necessary to take another measure (Ranger et al. 2013, p.250). In this way, it was possible to design various pathways (Ranger et al. 2013, p.233, 239, 258; Reeder and Ranger 2011, p.6). In the prior step (2a), the Team had tested diverse measures (and portfolios) under different future scenarios and against several criteria (e.g. effectiveness). Using this method, it was possible to identify thresholds (conditions under which a measure ceases to be effective) and then explore alternative measures to tackle such thresholds. In this way, a pathway emerged. Thus, several pathways were designed, and successively iterated and refined (Lowe et al. 2009, p.86; Ramsbottom and Sheppard 2017, p.10). Hence, each HLO consists of a pathway of measures to cope with thresholds over time (Reeder and Ranger 2011, p.6). ▪ The development of the *HLOs* (pathways) implied sequencing the measures to assemble several possible pathways over time: when a measure reaches a threshold level, another measure is needed, and a pathway emerges (TE2100 Appendix L 2009, p.3-4, 1, 12). The measures previously identified (in Step 2a) were used *to create 'strategic packages*' of measures – i.e. to create various pathways (HLOs) that are able to deal with different levels of water level rise over time (HM Treasury 2009, p.23; Ramsbottom and Sheppard 2017, p.6). To design pathways, it was necessary to assemble sequences of measures (*individual* or *portfolios*) to manage flood risk over time; and this implied analysing when each measure would reach a threshold (e.g. maximum acceptable flood probability) and another measure is needed (Ramsbottom and Sheppard 2017, p.4). The individual measures and *portfolios* previously identified (in 2a) were used to assemble the various HLOs (pathways). By sequencing such measures, it was possible to generate (assemble) various pathways (HM Treasury 2009, p.23; Ramsbottom and Sheppard 2017, p.6). Five possible pathways (HLOs) were developed and represented in a *route-map*. On their whole, the HLOs can cope with the estimated plausible future water rise in the TE until 2100 (Reeder and Ranger 2011, p.8; Ranger et al. 2013, p.250; Jeuken and Reeder 2011, p.4; Bloemen et al. 2018, p.7). Overall, the design of the pathways (HLOs) involved an iterative process where measures were identified and tested under various scenarios, and used to assemble diverse pathways that were successively refined (TE2100 Appendix L 2009, p.3-4, 1, 12). Each pathway was tested under different scenarios, to assess its suitability and robustness (Reeder and Ranger 2011, p.9; Jeuken and Reeder 2011, p.4). This step resulted in a range *of adaptation pathways'* that are *'appropriate to cope with the plausible range of climatic changes that could be seen by 2100*' (Reeder and Ranger 2011, p.5), and which can be adapted to uncertain future conditions and changes (TE2100 Appendix L 2009, p.3-4, 1, 12). The various pathways keep risk below acceptable levels while maintaining *flexibility* – i.e. while keeping open options (alternatives) to manage future risk (Ranger et al. 2013, p.233, 239, 258, 249).
	2c. Appraise pathways, and their measures, using various criteria, and under different scenarios; compare and rank the pathways	**Appraise the pathways (so-called '*Options*')** In this step, the pathways (*Options* with their sub-options) were appraised in a *Strategic Environmental Assessment* and in a *Formal Options Appraisal* (EA 2012, p.40; Bloemen et al. 2018, p.8). The pathways that were assessed, denominated '*Options'*, are similar to the HLOs illustrated in the *route-map*, but with some refinements (Ranger et al. 2013, p.251) (see Table 4). In the *Formal Options Appraisal*, the pathways (*Options*) were appraised under several scenarios, using a cost-benefit analysis (CBA) and multi-criteria analysis (MCA) (Ranger et al. 2013, p.251; Reeder and Ranger 2011, p.6; Bloemen et al. 2018, p.7; Ramsbottom and Sheppard 2017, p.6). The *Formal Options Appraisal* is reported by Penning-Rowsell et al. (2013) and the technical report of TE2100 (EA 2009). **2c1) Appraise '*Options*' (pathways) under the 'most-likely' scenario** Firstly, the *Options* (pathways) were appraised in a CBA and MCA under the *most likely* scenario (Ranger et al. 2013, p.251; Reeder and Ranger 2011, p.6, 11; Bloemen et al. 2018, p.7). The Team conducted a CBA of each *Option* (pathway) under the *Defra06 central* scenario (deemed the '*most likely*' scenario) (HM Treasury 2009, p.25; Penning-Rowsell et al. 2013, p.1392). The CBA showed what was the best Option under this scenario (HM Treasury 2009, p.25). Then, a MCA was conducted (under the *Defra06 central* scenario) to capture potential impacts of *Options* (on business, environment, etc.), which were then included in the CBA (ibid). In sum, each pathway was assessed on its costs, benefits, and

		impacts (in CBA and MCA) under the 'central scenario' (*most likely*) (Ranger et al. 2013, p.243; Reeder and Ranger 2011, p.6,11; Bloemen et al. 2018, p.8). **2c2) Appraise '*Options*' (pathways) under other scenarios** Secondly, the results of the CBA and MCA (the performance of the various pathways) were tested under other (climate and socioeconomic) scenarios (Penning-Rowsell et al. 2013, p.1400; Ranger et al. 2013, p.243; Bloemen et al. 2018, p.8). It was conducted a CBA of all *Options* under other scenarios considered, to examine how the *Options* perform under different futures and how their costs and benefits vary. This helped to detect weaknesses of some Options in dealing with uncertain future conditions (as they reach critical levels in variables), which may lead to a preference for other Options (HM Treasury 2009, p.25).This assessment was also useful '*to gauge the circumstances under which a switch to another route might be desirable*' (Reeder and Ranger 2011, p.6). **2c3) Compare and rank the *Options* (pathways)** Thirdly, the pathways were ranked under four scenarios: the *Defra06 central* scenario, High+ scenario, and socioeconomic scenarios A and B (Penning-Rowsell et al. 2013, p.1392, 1400; Ranger et al. 2013, p.243; Reeder and Ranger 2011, p.6; HM Treasury 2009, p.25) (Figure 20). The appraisal allowed the identification of the *Option* (pathway) with the highest cost-benefit ratio under the *central* (*most likely*) scenario and other scenarios (HM Treasury 2009, p.26). It showed what was the preferable route under these scenarios (Ranger et al. 2013, p.243; Bloemen et al. 2018, p.7).
Decide on the Plan + **Define the monitoring and review system**	**3a. Choose the preferred pathway(s); elaborate 'implementation plan(s)'**	***Decision analysis* (i.e. select the preferred pathway(s)) and generate *implementation plan(s)*** This step involved choosing the *preferred route* (pathway) under the most likely scenario and examining if a *switch of route* will be necessary in the future. The final TE2100 Plan recommends: '*making the best use of the existing flood defence system*' and a taking a decision between HLO1 or HLO 3 by 2050 (Reeder and Ranger 2011, p.6). Thus, a possible investment in a new barrier is delayed until necessary, and the Plan suggests a possible date for such barrier (to be operating) in the *Defra 06 central scenario*: 2070 (Bloemen et al. 2018). The *Option* recommended is based on the *Option* that, in the appraisal (of Step 2c), showed the highest cost-benefit ratio under the 'most likely' scenario. This *Option* consists of a package of actions implemented over time, which are recommended in the Plan (HM Treasury 2009, p.26). The final Plan includes a program of measures and works – the '*Action Plan*'.
	3b. Define the monitoring, evaluation, and review system	**3b1) Estimation of 'decision-points'** This step involved the estimation of important 'decision-points', namely those associated to points when it would be necessary to switch from the 'central route' to another route (Ranger et al. 2013, p.243). Using the route-map, the Team estimated 'implementation points' and 'decision-points' (Ranger et al. 2013, p.250). First, it was necessary to investigate the adequate timing for implementing a measure – i.e. the implementation point (since postponing a measure could leave people further exposed to floods in the meantime or imply costly repairs to older defence infrastructure) (ibid). A *decision-point* is a point at which an action (pertaining to a given HLO) must be chosen and approved; its estimation considers the "lead-time" required for designing and constructing such action (HM Treasury 2009, p.26). It is expressed as a value in an indicator monitored; and its identification is conditional on the monitoring (observation) of the indicators; observations of the indicators trigger such decision-points (Ranger et al. 2013, p.243, 233, 239, 252). Thus, the timing for deciding on, and the timing for implementing, a measure may change depending on the monitoring results (Bloemen et al. 2018). The decision-points help to ensure that measures are timely taken and cost-effective, to guide their implementation (Ranger et al. 2013, p.258). **3b2) Defining a monitoring programme, and setting a periodic review and update of the Plan** This step also required the definition of the monitoring programme, which includes 10 'indicators of change' to be monitored that affect tidal flood risk (e.g. relative SLR, peak surge tide levels, erosion, etc.) (EA 2012, p.30; Ranger et al. 2013, p.233, 239, 258; Reeder and Ranger 2011, Lowe et al.2009; HM Treasury 2009, p.26). The monitoring programme keeps track of the indicators (Ranger et al. 2013, p.256). These indicators correspond to key-variables that should monitored to check if a switch of measure or pathway is necessary (Reeder and Ranger 2011, p.6). The plan was designed to be adjustable and respond to possible changes in any indicator or updated projections. If monitoring shows that water level (or other indicators) is increasing faster or slower than predicted in the *central scenario* (assumed in 2010), then decision-points are anticipated or postponed. This helps to ensure that decisions are made at the right time and measures are cost-effective. If a certain threshold is considered critical, it can be monitored and investigated with further detail, so that the *route-map* can be adjusted over time (Ranger et al. 2013, 254-255). Besides, the Plan must be reviewed (revaluated) every 10 years at least, or more frequently (if there is a substantial change in one or more indicators) (EA 2012, p.30), and a mid-term monitoring review must be

		undertaken every 5 years (Ranger et al. 2013, p.243; Bloemen et al. 2018). The Plan's reviews must be informed by the monitoring programme (ibid). In this way, periodic updates of the pathways may occur. Overall, the effectiveness of the Plan depends on the continual monitoring of indicators, and regular review (revaluation) of the Plan and adjusting as time unfolds (Ranger et al. 2013, p.254; Reeder and Ranger 2011; Lowe et al. 2009, p.85, 90; TE2100 Appendix L 2009). Iterative planning is part of this.
Implement	**4. Implement the plan** (its actions)	***Implement plan(s)***. This step consists of implementing the measures (*actions* / *interventions*) envisioned (Reeder and Ranger 2011, p.7). The final plan was published in November 2012 (Ranger et al. 2013). The implementation of its actions began soon after. After the publication of the Plan, the *implementation partners* to whom the Plan sets recommendations should deliver their actions (London Councils 2018).
Monitor, evaluate, and review	**5. Monitor and evaluate, and review the Plan** (feed-back results to steps 1+2)	**Monitoring and evaluation, and periodically review the Plan** The monitoring and evaluation (of external conditions and outcomes of the Plan) and the periodic review of the Plan allow an eventual anticipation, postponing, or change of route or measure (Reeder and Ranger 2011, p.6; HM Treasury 2009, p.28). Based on observed and predicted changes in indicators, it is necessary to take decisions on the acceleration or deceleration of the actions recommended in the Plan (Ranger et al. 2013, p.243) e.g.: a change in the rate of SLR might require accelerating or delaying certain measures, or high rates of erosion in the existing defences could accelerate the need to upgrade defences (Reeder and Ranger 2011, p.6). The first monitoring review report was published in 2016. In the review of the Plan, it is necessary to evaluate if the recommended *Option* (pathway) and its measures still provide the 'highest cost-benefit ratio' under the currently predicted to be the 'most likely' scenario (HM Treasury 2009, p.28). This step may lead back to previous steps (Step 1 or Step 2)

Table 2. Steps of the TE2100 planning process. Source: Own elaboration based on several authors. See more in Note 109.

STEP 1B: RESEARCH STUDIES CONDUCTED IN PARALLEL TO THE PROJECT, AND GENERATION OF SCENARIOS

During the development of the Plan, the EA commissioned research studies to the Met Office and other organizations to analyse the current flood risk in the TE (considering the existent flood defence system) and how it could change in the future, and how to manage changing risk and adapt (EA 2012, p.1, 6, 28; TE2100 Appendix L 2009). In specific, the Team commissioned research to better understand climate change effects on relative SLR, storm surge and river flows, and the plausible future increases in extreme water levels in the TE, and to develop a range of future scenarios of water level rise until 2100 (EA 2012, p.28). This research was conducted in conjunction with the development of the *UKCP09 Marine and Coastal Projections*, and both studies (for TE2100 and for UKCP09) provided information on mean and extreme sea levels for the entire UK (Lowe et al. 2009, p.5, 7, 88) (Note 111). Moreover, this research occurred in parallel with the development of *Options* (Ranger et al. 2013, p.246, 243; Reeder and Ranger 2011, p.7). The results of this research were scheduled to be available by the end of the TE2100 Project, thus, in the meantime, the TE2100 Team developed four interim scenarios (TE2100 Appendix L 2009; Lowe et al. 2009, p.88; Ranger et al. p.258).

Step 1b2) Developing 'scenarios' of water level rise to inform planning

The interim future scenarios of water level rise developed by the Team were (TE2100 Appendix L 2009, p.7; EA 2012, p.28; Lowe et al. 2009, p.88; HM Treasury 2009, p.22; Ranger et al. 2013, p.243; Reeder and Ranger 2011, p.7, 79; Jeuken et al. 2014, p.11; Ramsbottom and Sheppard 2017, p.8)[24] (Figure 14):

- High ++ scenario (first guess). It assumes a 4,2m rise by 2100. It is a *worst-case scenario* that considers the maximum plausible increase in all elements of extreme water levels. The H++ was

[24] Pending on research work that was being conducted, the TE2100 Team developed four interim future scenarios of plausible water level rise (Lowe et al. 2009, p.88; TE2100 Appendix L 2009). The TE2100 had a different approach to climate models and scenarios from the commonly used: here, such tools were expected to be decision-relevant and inform the plan. Instead of using only the best available Global Circulation Models and Regional Circulation Models, the Team recognized uncertainties about future water levels in the TE and limitations of models. Thus, it generated various plausible scenarios of future water level rise, based on GCMS, RCMS, numerical models, climate projections, past observations, detailed analysis and expert judgement (Ranger et al. 2013, p.258) (Note 112). Focusing on mean SLR and storm surge behaviour, the scenarios of water level rise were developed, based on prior work of UKCIP, Defra and other entities (HM Treasury 2009, p.22).

developed in 2005 (before research studies were completed), but, in 2009, it was revised down to 2,7m (based on new studies and detailed modelling) which originated the High + scenario.[25]

- Defra 06 'central' scenario. It assumes a 0,9m rise by 2100. It is based on the guidance of DEFRA 2006 and the UKCIP02 scenario.[26] Later, this scenario was deemed the 'most likely' scenario.
- Medium High scenario. It assumes a 1,5m rise by 2100. It is based on Defra 2006 guidance and the homonymous UKCIP02 scenario.
- High + scenario. It assumes a 2,7m rise.[27] It is based on Defra 2006 guidance and UKCIP02 scenario.

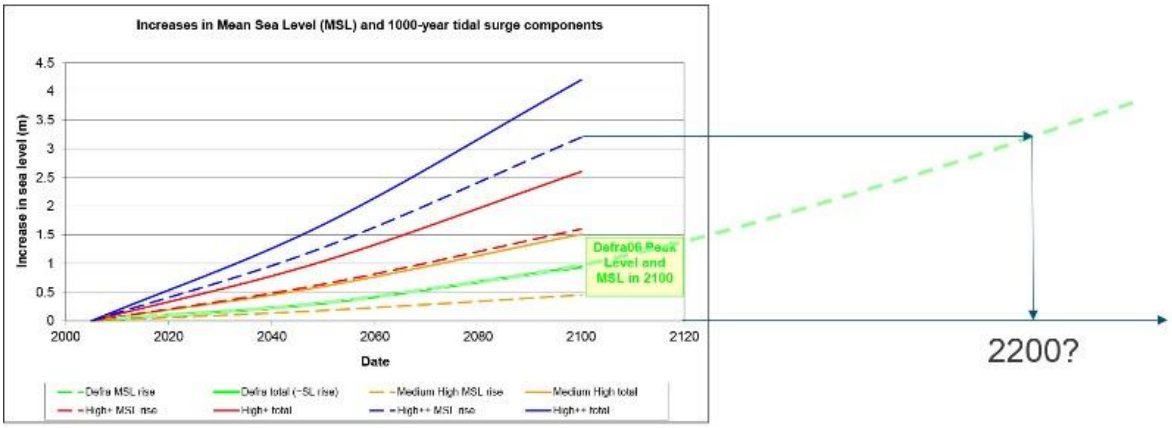


Figure 14. The four scenarios of water level rise developed in the TE2100 (which consider MSL and tidal surge): the High++ (4,2m), the High+ (2,7m), the Medium High (1,5m), and the Defra06 central (0,9m). Source: Ramsbottom and Sheppard 2017, p.8. When projecting the Defra06 scenario (green) until 2200 a higher SLR is reached. Hence, the planning of measures with long lifespans (and the replacement of defences) must consider these higher pictures in the long-term.

Moreover, four socioeconomic scenarios were developed for the TE and London (Figure 15) (Ranger et al. 2013, p.242; Reeder and Ranger 2011; Penning-Rowsell et al. 2013, p.1401; Jeuken et al. 2014, p.13).

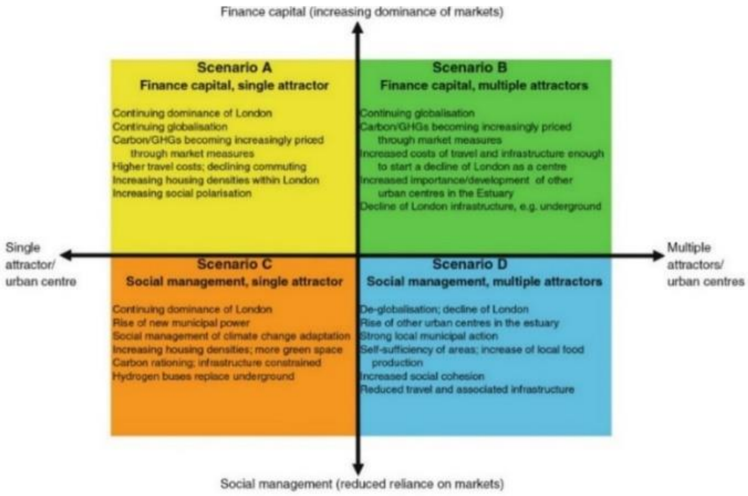


Figure 15. The socioeconomic scenarios developed by TE2100. Source: Penning-Rowsell et al. 2013, p.1401.

[25] The H++ is a *high impact, low probability* scenario (Lowe et al. 2009, p.10). It assumes a combination of extreme values for SLR (thermal expansion, polar ice melt) and storm surge (TE2100 Appendix L 2009). It is an intentionally pessimistic scenario, based on expert inputs (Ranger et al. 2013, p.242; Reeder and Ranger 2011). Later, modelling work (carried out by the TE2100 and UKCIP) showed that a worst-case scenario is likely to be nearer 2,7m than 4,2m (HM Treasury 2009, p.22).

[26] Based on the DEFRA's *Flood and Coastal Defence Appraisal Guidance* (FCDPAG3) (DEFRA 2006) and consistent with the upper-bound predictions of UKCP09 (Lowe et al. 2009; Ranger et al. 2013; HM Treasury 2009, p.22). Later, modelling work confirmed this central scenario.

[27] It assumes a 2m of SLR + 0,7m increase in storm surge height. Projections predicted no relevant future changes in storm surges, but statistics about extreme events were added to SLR projections. It is a *worst-case* scenario (but unlikely) (Jeuken et al. 2014, p.11; EA 2012, p.28).

This range of scenarios was generated by the TE2100 Team in collaboration with the scientific community, based on climate and hydrological model calculations (Jeuken et al. 2014, p.11, 14).

Overall, the climatic scenarios were used to: understand the plausible range of extreme water levels in the future, to explore '*response options*' (measures), test the robustness of the measures (i.e. to see if measures were robust under different plausible scenarios and detect vulnerabilities of the Plan, rather than optimizing a given measure for a specific scenario), and in this way, develop several pathways (Ranger et al. p.242, 258; Lowe et al. 2009, p. 88; Reeder and Ranger 2011, p.7).

The main purposes of using several scenarios are identified bellow (per stage of the planning process):

- The H++ (first guess) was necessary in Step 1b2 (*assessing future flood risk*) (Ramsbottom and Sheppard 2017, p.8), it served to assess potential future sensitivities / vulnerabilities to climate-related risks (Ranger et al. 2013, p.242; Reeder and Ranger 2011, p.6).
- The H++ scenario (first guess) was used to inform the initial identification of measures (*responses*) (in Step 2a), and to set the upper bound for development of pathways (i.e. the boundary for the route-map) (in Step 2b) (Ranger et al. 2013, p.242-243; Reeder and Ranger 2011, p.7, 6).[28] Then, the four interim scenarios were used for testing the measures (*responses*), and in this way, develop the *High-Level Options* (pathways) (TE2100 Appendix L 2009, p. 2, 7, 10; Lowe et al. 2009, p.88).
- In 2009, when the Plan was being completed, the results of the studies commissioned became available (London Councils' TEC 2007). The studies identified what was the 'most likely' scenario (the 'Defra06 central') (Reeder and Ranger 2011, p.7; TE2100 Appendix L 2009, p.4), and provided updated figures for the High++.[29] The revised scenarios served to refine the Plan (though the *Route-map approach* used proved to be robust enough so that the actions recommended in the Plan for near-term did not change) (Reeder and Ranger 2011, p.7).
- For the appraisal of *Options* / pathways (Step 2c), two climate scenarios were used. Firstly, the Options were assessed in a BCA and MCA under the *Defra06 Central* scenario, and then these results and the Options were tested under the *Defra 06 Central* scenario and the *High +* scenario, and the Options were ranked under such scenarios (Penning-Rowsell et al. 2013, p. 1400; EA 2012, p.28). The socioeconomic scenarios were also used in the appraisal (Jeuken et al. 2014, p.13).
- The Team refined the HLOs, and based on this, designed the *Options* under the *Defra06 central* scenario (which were included in the final Plan) (TE2100 Appendix L 2009, p.6). This scenario was used for the detailed design of final *Options* (Step 3a) (Ramsbottom and Sheppard 2017, p.9).
- Some scenarios were used to estimate '*decision-points*' (Step 3b) (Ranger et al. 2013, p.243).

Step 1c: Defining the FRM policies and allocating them to different 'policy-units'

The Team defined five FRM policies to be allocated to different areas of the Estuary (Table 3). Each policy sets the level / standard of FRM that is justifiable in a certain area according to the number of people, assets and value located in such area. The FRM policies served as the starting point / basis for developing the FRM options and actions (i.e. 'estuary-wide options' and 'local actions'); each policy establishes different design criteria for the actions (EA 2012, p.32,34, 45; London Councils' TEC 2007, p.4; Penning-Rowsell et al. 2013, p. 1388).

---

[28] The H++ was used to identify limits to the measures and long-term adaptation requirements that the pathways should meet (Ramsbottom and Sheppard 2017, p.9), and to set an upper bound for the development of Options (Ranger et al. 2013, p.242; Reeder and Ranger 2011).

[29] Later, the Team used the last three interim scenarios, and also a 'low scenario' of 0,5m rise, to explore possible changes in the 'baseline' / reference line (Penning-Rowsell et al. 2013, p.1400; HM Treasury 2009, p.22).

FRM policies of the TE2100 Plan
P1: No active intervention (but continuing to 'monitor and advise'), i.e. including flood warning, advise and maintenance.
P2: Reduce the existing FRM actions, i.e. reduce action, accepting that **flood risk will increase over time**.
P3: Continue with existing or alternative actions (to manage flood risk) at their current level, accepting that **the likelihood and / or consequences of a flood will increase** because of climate change effects, e.g. SLR.
P4: Take further action to keep up with the effects of climate change and land use change so that **flood risk does not increase in relation to the current risk**; i.e. sustain the current flood risk into the future responding to potential increases in flood risk driven by urban development, land use change and climate change.
P5: Take further action to **reduce the risk of flooding now and / or in the future**.

Table 3. FRM policies used by the EA in the TE2100. Source: EA 2012, p.44, 8; Penning-Rowsell et al. 2013, p.1388.

Based on an assessment of how much FRM activity could be justified in different parts of the TE, a FRM policy was assigned to diverse areas (Figure 16). The Plan's area was divided into 23 'policy units', and a FRM policy was allocated to each unit (EA 2012, p.29, 32, 34) (Note 113). The Team assessed the socioeconomic, environmental and physical characteristics and values of each policy unit, and analysed what level of FRM could be justified (how much FRM activity or investment would be appropriate), and based on this, allocated a FRM policy to each policy unit (EA 2012, p.32,34, 44-45; London Councils' TEC 2007, p.4; Penning-Rowsell et al. 2013, p. 1388).[30]

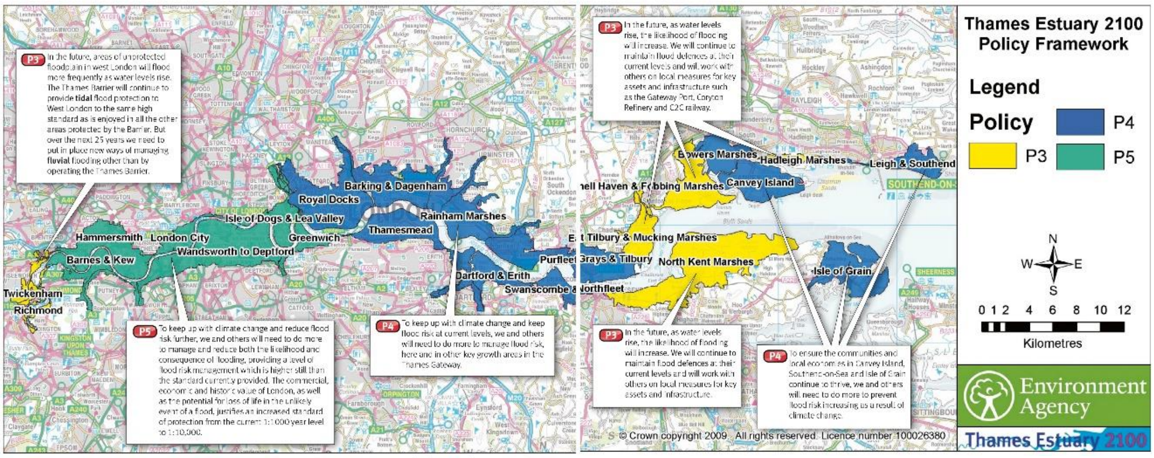


Figure 16. The FRM policies allocated to different areas of the Estuary. Source: EA 2012, p.44-45.

This step involved, firstly, an assessment of the pre-existent *Standards of Protection* (SoPs, expressed as an 'annual tidal flood probability') in different parts of the TE; and then, the definition of a new 'design SoP' that represents the '*maximum acceptable flood probability*' required in each part (which would be used for designing measures) (Ramsbottom and Sheppard 2017, p.9). The pre-existent SoPs[31] in the TE were: 0.1% (1 in 1000-year return period) in 2030 for most of the Estuary; 0.5% (1 in 200 years) for parts of the lower Estuary; and 1% (1 in 100 years) for fluvial areas (ibid).

Then, the TE's floodplain was divided into the 23 policy units, and, for each policy unit, the Team examined whether flood risk should be allowed to (i) increase, (ii) remain the same, or (iii) reduce, (considering climate change effects on flood risk). In this way, a new 'design SoP' was defined for different areas of the Estuary, as follows:

30 Several methodologies were used to assess what policy could be justified in each area / part of the TE. The FRM policies, and their allocation process, are the same used in the EA's *Catchment Flood Management Plans* in England and Wales. This ensures that the FRM approach is coherent at national scale and that the allocation of scarce resources for FRM is fair (EA 2012, p.45-46; Penning-Rowsell et al. 2013, p.1388). P1 was served a baseline, but it was not selected for any of the 'policy units' (EA 2012, p.45).

31 These SoPs express the level of protection that defences must provide, as an annual flood probability (%) or a return period in years (ibid,p.4).

- London: 0.01% (1 in 10 000-year return period). This is an increase in the SoP in relation to the pre-existent. This SoP will be achieved when the first major intervention to the defence system occurs.
- Developed areas downriver of the TB: the same 'design SoP' as existent, which requires raising existing defences (to address the increase in flood risk associated with climate change).
- Policy units with few assets at risk: a reduced SoP (achieved by not raising the defences as the sea level rises and fluvial flows increase) (Ramsbottom and Sheppard 2017, p.9).[32]

The new design SoPs set out a threshold value of acceptable flood probability for the flood defence system that should not be exceeded (Ramsbottom and Sheppard 2017, p.4).

Importantly, the FRM policies were refined during the planning process (development of HLOs), based on stakeholder consultation. Thus, in Step 3, some pathways (and measures) were modified in accordance with the alterations made in FRM policies (London Councils' TEC 2007). The final Plan specifies a policy for different parts of the Estuary, most of them aim at maintaining the existent level of flood risk or reduce it (Jeuken et al. 2014, p.6). The FRM policies provided a common basis on which the involved parties could plan their actions for the short-, medium- and long-term, and will steer the implementation of actions and investments (EA 2012, p.29, 44).

STEP 2: IDENTIFY MEASURES, DEVELOP PATHWAYS, AND APPRAISE THEM

Step 2 involved the identification of possible measures, assembling of pathways, and their appraisal. In the TE2100, the pathways (*Options*) were developed in an **iterative way** (in three main stages **– 2a, 2b and 2c)** which involved stakeholder consultation (Jeuken et al. 2014, p.6). To develop the pathways – so-called '*High-Level Options*' – the Team developed and applied the 'Route-map approach' (TE2100 Appendix L 2009, p.3-4). Step 2, and its sub-steps, are described next.

Step 2a: Exploring and identifying possible FRM measures

In this step, the Team explored and identified possible measures to manage flood risk, i.e. FRM measures, also called *response options*/ *responses* (EA 2012, p.32; Reeder and Ranger 2011, p.6; Ranger et al. 2013, p.242, 243; Bloemen et al. 2018, p.7; Ramsbottom and Sheppard 2017, p.4, 6, 10-11). A measure or *response* consists of an action to keep flood *risk below target levels* (as defined in the policy objectives) (HM Treasury 2009, p.23), and to cope with the thresholds previously identified (Reeder and Ranger 2011, p.6). Various measures to deliver the FRM policies (of each policy unit) were explored (London Councils' TEC 2007, p.4).

Initially, various measures were identified in a conceptual analysis based on the initial H++ scenario (Ranger et al. 2013, p.242, 243): so-called *early conceptual options* (presented in a public consultation in 2005) (Figure 17) (EA 2012, p.34, 32; Ramsbottom and Sheppard 2017, p.6). A measure (*response*) can be either an individual measure or a *portfolio* of measures (a combination of measures that work together coherently), and it can be a generic 'estuary-wide' measure or a measure for a specific area of the TE (EA 2012, p.34, 32; Ramsbottom and Sheppard 2017, p.5-6; HM Treasury 2009, p.23). After some discussion, some measures were excluded (e.g. a tide-excluding barrage), but the *early conceptual options* were the starting point for the subsequent refinement of measures (EA 2012, p.33).

[32] This step involved the definition of 'reference lines', e.g. defence crest levels, flood water levels correspondent to pre-existent SoPs, a baseline (flood water level with no overtopping of defences). Besides, other requirements were defined, e.g.: the maximum number of closures of the TB per year (which influences the timing of maintenance and the design standard), limits of defence raising in public areas in London; the lifespan of new structures, residual lifespan of existing structures, habitat creation requisites (Ramsbottom and Sheppard 2017, p.4, 9, 10).

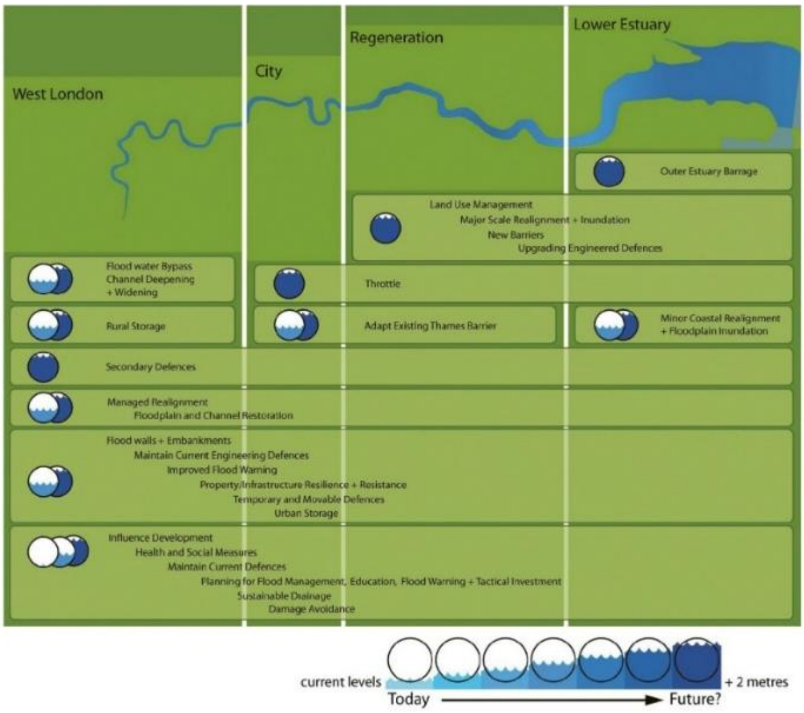


Figure 17. The individual measures and 'portfolios' initially identified, called 'Early Conceptual Options'. Source: EA 2012, p.33.

In Step 2a, the Team sought to identify all available measures to manage flood risk (individual measures or portfolios of measures). Some measures relevant at the estuary-wide scale were, e.g.: improving existing defences (raising existing defences, such as river-walls), optimizing defence repair and replacement, allowing future adaptation of defences (e.g. building larger foundations), adjusting existing defences, creating flood storage areas, constructing a new flood barrier / barrier with locks, or convert the TB to a barrier with locks (EA 2012, p.31; HM Treasury 2009, p.23) (Note 114).

Then, each measure was examined on its lifetime, engineering limits, effectiveness, cost, environmental implications, and flexibility (potential for making adjustments over time) (Ranger et al. 2013, p.242; Reeder and Ranger 2011, p.6; Bloemen et al. 2018, p.7; EA 2012, p.35).[33] In specific, each measure was tested against different (climate and socioeconomic) scenarios to assess its effectiveness / lifetime and suitability, and to identify thresholds (i.e. points where a measure ceases to be effective and new measure is required) (TE2100 Appendix L 2009, p.3-5; Ramsbottom and Sheppard 2017, p.4, 6, 10-11). The detection of the threshold in each measure informed the design of the pathways: when a measure reached a threshold, a new measure is needed, and, in this way, a pathway emerges (TE2100 Appendix L 2009, p.3-5). The Team tested various measures (individual or portfolios, relevant for diverse parts of the TE) under different futures and against key decision criteria (effectiveness, suitability, robustness, etc.). Using this method, it was possible to detect a threshold critical to each measure and explore alternative measures to tackle that threshold (Lowe et al.2009, p.86). Then, each measure was plotted on a diagram showing the amount of change in a driver of risk (variable) that each measure can cope with; after plotting all measures on the same diagram, it was possible to assemble packages of sequenced measures, i.e. pathways (Ramsbottom and Sheppard 2017, p. 4, 6, 10-11). The High++ scenario was initially used to identify limits of the measures, then, other scenarios were used (ibid, p.9).

[33] This assessment may also include local studies, higher assessments, and expert judgement, however, a detailed appraisal of the cost and benefits of pathways (and their measures) only occurred in Step 2c (Reeder and Ranger 2011, p.6). It is also important to check interactions of measures with other issues, e.g. urban plans / policies, development pressures, impacts on ecosystems (ibid). In this case, the assessment of the effectiveness and suitability of some measures (e.g. raising defences) required hydraulic modelling, outline designs, cost estimation, brief assessment against environmental requirements, in local studies and public consultations (Ramsbottom and Sheppard 2017, p.4, 6, 10-11).

In sum, Step 2a consisted of the exploration of all FRM measures (responses) available and identification of those that are suitable through a screening process (Ramsbottom and Sheppard 2017, p.4, 6, 10-11).

Step 2b: Developing the *High-Level Options* (pathways)

This step consisted of the development / design of several adaptation pathways or routes, so-called *High-Level Options* (HLOs) (Reeder and Ranger 2011, p.5, 6, 8; Ranger et al. 2013, p.242, 233, 239, 258; Ramsbottom and Sheppard 2017, p.6; Jeuken et al. 2014, p.6). A HLO is a pathway, a package of measures sequenced and implemented over time. The pathways (HLOs) were developed in an iterative process, in which the measures identified were tested under diverse scenarios and used to assemble several pathways, which were successively refined (TE2100 Appendix L 2009, p.3-4, 1, 12).

1. Each measure (individual measure, or portfolio) is able to cope with a certain level of water level rise until it ceases to be effective – such level represents a *threshold* in terms of water level (and in time). When a threshold is reached, a new measure is required. Figure 18 shows various measures (*interventions*) that can be used when a threshold is reached, under the 'best estimate' scenario (HM Treasury 2009, p.24). To develop a pathway (HLO), the Team investigated ***when*** measures will be required (EA 2012, p.34), i.e., the moment when a given measure reaches a threshold and a new measure is needed in different scenarios, and what alternative measures were available. In this way, various *pathways* were progressively developed and refined. Each HLO contains various measures (*interventions*) implemented over time; the *route-map* shows when a measure starts, and when it ceases to be effective (and a new measure is required) (EA 2012, p.38). Thus, the identification of thresholds (limits) in the existing FRM system informed the development of pathways, e.g.: the modification of the TB can only cope with a certain level of SLR which represents a threshold (TE2100 Appendix L 2009, p.3-5, 10).
   The measures used to develop the HLOs were based on FRM policies allocated to different policy units; thus, the HLOs were developed to deliver such policies (London Councils' TEC 2007, p.3-4). A HLO (later named *Option*) is made up of various *interventions* (measures) sequenced and implemented in a staged way that act together to achieve the recommended policies and provide an overall FRM solution over the century (EA 2012, p.34, 38). Ultimately, a HLO is a *schedule*, a sequence of measures implemented for particular time periods as a response to specific thresholds reached in the water levels; and such sequence provides a general solution to tackle water level rise over time (HM Treasury 2009, p.24).

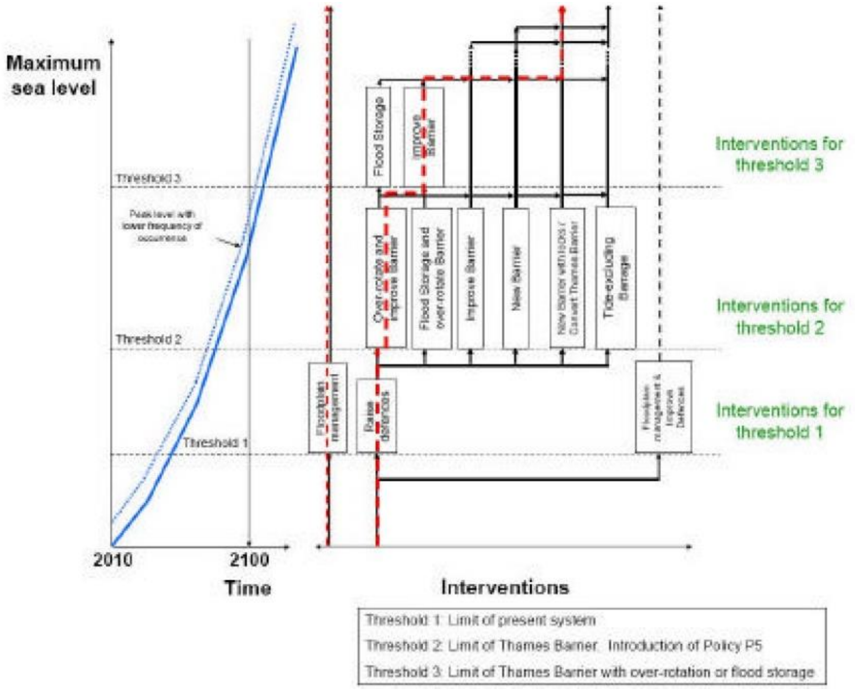


Figure 18. Thresholds and possible *interventions* (measures) available to cope with them, under a 'best estimate' scenario. The *interventions* are shown in the vertical boxes. Threshold 1 corresponds to a limit of the existent flood defence system (expected around 2030 / 2040, in this scenario); threshold 2 corresponds to a limit to the TB (expected around 2070); Threshold 3 represents a limit to the TB rotated or with flood storage (expected after 2100).The red dashed lines represent two possible pathways (HLOs) (HM Treasury 2009, p.25).

Several scenarios were used *to determine the* (moment of) *thresholds when interventions are needed to keep the flood probability within the acceptable limits* (Ramsbottom and Sheppard 2017, p.5).

2. The development of the HLOs entailed sequencing and assembling the various measures into possible pathways (routes) over time: when a measure reaches a threshold level, another measure is needed, and a pathway emerges (TE2100 Appendix L 2009, p.3-4, 1, 12). Thus, each HLO can be deemed a pathway of measures to cope with thresholds over time (Reeder and Ranger 2011, p.6).

   To assemble and design the pathways (HLOs), it was necessary to sequence measures (individual or portfolios) to manage flood risk over time. This implied analysing when each measure will reach a threshold (the maximum acceptable flood probability) and another measure is needed (Ramsbottom and Sheppard 2017, p.4). Thus, the measures identified in Step 2a were used to assemble various pathways (HLOs) (HM Treasury 2009, p.23; Ramsbottom and Sheppard 2017, p.6). By sequencing the measures previously identified, it was possible to assemble and design various pathways (ibid). The measures identified were used to create *'strategic packages'* that are able to deal with different levels of water level rise over time, i.e. to assemble various pathways (HLOs) (HM Treasury 2009, p.23). The HLOs designed were represented in a *route-map* (Figure 19 left).

3. Furthermore, four scenarios were illustrated in the *route-map* to see which HLOs were able to deal with which scenario (HM Treasury 2009, p.23-24) (Figure 19 right). Then, the suitability of each pathway (HLO) was tested under different scenarios, to assess its robustness (Reeder and Ranger 2011, p.9; Jeuken and Reeder 2011, p.4). The Team developed methods to test the measures and pathways (HLOs) under different climate scenarios, to analyse how effective these pathways will be and whether it will be necessary to change them if water level rises beyond the then-current predictions (EA 2012, p.27). The diverse HLOs (and their variations) were further developed and tested on their effectiveness and efficacy in delivering the *strategic vision* (EA 2012, p.35, 56).

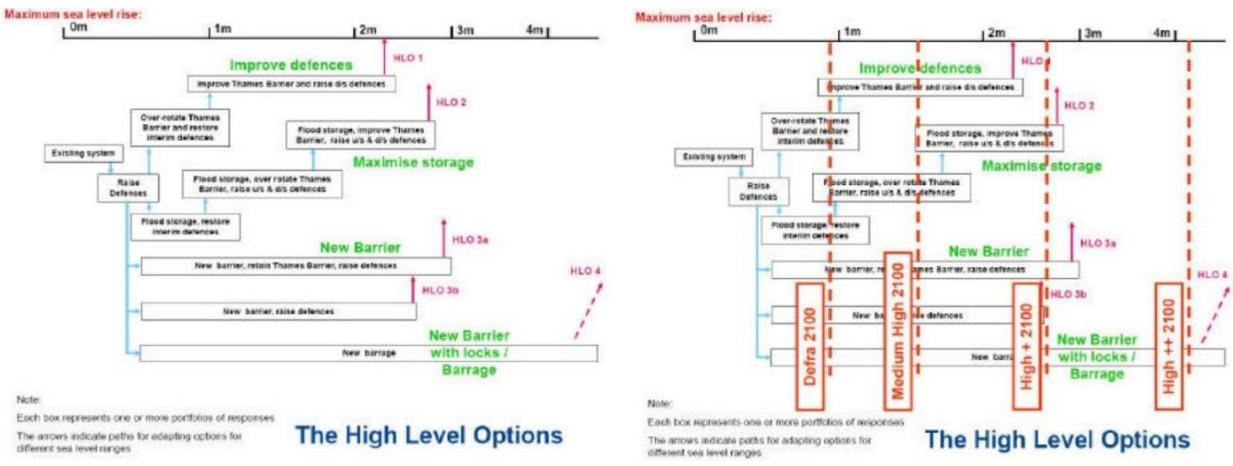


Figure 19 left. The HLOs to manage tidal flood risk. Source: HM Treasury 2009, p.23-24. Each HLO is a pathway; each box is a measure (individual or *portfolio*); the blue arrow is a path to adopt a new measure (and adapt to a different level of SLR). Each HLO can cope with a certain level of SLR, e.g.: HLO1 can cope with a 2,3m rise; HLO2 and 3 can cope with slightly higher levels of SLR; HLO4 is the ultimate solution to cope with a 4,2m rise. **Figure 19 right**. The HLOs against four different scenarios of water level rise considered. All HLOs can cope with the water levels expected in the '*Defra central*' and '*Medium High'* scenarios; HLO 2, 3a and 4 can cope with the *High+*, but only HLO4 can cope with the initial *High++*.

Each HLO contains various measures implemented in sequence. HLO 1 involves improving the existing flood defence system, namely the TB. HLO2 involves maximising flood storage in the floodplain. HLO3 involves constructing a new barrier (a gated opened structure, only closed during floods). HLO4 involves the construction of a new tidal barrage (partially or fully closing the river, changing its tidal characteristics) or a barrier with locks (TE2100 Appendix L 2009, p.4; HM Treasury 2009, p.23, 24; London Councils' TEC 2007, p.4; Jeuken and Reeder 2011, p.6; Ranger et al. 2013, p.250; Ramsbottom and Sheppard 2017, p.10).

In sum, the Team developed various possible pathways (HLOs) to manage flood risk, and progressively tested and refined them (EA 2012, p.32-33). On their whole, the HLOs were designed to span the estimated plausible range of increases in water levels in the TE until 2100 (up to 4,2m) (Reeder and Ranger 2011, p.8; Ranger et al. 2013, p.250; Jeuken and Reeder 2011, p.4; Bloemen et al. 2018, p.7).

Step 2b resulted in a series of adaptation pathways that are *'appropriate to cope with the plausible range of climatic changes that could be seen by 2100*' (Reeder and Ranger 2011, p.5), and that can be adapted to changes and uncertain future conditions (TE2100 Appendix L 2009, p.3-4, 1, 12). The various pathways keep risk below acceptable levels while maintaining flexibility, and 'flexibility', here, means keeping open options (alternatives) to manage future risk (Ranger et al. 2013, p.233, 239, 258, 249). Importantly, the development of the HLOs involved a large study programme and ongoing dialogue with stakeholders to grasp issues critical to their elaboration and assessment (Lowe et al. 2009, p.87).[34]

Detailed *Options* for appraisal

Then, the Team further developed and refined the HLOs into detailed *Options* for appraisal, under the *Defra06-central* scenario (the *most likely* scenario based on 2010 Government climate guidance). Assuming this scenario, and based on the HLOs, the Team developed four generic *Options* (TE2100 Appendix L 2009, p.4; Ramsbottom and Sheppard 2017, p.9, 11; Jeuken et al. 2014, p.6) – so-called *Estuary-wide Options*[35] (London Councils' TEC 2007, p.4) (Note 115).

The Team designed four *Estuary-wide Options* (pathways) to manage and reduce flood risk throughout this century (EA 2012, p.30, 6) and deliver the TE2100's *strategic vision* (the FRM objectives), though the *Options* vary in the way of delivering it (EA 2012, p.35, 56) (Table 4). Subsequently, these *Options* (pathways) were appraised (in Step 2c). These Options are presented in the Plan (EA 2012, p.59-65).

The *Estuary-wide Options* (and the former HLOs) were designed to achieve the FRM policies (an *option* is a pathway made up of several interventions sequenced and implemented over time that act together to achieve the recommended policy) (EA 2012, p.30, 34). The *Options* presented in the Plan contain mostly measures to provide a higher SoP, but also measures to 'do minimum' and measures to reduce the SoP (e.g. managed realignment in the lower TE) (Ramsbottom and Sheppard 2017, p.11, 18).

Importantly, although these *Options* were developed under the *Defra06 central* scenario (deemed the *most likely* scenario), they are adaptable if greater rates of change are experienced, and the way in which they can be adapted is explained in the Plan (TE2100 Appendix L 2009, p.4). These Options should be able to deal with the range of changes in water level expected during the Plan's life and adaptable to more severe conditions that may happen (Ramsbottom and Sheppard 2017, p.5).

---

[34] The HLOs were elaborated in 2007, and subjected to extensive online stakeholder consultation, which helped to refine them (Reeder and Ranger 2011, p.9; London Councils TEC 2007). Stakeholder involvement, and the results of the research undertaken on climate change, were crucial to refine the HLOs, namely to: show that the Project was using the right range of plausible water levels for this century; revise the H++ scenario (from 4,2m to 2,7m) and recognise that, under this revised H++, it is less likely that a new tide-excluding outer barrage will be needed in this century (Lowe et al. 2009, p.89, 90; Met Office 2012), thus, this measure was removed from the *Options* considered (EA 2012, p.28). After some investigation and appraisal, and the 2005 consultation, some options were excluded (EA 2012, p.33).

[35] The *estuary-wide Options* are based on the HLOs that were further developed and detailed assuming the *Defra06* scenario (the *most likely* scenario) (TE2100 Appendix L 2009, p.4; Ramsbottom and Sheppard 2017, p.6, 9, 11). (see Note 115). These *Options* were derived from (and correspond) to the HLOs developed in Step 2b, which were refined for the *Defra06* scenario. The HLOs were further developed into generic, *estuary-wide options* (EA 2012, p.35). These *Options* are *tangible ways of delivering the assigned policies* with different costs and levels of complexity (Penning-Rowsell et al. 2013), they also consider other objectives of the TE2100 beyond FRM, e.g.: the need to maintain the existing defence system, habitat requirements, amenity and landscape needs, links with riverside developments, etc. (Ramsbottom and Sheppard 2017, p.11, 9). These *Options* (presented in the *Draft Plan*) were derived from the HLOs and detailed assuming a 0,9m rise by 2100; under this scenario, it will not be necessary to build a new barrier, or rebuild the TB, until 2070 (Jeuken et al. 2014, p.6).

Estuary-wide Options*, also called *Options	
Option / pathway	**Description (see Note 115 for a detailed explanation)**
DM	Do minimum
1.1	Improve the existing defences, minimum maintenance, no adaptation * (i.e. raise defences when needed)
1.2	Improve the existing defences, minimum maintenance, with adaptation * (i.e. allow for future adaptation of defences)
1.3	Improve the existing defences, optimize maintenance, no adaptation *. (i.e. raise defences when they are replaced; optimise the balance between defence repair and replacement)
1.4	Improve the existing defences, optimize maintenance, with adaptation * (i.e. optimize defence repair and replacement, and allow for future adaptation of defences)
2	Best of option 1 group, with tidal flood storage from 2070 (store tidal waters to reduce flood levels; 4 potential sites)
3.1	Best of option 1 group, with new barrier at Tilbury from 2070 **
3.2	Best of option 1 group, with new barrier in Long-Reach from 2070 **
4.1	Best of option 1 group, with new barrier with locks at Tilbury from 2070
4.2	Best of option 1 group, with new barrier with locks at Long-Reach from 2070
4.3	Best of option 1 group, with converting existing Thames Barrier to barrier with locks from 2070 ***

Table 4. The *estuary-wide Options* (and their variations). These are the *Options* (pathways) that were appraised in Step 2c. Source: based on Penning-Roswell et al. 2013, p.1389; Ranger et al. 2013, p.251; EA 2012, p.35, 57-58. E.g. Option 1.4 involves: improving the existing defence system (optimised maintenance and enhancement of the system), with modifications to the TB in 2070, and adapting it to become a barrier with locks after 2135; Option 3.2 involves: the best of option 1 group until 2070, building a new barrier at Long Reach by 2070, and converting it a barrier with locks or open barrage after 2135 (EA 2012, p.47, 49).

* Adaptation means *frontloading*, provision for works that may be needed later, e.g. foundations suitable for raising defences in the future.
** Designed to resist the highest surge tide predicted under the 2009 Government climate guidance.
*** Convert Thames Barrier to a barrier with locks when the limit of closures per year is reached.

Step 2c: Appraising the *Options* (pathways) and ranking them

In this step, the *Options* (the pathways previously detailed) were appraised in several studies. The Team assessed all *Options* in a *Formal Options Appraisal* and in a *Strategic Environmental Assessment* (EA 2012, p.40; Ranger et al. 2013, p. 237, 239; Ramsbottom and Sheppard 2017, p.11; Bloemen et al.2018, p.8). Two main methods were used to assess what were the best Options (*the best course of action*): a *Formal Options Appraisal* including (economic) cost-benefit analysis and multi-criteria analysis, and a *Strategic Environmental Assessment* (SEA). These methods were used to assess costs, benefits (and cost-benefit ratio) and impacts that each Option might have in the future and compare the Options on these aspects (EA 2012, p.46-48).[36] (Note 116).

In the Formal Options Appraisal, the *Options* (pathways) were assessed in a cost-benefit analysis (CBA) and a multi-criteria analysis (MCA)[37] (Penning-Rowsell et al. 2013, p.1386-1387; Ranger et al. 2013, p.243, 251; Reeder and Ranger 2011, p.6; HM Treasury 2009, p.25; Bloemen et al. 2018, p.7; Ramsbottom and Sheppard 2017, p.11). The appraisal is reported by Penning-Rowsell et al. (2013). The *Options* that were appraised (Table 4) are similar to the four HLOs but with refinements (Ranger et al. 2013, p.251; Penning-Roswell et al. 2013, p.1389). The *Options* were assessed on their costs, benefits and impacts, under various scenarios, and also through societal valuation (Penning-Rowsell et al. 2013, p.1386; Ranger et al. 2013, p.243; Ramsbottom and Sheppard 2017, p.9).

The method of appraising Options implied:

---

[36] The TE2100 Project involved a CBA, MCA, SEA, detailed risk modelling, engineering analyses and stakeholder consultation (Ranger et al. 2013, p.237, 239). These methods were essential to ensure that the proposed Options were feasible and adequate according to technical, economic, environmental and social criteria (Ramsbottom and Sheppard 2017, p.16). The SEA was legally required, to evaluate the potential effects of the Plan before it was approved, propose alternatives to measures with detrimental effects and mitigation measures (EA 2012, p.46).

[37] The CBA and MCA methods used in the *Formal Options appraisal* were consistent with the EA's *Flood and Coastal Risk Management Appraisal Guidance* (FCRM-AG) (EA 2012, p.46; Ranger et al. 2013, p.251). MCA was, in part, a novelty for a large-scale plan as the TE2100, though the method was piloted by the EA in 2008 and adopted in the FCRM-AG (Penning-Rowsell et al. 2013, p.1388). Other methods may be used, e.g. cost-efficiency analysis. The appraisal was similar to a *Real Options Analysis* (Reeder and Ranger 2011).

1) the estimation of the cost of the different *Options* (including capital, maintenance and GHG costs);
2) the estimation of benefits of *Options* in terms of avoidance of flood damages to property and business, prevention of risk to life and losses, other economic, environmental and social benefits;
3) the estimation, in the MCA, of economic, social, environmental, and technical impacts of Options[38];
4) the comparison (weighting) of *Options* (based on costs, benefits, and impacts previously calculated).
5) the elaboration of recommendations for the choice of Options based on the benefits-cost ratio (Penning-Rowsell et al. 2013, p.1387, 1395) (see more in Note 117).

Although the 'value-for-money' (cost-benefit ratio) was a central aspect to the Project, though the Plan should satisfy economic, social, and environmental objectives that were addressed in the MCA and SEA (Ranger et al. 2013, p.239).[39] The measures should deliver an adequate level of flood risk reduction at the best cost-benefit ratio, but also environmental and social benefits (London Councils' TEC 2007).

In this appraisal, the *Options* were assessed under different future scenarios: first, the *Options* were appraised on their costs and benefits (CBA) and on their impacts (MCA) under the *Defra06 central* scenario (*most likely*), and then, the results of the CBA and MCA were tested under other climate and socioeconomic scenarios (i.e. the prior steps were repeated under different scenarios).[40] Subsequently, the *Options* were ranked under two climate scenarios (the *Defra06 central* and the High+), and two socioeconomic scenarios (A and B) (Penning-Rowsell et al. 2013, p.1392, 1400; Ranger et al. 2013, p.243; Reeder and Ranger 2011, p.6; HM Treasury 2009, p.25). Figure 20 shows the ranking of *Options*.

Climate change: Socio-economic change:	Defra Central	High Plus Central	Defra Scenario A	Defra Scenario D
	Option	Option	Option	Option
1st	3.2	3.1	1.4	3.2
2nd	1.4	3.2	3.2	1.4
3rd	3.1	4.2	3.1	3.1
4th	2	2	2	2
5th	4.2	1.4	4.2	4.2
6th	4.3	4.3	4.3	4.3
7th	4.1	4.1	4.1	4.1
8th	DM	DM	DM	DM
Residual property damage (top-ranking Option)	£1,257m	£3,517m	£1,591m	£1,524m

Figure 20. Ranking of *Options* (pathways) under different climate and socioeconomic scenarios. In the right two columns, socioeconomic scenarios are combined with the Defra climate scenario. Source: Penning-Roswell et al. 2013, p.1402. In the Defra06 central scenario, Option 3.2 is the preferred option followed by 1.4; in the High+, there is a preference for 3.1 and 3.2. In socioeconomic scenario A and D, the top options are Option 1.4 and 3.2, showing that these options are robust in appraisal terms.

The main results of the Options' appraisal were the following:

- Continuing to protect the TE from tidal flood risk and the sea is highly cost-beneficial (Penning-Rowsell et al. 2013, p.1383, 1403; Ranger et al. 2013, p.252), regardless of the scenario that occurs.[41]
- The '*front-runner' Options* suggested by the appraisal (the 'top-two' pathways) are: Option 3.2 (which involves improving the existing flood defence system and building a new barrier at Long Reach by 2070) and Option 1.4 (which involves improving the existing defence system and

[38] The categories of impacts considered in the MCA were: economic impacts on property, key-infrastructures, agricultural land use, navigation, transport, indirect impacts on business; environmental impacts on habitats, biodiversity, water quality and quantity, natural processes, landscape, historical environment; social impacts on recreation, safety, security (risk to life), sense of community; and technical impacts (technical risk) (EA2012, p.46; Penning-Roswell et al. 2013, p.1391). Thus, the Options appraisal considered both monetized factors (e.g. property at risk, risk to life, technical risk) and non-monetized factors (e.g. recreation, habitats, biodiversity) (Ranger et al. 2013, p.251).

[39] The *value-for-money* (economic efficiency and cost-benefit of Options) was imperative in the Options Appraisal as large amounts of public money will be used to continue to protect London from flood risk. The appraisal focused on examining the economic efficiency of long-term measures within the Options. The Options were also subjected to broad public consultation, which helped identify social and environmental concerns. Time was also relevant: different results arose for 2050 and 2100 (Penning-Rowsell et al. 2013, p.1386).

[40] The use of scenarios means that the date of implementation of a measure can be anticipated/delayed in time, though the measure is the same.

[41] This is the case for many urbanized estuaries worldwide, which are too valuable not to provide them a high standard of flood protection, regardless of how expensive this is; the economic justification for such protection becomes stronger with SLR (Penning Rowsell et al. 2013).

enhancing the TB by 2070). These two options ranked high under various scenarios. Until 2050, all *Options* involve improving the existing defence system, and Option 1.4 is the most cost-effective way of doing this. These results reflect the 2010-view of the *preferred Options*, but the TE2100 Plan is *designed to be kept under review and adapted as necessary in response to monitored change* (Penning-Rowsell et al. 2013, p.1401-1402, 1383). The benefit 'reduction of property damages' is similar in all Options because they have to meet the same FRM policies. The main factors that differentiate benefit-cost performance of Options were the cost, other benefits for transport and infrastructure, and impacts in water (ibid).

- Given the high standard of protection already existent in the TE, and the robustness of the existing defences, new major interventions (measures) are expected to be needed around 2070. Meanwhile, there will be time to monitor the situation, to carefully plan the measures for the mid- and long-term (instead of rushing into the construction of new engineering works without properly anticipating what is needed to manage flood risk in the future), and to implement measures in the short-term (e.g. measures to improve existing defences and limit the increase in flood risk). This is in line with the adaptive approach to FRM of the TE2100 (Penning Rowsell et al. 2013, p.1383, 1403). Before the TE2100 started, there was a concern that new defences would be required much earlier than 2070.
- The measure '*improving existing flood defences*' can cost-effectively 'buy time' before it is necessary to make a more 'irreversible' decision on the measure for the long-term (e.g. a 'new barrier') (Ranger et al. 2013, p.255; Reeder and Ranger 2011, p.11). Indeed, applying 'no-regrets' measures first is a cost-effective way of 'buying-time' before making 'more irreversible' decisions; it offers time to monitor, acquire new knowledge, learn, and make better decisions (ibid).
- The year 2050 represents a critical point in time: until then, it is necessary to implement measures to sustain the high standard of protection provided by the existing FRM system, and to make decisions on the measures that will be needed later (in the longer-term) and which should be operational around 2070 (based on Defra06 scenario) (Penning-Rowsell et al. 2013, p.1387).

In sum, in Step 2c, the Team appraised the *Options* (on their cost, benefits and impacts), and identified the *most promising Options* (EA 2012, p.32-33, 30, 6). The Formal Options appraisal allowed the identification of the *front-runner Options* for managing flood risk in the future, i.e. 'top', preferable pathways, under different scenarios (Penning-Rowsell et al. 2013, p.1383). Based on the whole appraisal, Penning-Rowsell et al. recommended *Option 1.4* until 2050. However, this Option was incorporated in the proposed post-2050 actions (Penning-Rowsell et al. 2013, p.1395).

BOX 2. Results of the 'Formal Options Appraisal' and 'SEA'

Each *Option* (pathway) was appraised on its costs, benefits and impacts in the Formal Options Appraisal, and on environmental impacts and compliance with environmental legislation in the SEA (EA 2012, p.6, 30).

The *Formal Options Appraisal* (including the CBA and MCA) allowed the identification of two *front-runner options*:

- **Option 1.4** (improving the existing defence system) involves: optimised maintenance and enhancement of the existing defence system; making modifications to the TB by 2070; and further adapting it to become a barrier with locks after 2135). This entails: the continuation of defence improvements, with a major improvement to the TB in 2070; optimising defence repair and replacement and allowing for adaptation to future change (EA 2012, p. 49, 47, 56). This Option requires *maintenance and improvement works* in the flood defence system until the point when a major intervention will be needed (estimated in 2070) (Ramsbottom and Sheppard 2017, p.11).
- **Option 3.2** involves: the best of Option 1 group until 2070 (i.e. maintenance and enhancement of existing defence system), and constructing a new barrier at Long Reach by 2050 (to be operating by 2070), and converting it a barrier with locks or open barrage after 2135 (EA 2012, p.47, 30, 56).

For the period until 2070, the measure '*maintenance and enhancement of the existing system'* (within Option1.4) was largely preferred, regardless of the 'end-of century' measure chosen thereafter. Thus, it is recommended in the Plan (EA 2012, p.47). Option 1.4. '*maintenance and enhancement of the existing system'* is the recommended option for the pre-2070 (EA 2012, p.49). For the post-2070, the Appraisal suggested *Option 1.4* and *Option 3.2* as front-runner options for the end of the century (Option *3.2* might be better by a small margin). However, given the uncertainty about the long-term future, and the absence of an immediate need to decide on the 'end-of-the-century' option, such decision will only be made in the 2050 Plan review (EA 2012, p.49). The Plan (2012 version) does not prescribe a single 'end of the century' option (EA 2012, p.47).

The **SEA** showed that the environmentally preferred option both for the pre-2070 and post-2070 period is *Option 1.4*, because *Option 3.2* is likely to infringe environmental legislation (EA 2012, p.49).

STEP 3: DECIDING ON THE PLAN, AND DEFINING THE MONITORING AND REVIEW SYSTEM

Step 3a1: Choosing the 'preferred options' (preferred pathways), i.e. *deciding on the Plan*

Drawing on the results of the Options appraisal, the Team selected the 'preferred Option' (pathway). The Plan recommends the following pathway (*Option*):

- **For the first 60 years of the Plan (2010-2069)**, the measure '*maintaining and improving the existing flood defence system*', which is part of *Option 1.4,* is deemed the best / optimal solution (EA 2012, p.35, 56, 58). For this period, the recommended measure to manage flood risk in the TE is '*improving the existing flood defence system*' (within *Option 1.4*) (EA 2012, p.56). The measure '*maintaining and improving the existing flood defence system*' (within Option 1.4) is recommended as the optimal solution for the first 60 years of the Plan (EA 2012, p.35). The appraisal showed that *Option 1.4* is the optimal approach for the first 60 years of the Plan, under the scenario expected (EA 2012, p.58) (the *Defra06 central* scenario, the *most likely* according to 2010 Government's guidance on climate change). A detailed programme was made for the first 40 years based on *Option 1.4* (EA 2012, p.56).
- Under the scenario expected in the 2010 Government climate guidance**, by 2070**, a new **measure** to manage flood risk up to the end of the century will be needed; such measure for the 'end of the century' (denominated '*end-of-the-century option*'[42]) must be in place by 2070, and its design and construction take time, thus, a decision about it must be made around 2050. Until 2050, all the four *Estuary-wide Options* (pathways) will remain under consideration (EA 2012, p.35).
  From 2070 onwards, it is expected that different solution / way to manage flood risk until the end of the century will be required, due to rising sea level (EA 2012, p.56). By 2070, a new measure (and related arrangements) will be necessary to manage flood risk up to 2100 and into the 22nd century (based on the scenario expected in 2010 Government climate guidance) (EA 2012, p.35, 41). In 2009, the Options Appraisal identified two 'front-runner' options for the post-2070 period: Option 1.4 (which involves *continuing the defence improvements*, and a *major improvement to the TB*), or Option 3.2 (which involves a *new barrier at Long Reach*) (EA 2012, p.56, 58). Nevertheless, given the uncertainty about future conditions, all the *Estuary-wide Options* (pathways) remain candidates for appraisal in future reviews of the Plan (e.g. the 2050 review) (EA 2012, p.56, 58). The design and construction of major measure for the 'end-of-the-century' will require a lead-time; considering this, and based on the scenario expected, it is estimated that a decision (choice) on the preferred 'end-of-the-century' measure must be made around 2050, so that it can be designed and constructed, and be ready for use in 2070 (EA 2012, p.56, 35). At that moment (2050), all the *Estuary-wide Options* (pathways) will be under consideration (EA 2012, p.35)[43] (Note 118). In sum, it is expected that a major measure / intervention in the system will be needed by 2070, and there are two 'front-runners': a major upgrade of the TB (within Option 1.4 / HLO1), or a new barrier at Long Reach (within Option 3.2 / HLO3a). Such major measure will be required in 2070, and its design and construction should start in 2050; but these dates may change if the SLR rate differs from the projection assumed in the Plan (Ramsbottom and Sheppard 2017, p.11).

Though the climatic and other conditions might change until the 2050 review of the Plan, the Team had a greater level of certainty about the FRM requirements for the first 40 years, hence, it prepared a detailed investment program up to 2049 and a *high-level* program for 2050-2100 (EA 2012, p.56). It is

[42] The Plan refers to 'end-of-the-century options' as pathways that may be implemented in the long-term future, i.e. after 2070 and up to 2100, and beyond. Here, the term 'option' is used interchangeably: it can mean either a measure for the long-term, or a possible long-term pathway.
[43] The *end-of-the-century* measure will entail a lead-time to plan, design and construct; given this, it is estimated that the decision on such measure must be made around 2050 (in the scenario expected). The work on the end-of-the-century measure must start in advance of 2070, it is estimated that by 2050, this measure must start to be planned, designed, and constructed (EA 2012, p.9, 35, 41).

expected that major changes or interventions in the existing flood defence system will not be necessary until 2070; and that the TB, with some modifications, will continue to provide flood protection up to 2070 (EA 2012, p.32, 5).[44] Despite that, it is necessary to maintain the high standards of operation and maintenance of, and also improve, the existing defence system. Substantial improvements in the existing system will be needed before 2070 (e.g. *raising the crest level of most of the flood defences*, and *replacing a large proportion of the defence structures as they reach the end of their lives*), thus, the Plan contains a programme of continual maintenance and improvement works needed in first 40 years (EA 2012, p.32). Regardless of the measure chosen for the 'end of century', until 2070 it will be necessary to raise defences upriver and downriver of the TB (Ramsbottom and Sheppard 2017, p.11).

Importantly, the *Options* (pathways) presented in the TE2100 Plan, particularly the measures for the end of the century indicated in the long-term programme (called 'end-of-the-century options'), are based on the *Estuary-wide Options* that performed best in the Options Appraisal, however, over the next 50 years, changes in climate or other factors might suggest another option for the long-term. The decision on the 'end-of-the-century' measure will be taken in the 2050 review of the Plan (according to the scenario expected) (EA 2012, p.41). Although two 'front-runner' options emerged in the appraisal as appropriate for the long-term, the decision on the 'end-of-the-century option' will only be made by 2050, and implemented between 2050 and 2070 (under the scenario expected). The Plan's recommendations are based on the results of the 2009 Options Appraisal, but the final decision on the 'end-of-the-century' option is expected to be made in the 2050 review of the Plan, and, in the meantime, Plan's reviews will be carried out (every 10 years, or more frequently), and in each review there will be further consultation on the 'end-of-the-century option' (the Team will assess if the 'end-of-the-century option' preferred in the 2012 Plan needs to be changed) (EA 2012, p.72-73).[45]

The TE2100 Plan (2012 version) defined the *Options* (pathways) assuming the *Defra06* scenario (*most likely* scenario), but it is *flexible and adaptable* to change and uncertain future: the Team sought to ensure that options were not limited if the future evolves in different ways than expected when the Plan was developed (TE2100 Appendix L 2009, p.4). The plan was developed to be adaptable to a maximum 2,7m rise in water levels (in line with the High+ scenario) (EA 2016, p.18). Though the pathway that is being currently followed was designed based on the *Defra06* scenario, the choice of the option / pathway for the long-term will depend on the rate of SLR observed (London Councils 2018).

All in all, the Plan is a strategy to manage tidal flood risk throughout this century, which provides two main alternative measures for the long-term future: upgrade the TB (within Option 1.4), or, replace it with a new barrier (within Option 3.2) (Ranger et al. 2013, p.237). Given the uncertainty about future changes and conditions, it would be risky to commit to one pathway based on the current best projection. Considering this uncertainty, the scale of the investments required in 2050, and the long lead-times for implementation of some measures, it will be essential to monitor the situation and carefully plan the measures needed in the mid- / long-term (Ranger et al. 2013, p.252). Until 2050, all the four *Options* (pathways) will be considered; a decision between them only needs to be made in the future, and, then, there will be more knowledge (monitoring and advancements in SLR modelling) (ibid).

[44] Investigations during the Project showed that: the capacity of the 2002-existing flood defence system (including the TB and other defences) was greater than initially thought, and a major change / intervention to the system, will not be needed until 2070 (under the scenario expected). It is expected that, by 2070, a major intervention in the system must be in place (EA 2012, p.5, 32). Many existing defences are expected to reach the end of their design life until 2070, e.g. the TB (which is expected to continue to provide its SoP – the highest in the country – until 2070). However, the maintenance of the TB must be continued to ensure its reliability and avoid greater future costs. Upstream defences and plans also need to be adapted to increasing water run-off from winter rains (Met Office 2012). The TB is expected to remain viable until 2070, and a project for replacing it, or a major intervention, should start by 2050 (Ranger et al. 2013, p.250).

[45] The EA will discuss the *end of the century options* with the Government and implementation partners. These options must be recognized in anticipation for planning purposes, even if later (in Plan's reviews) there is a preference for other options (EA 2012, p.72-73).

Step 3a2: Defining 'implementation plans' (i.e. *planning the implementation)*

The TE2100 Plan contains an Action Plan which lays down the actions necessary to manage flood risk over the next 100 years at the estuary-wide scale and at the local level (EA 2012, p.30, 41). It presents the recommended actions for a 'estuary-wide' zone (*Action Zone 0*), and for 8 local *Action Zones* (each zone contains various 'policy units' with similar characteristics and types of actions) (EA 2012, p.50). In specific, the Action Plan defines: *what* actions must be implemented per Action Zone (according to the FRM policy allocated to each policy unit), *when* to implement them, *who* will deliver these actions (*implementation partners*) and *how* this will be done (EA 2012, p.6, 35, 41, 50-55)[46]. Moreover, the Action Plan identifies the FRM policy recommended to each 'policy unit' within an Action Zone (EA 2012, p. 52-53) (Note 119). The Action Plan is phased, and the recommended actions are distributed, in 3 time-periods: short-term (first 25 years, 2010-2034); mid-term (middle 15 years, 2035-2049) and long-term (2050-2100) (EA 2012, p.6, 30).

Each time-period has specific objectives associated:

- **First 25 years (2010-2034): *maintaining confidence and planning together***. This involves continuing the maintenance, operation and improvement of flood defences, creating new habitats, safeguarding space for future FRM actions, working in partnership with others to reduce flood risk, inform the preparation and updating of local strategic plans and spatial plans.
- **Middle 15 years (2035-2049): *renewal and reshaping the riverside***. This involves raising or refurbishing or replacing many of existing defences (e.g. floodwalls, embankments, small barriers). These projects offer opportunities to reshape the riverside areas, which require working with spatial planners, designers, environmental groups, residents and workers in the TE.
- **Up to 2100 (2050-2100): *preparing for and moving into the 22nd century***. A major intervention in the flood defence system is estimated to be needed by 2070 (under the *most likely* scenario expected). This should be designed and constructed from 2050 onwards. The decision on the 'end-of-the-century' measure will be made in the 2050 review of the Plan, followed by its design and construction, so that it is in place by 2070 (EA 2012, p.40-41).

The following actions / activities are recommended (see more in Note 118):

- **For the first 25 years (2010-2034)**: continuing with the existent way of managing tidal flood risk which requires actively maintaining and improving the existing FRM system (including existing flood defences and flood preparedness plans). The TB, in particular, is expected to remain viable until 2070 (under the scenario expected), provided that its continual maintenance and improvement are ensured. Moreover, the implementation partners must work to guarantee that new spatial development is deployed away from flood risk areas and ensure the safety of those living in already vulnerable areas now and in the future. It is also necessary to increase *multi-agency floodplain management activities* and initiate an *intertidal habitat replacement programme* (EA 2012, p.29).
- **For the mid 15 years (2035-2049)**: a *major renewal and replacement of the Thames tidal flood defences*, and *continuing the floodplain management activities* and *intertidal habitat replacement*. In this period, there will be opportunities to renew and reshape the riverside, thus, the Plan recommends

[46] *What* actions are needed to achieve the FRM policy in each policy unit, and *when* these actions must be implemented (EA 2012, p.6, 35, 41, 50-55). The Action Plan was based on the prior steps (London Councils' TEC 2007). After the development of Options, it was necessary to downscale them to each policy unit (*Understanding the local issues*): various actions could be used to achieve the FRM objectives in each policy unit and, at the same time, meet the requirements of the *estuary-wide options* (EA 2012, p.36). The Action Plan defines the actions recommended to manage flood risk in the TE until 2100, based on the FRM policy allocated to each *policy unit* (London Councils' TEC 2007).

that the '*multi-agency riverside strategies developed in the first 25 years are updated to inform longer-term spatial planning and asset management decisions and investments'* (EA 2012, p.30).

- **For the long-term (2050-onwards**): around 2050 the Plan must be reviewed, and a decision must be made on the 'end of the century' option (according to the scenario expected in the 2010 government's climate guidance). The planning, design and construction of a major measure / intervention for the 'end of the century' must start in 2050 to guarantee that it is in place in 2070. In the 2009 Options Appraisal, the Team identified two 'front-runner' options for the long-term: Option 1.4 (which involves *upgrading and modifying existing flood defences and floodplain management* measures) or Option 3.2 (which involves *constructing a new barrier at Long Reach*). Nevertheless, the 'end of the century' measure may be different '*as a result of a Plan review and changed conditions'* that may arise over time (EA 2012, p.30).
- The creation of 876ha of intertidal habitat over the Plan's lifespan, to replace areas lost due to SRL. Five potential sites for habitat creation are identified on the maps of *Options* (EA 2012, p.30, 36, 60). The Action Plan recommends potential sites for habitat creation (EA 2012, p.6).
- The creation of a 'TE land strategy' to guarantee land for future FRM measures and bring together diverse 'strategic plans' and 'vision statements' existent across the TE (EA 2012, p.30).

Essentially, the **Action Plan** provides a detailed programme of works until 2049 (works for upgrading the existing flood defence system); and a programme for the post-2050 period which is based on the *Options* that performed best in the appraisal under the *most likely* scenario expected (EA 2012, p.41). The first 40-year investment plan outlines the actions to upgrade the existing flood defence system (Ranger et al. 2013, p.252), and it will guide the implementation of the actions recommended, even under more extreme scenarios that might arise (Reeder and Ranger 2011, p.10).

Through its Action Plan, the TE2100 Plan will steer future FRM actions, activities and investments in the TE, namely: works (and expenditure) to maintain and / or replace existing defences (i.e. 330 km of floodwalls, river-walls, embankments, flood barriers and gates), flood warning measures, floodplain management measures[47], or other actions to manage tidal flood risk in the Estuary (EA 2012, p.6).

Moreover, the Action Plan also serves to direct the actions required from multiple stakeholders (EA 2012, p.29). The Action Plan was designed to facilitate a *multi-partner approach* essential for the successful implementation of the TE2100 Plan; it is a '*multi-agency plan of actions*' that is adaptable to changes, which implies 'continued partnership working' of those involved in the planning and implementation of FRM measures across the TE (EA 2012, p.2, 30, 35). The *implementation partners* are e.g.: the EA, local planning authorities (e.g. London Councils and local Boroughs), local communities, landowners, *Natural England, English Heritage,* etc. (EA 2012, p.41; London Councils' TEC 2007; London Councils 2018)[48].

Therefore, the Action Plan provides key information to regional and local government authorities, in order to inform: their spatial plans and decisions on new spatial developments / re-developments in the floodplain; the work and expenditure of the partners responsible for spatial planning and asset management decisions (e.g. local councils and boroughs, *Resilience Planning Forum*s), recovery and blue-light services (EA 2012, p.30, 7).

[47] Floodplain management measures are measures to improve the resistance and resilience of properties, increase the reliance of flood warnings, and community flood management strategies (EA 2012, p.83).

[48] Local authorities are responsible for delivering the recommended actions for spatial planning and emergency procedures, *Natural England* and *English Heritage* are responsible for guidance and including the needs of habitats and heritage into the design of Options) (EA 2012, p.41).

Step 3b1: Specifying *decision-points*

The route-map was then used to examine when an important decision should be made and a measure should be implemented (Reeder and Ranger 2011), i.e. to identify *decision-points* and *implementation points* (Ranger et al. 2013, p.250).[49] A *decision-point* is a point at which a decision on a given measure must be made, which triggers its planning and construction (Ranger et al. 2013, p.252; Reeder and Ranger 2011). i.e. the point where a decision is taken to implement a measure (Ramsbottom and Sheppard 2017, p.12). A decision on measures must be made ahead of when such measures are needed (as some measures imply a lead-time of several years) (EA 2012, p.34).

The Plan explains how to estimate a *decision-point* for a given measure (Figure 21 left). It is necessary to: identify the threshold-value in an indicator (e.g. the water level) at which the measure will be needed[50]; analyse when such threshold occurs in a given scenario; then, add the lead-time required to design and construct such measure and also an 'uncertainty band' (e.g. about SLR rate). Moreover, it is necessary to consider the observed / recorded values in the indicator. In this way, *decision-point* can be estimated, and expressed as a value in the indicator (Ranger et al. 2013, p.252; Reeder and Ranger 2011; HM Treasury 2009, p.26; Lowe et al. 2009, p.90; Ramsbottom and Sheppard 2017, p.12). Hence, the decision-point is conditioned by the monitoring and observation of actual changes in the indicators (recorded values in the indicator, e.g. SLR) (Ranger et al. 2013, p.252; Reeder and Ranger 2011; HM Treasury 2009, p.26)[51], thus, the timing this decision-point may change depending on the monitoring results (Bloemen et al. 2018). In addition, the moment of a decision-point can be derived under different scenarios; hence, it is important to consider potential updates in projections / scenarios that might arise, which may require updating the lead-times or 'implementation points', and thus, the 'decision points' (Reeder and Ranger 2011; Ramsbottom and Sheppard 2017, p.12).

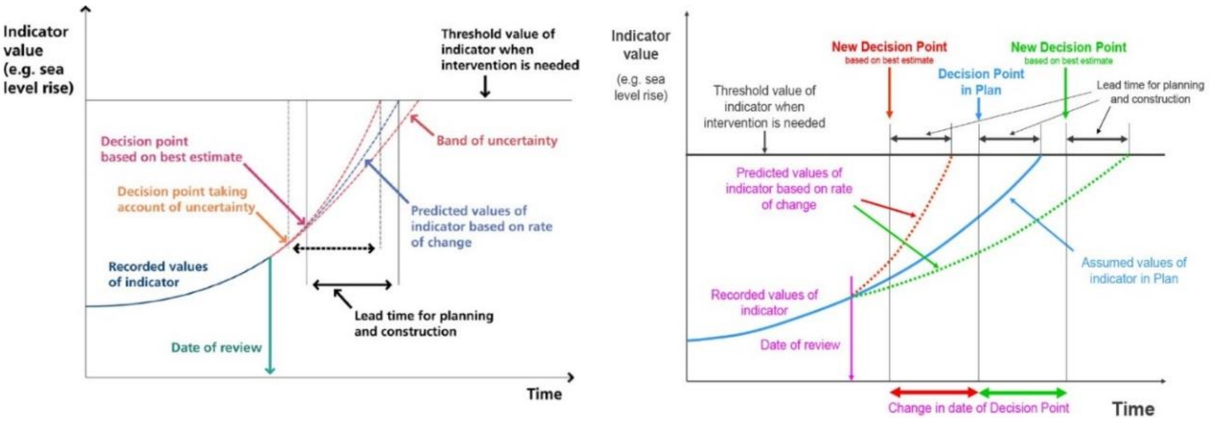


Figure 21 (left). Estimation of the 'decision-point' for a measure. Source: HM Treasury 2009; Ranger et al. 2013, p.252; Reeder and Ranger 2011. The decision-point is based on: the threshold-value in the indicator at which such measure is needed, the lead-time for such measure, the observed changes in the indicator (monitoring results), and the projected change in the indicator (e.g. when the threshold-value will be reached in the *most likely* scenario). **Figure 21 (right).** Effect of two different future SLR scenarios (than that used in the Plan) on the decision-point. The rate of change predicted in a new scenario may be faster (red) or slower (green) than the assumed by the Plan (blue). A faster rate will require bringing forward the decision-point, while a slower rate will delay it. Source: Ramsbottom and Sheppard 2017, p.12.

The way of estimating decision-points allows the update of the dates of a 'decision-point' and an 'implementation point' in case updated scenarios arise; thus, the prediction of how the indicator will

[49] Decisions should be made *ahead of when measures are needed*, and some will require a lead-time of several years or decades; therefore, the Team investigated the decision-points of some measures (EA 2012, p.34).

[50] For each indicator, it is defined threshold-value (a limit-value) at which a new measure will be necessary to keep risk below the acceptable level (e.g. 'the maximum acceptable flood risk') (Ramsbottom and Sheppard 2017, p.12).

[51] Rather than making decisions now that could prove 'inflexible', 'irreversible' or result in maladaptation.

change must inform the estimation of such points. If new scenarios emerge, and the date estimated for reaching a threshold-value changes, then it is necessary to update the date of the 'decision-point' (anticipate or delay it) (Figure 21 right). Furthermore, the results of the monitoring of the indictor (the observed change) must be used to update the date estimated for such point. If the date of a decision-point is altered, the Plan must be updated (Ramsbottom and Sheppard 2017, p.13). Hence, the moment for implementing a new action can be brought forward if the rate of SLR is faster than the projection that was used in the Plan (EA 2016) (see Note 120).

The TE2100 Plan indicates dates assumed for some important implementation-points and decision-points (Ramsbottom and Sheppard 2017, p.13). Under the *Defra06 central* scenario, the first important decision-point (which is related to the point at which the HLOs start to diverge) is expected in 2050: by then, a choice between *more irreversible* measures (e.g. a new barrage) will have to be made, but such decision will be supported by additional knowledge gained over time (Ranger et al. 2013, p.254; Reeder and Ranger 2011, p.10; HM Treasury 2009, p.26). However, if monitoring reveals that changes in the indicators are occurring faster or slower than predicted (in the *central* scenario used in the Plan), the decision-point may be *brought forward* or *put back,* to ensure that *decisions are made at the right time* and that the real 'cost-benefit ratio' of a measure is similar to that envisioned in the Options appraisal.

This method, with the route-map and decision-points, was devised to address possible changes observed in the indicators and potential updates in projections of future water level rise (Ranger et al. 2013, p.254). This required the definition of a monitoring and review system.

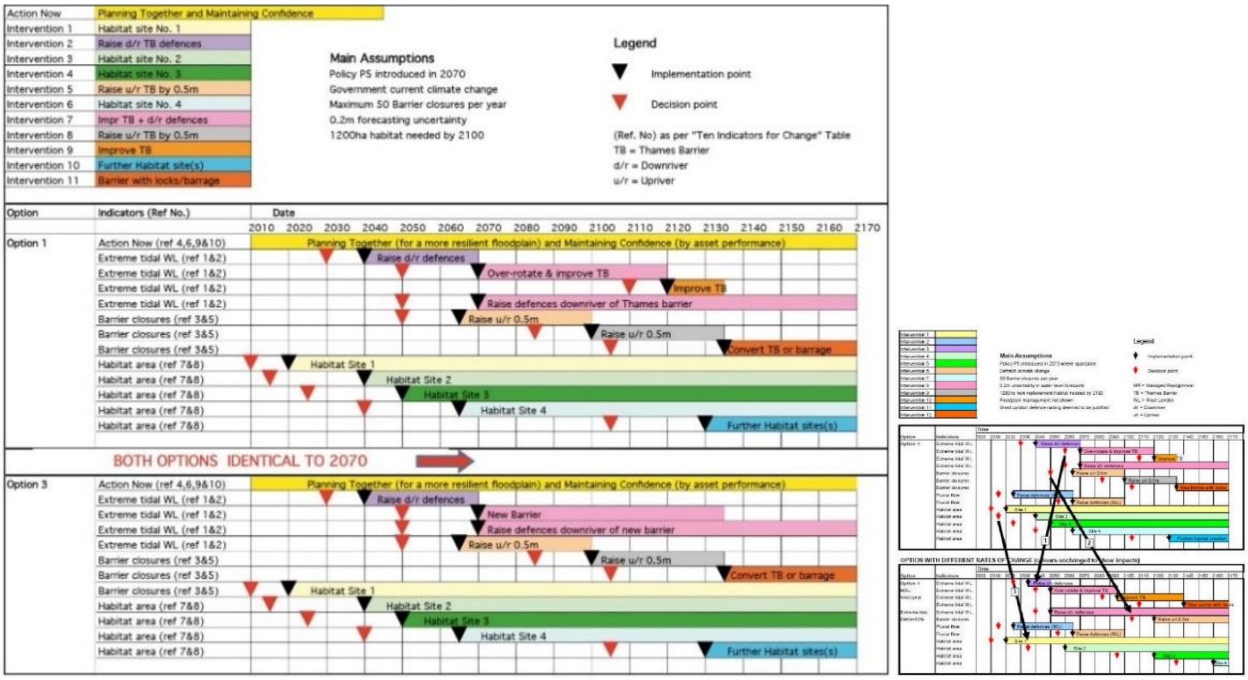


Figure 22 (left). Scheduling of two Options (pathways) – *Option 1* and *Option 3* – under the *most likely* scenario based on 2010 Government guidance. Each option contains several actions (measures) sequenced over time. Such actions are shown in the top-left corner and displayed in the horizontal bars. The bars show when an action starts, and when it ceases to be effective (and a new action is needed). The decision to take a new action must be made some years before its implementation: the 'decision date' and the 'implementation date' of each measure are represented with red and black arrows, respectively. The second left column shows monitored indicators (relevant for each action), which inform decisions over time. In this scenario, both Options can ensure FRM until 2100 and beyond it. These Options are similar between 2010 and 2070 but contain different actions from 2070 onwards (*improving existing defences*, or, *a new barrier*). The choice about the post-2070 action will be made the 2050 review of the Plan. Source: EA 2012, p.38. **Figure 22 (right).** Scheduling of *Option 1* under the *most likely* scenario showing how the implementation-point (black arrow) and decision-point (red arrow) of some measures may be altered as new data on the monitored indicators arises. If monitoring reveals that an indicator is changing faster or slower than expected, then the *implementation-point* and *decision-point* may be anticipated or delayed (bottom table). Source: HM Treasury 2009, p.27.

Step 3b2: Defining the monitoring and review programme

The Plan defines a monitoring programme, including 10 indicators of change (which affect tidal flood risk) to be monitored over lifespan of the Plan:

1) Mean sea level (mean sea level, mean tide levels in Tower Pier, SLR relative to land level);
2) Peak surge tide level and wave heights (e.g. the maximum water level resultant from tidal surge);
3) Peak river flows (combining tidal and fluvial flood risk, where tributaries meet the Estuary);
4) Condition of flood defence structures (e.g. integrity, performance, required repairs or renewals);
5) Frequency of closure and reliability of the TB and other barriers (due to floods);
6) Developed area, value and type of development, number of people and properties at risk;
7) Extent of erosion and accretion (areas threatened, impacts, effects of defences on such processes);
8) Intertidal habitat area (mudflats' and saltmarshes' area, compliance with EU habitats regulations);
9) Land-use planning, new urban developments, development activities (e.g. how well FRM and opportunities to create a *safer floodplain* are being *factored* into spatial development; changes in governmental policies; updated government guidance on climate change or scenarios; etc.);
10) Public / institutional attitudes on flood risk (appetite for flood-prone zones, *institutional preparedness*, emergency responsiveness) (EA 2012, p.30, 37; EA 2016; Ranger et al. 2013, p.233, 256; London Councils 2018; Ramsbottom and Sheppard 2017, p.12) (Note 121).

These indicators serve to monitor changes in the Estuary and its flood risk (EA 2016). Nevertheless, the monitoring system must monitor how the climate and flood risk are changing locally, which implies measuring local changes in key climate-related variables (e.g. rainfall patterns at the River catchment), but also monitor of global changes and climate change progress (the rate of climate change effects, e.g. polar ice-sheet melting), which implies ongoing observation and keeping track of *revised / updated future projections* and ongoing investment in climate science (predictive science) and services to support this (TE2100 Appendix L 2009; Lowe et al. 2009, p.85, 90; Met Office 2012).

Importantly, the success and effectiveness of the TE2100 Plan will strongly depend on: a process of continuous monitoring of local and global changes and conditions; but also of regular revaluation (reassessment) and review of the Plan, and adjustment as time unfolds (adapting the Plan and the physical system to changes early in time) (TE2100 Appendix L 2009, p.10; Ranger et al. 2013, p.254; Reeder and Ranger 2011; Lowe et al. 2009, p.85, 90; Met Office 2012). Therefore, it is also necessary to regularly review and update the Plan.

The Team recommended that the Plan is reviewed and updated every 10 years or more frequently (EA 2012, p.30). Periodic reviews (re-appraisals) of the Plan were set every 10 years at least (based on the monitoring of indicators) or more frequently if a substantial change happens in one or more indicators (EA 2012, p.30. 39; Ranger et al. 2013, p.254)[52], and a mid-term monitoring review must be undertaken every 5 years (TE2100 Appendix L 2009; Bloemen et al. 2018; Ramsbottom and Sheppard 2017, p.13; HM Treasury 2009, p.26-28; London Councils 2018). The results of the monitoring programme must inform the regular review and re-appraisal (and periodical update) of the Plan (EA 2012, p.36; TE2100 Appendix L 2009; Ranger et al. 2013, p.254; Bloemen et al. 2018; Ramsbottom and Sheppard 2017, p.13). The Plan sets up a major review for 2050 (EA 2012, p.30, 3, 41, 49, 56; Ranger et al. 2013, p.254).

In this way, the potential need of periodic updates of the adaptation pathways can be addressed (Bloemen et al. 2018). The monitoring results must be used to periodically update of the Plan, namely: the dates

[52] The TE2100 Plan must be regularly reassessed and reviewed (updated) every 10 years at least (based on the monitoring of the indicators), or more frequently if a significant change happens in one or more indicators (EA 2012, p.39, 30). Regular re-appraisals and reviews of the Plan must be conducted, and they must be informed by the results of the monitoring of indicators (EA 2012, p.36, 38).

when actions are needed, or if necessary, its pathways (Options), and / or their actions (Ramsbottom and Sheppard 2017, p.13).

The mid-term monitoring review process (every 5 years) assesses the changes (physical and socioeconomic) that are occurring in the Estuary over time, based on the 10 indicators. This monitoring review process is essential to evaluate if the FRM policies and recommendations defined in the Plan need to be adjusted. In specific, the monitoring and review serve to assess (based on the 10 indicators) whether the Estuary and flood risk are changing in a different way than what was expected in the Plan, whether the recommended actions remain the right choices or need to be revised, namely: if the timing of actions needs to be altered (whether the recommended actions need to be implemented earlier or later than expected), whether the type of actions recommended needs to be reviewed, and if the implemented actions are adequately managing flood risk (EA 2016, p.5).

Although the monitoring review occurs every 5 years, if the monitoring (in the interim period) reveals that a given indicator is changing faster (or slower) than what was expected, the 'implementation-point' and 'decision-point' of a measure may be anticipated (or postponed) (HM Treasury 2009, p.26-27; Ranger et al. 2013, p.254; Reeder and Ranger 2011, p.10). In practice, the decision-points and implementation points of measures (and the measures themselves, and the pathways) may be modified in light of new information that arises on indicators (HM Treasury 2009, p.27) (Figure 21).

There are various ways to address (deal with) changes, as these are monitored, or each time the TE2100 Plan is reviewed or updated.

- The reassessments / reviews of the Plan must be informed by the outputs of the monitoring of indicators. If a relevant change occurs in one or more indicators, it may be necessary to anticipate or postpone a measure. Certain values in the indicators will act as triggers of changes, e.g. a rapid change in an indicator may trigger an earlier decision). This is one of the ways through which the Plan can be adapted to changes that happen in the indicators. The pathway followed will result from a 'mix' of the best decisions taken at each time over the Plan's life (EA 2012, p.35, 36, 38-39).
- At each 5-year monitoring review and 10-year review, it is necessary to evaluate if a switch to another action (or pathway) is needed or recommended by new cost-benefit analysis, given the rate of change observed in the indicators (via monitoring) and in the light of new information (e.g. new scenarios). If SLR accelerates beyond expectations, it might be advisable to switch to a more 'interventionist' option (e.g. HLO4). Such a switch will be possible with no significant wasted investment in the early decades of the Plan. All the HLOs contain small incremental measures first and leave major irreversible investments as far as possible into the long-term (HM Treasury 2009, p.27-28).
- Thus, in each review, the chosen pathway may be changed, if the monitored indicators indicate so: if necessary, a pathway suitable for a higher or lower scenario may be taken, and the Plan adjusted (London Councils 2018). This helps to prevent that the Plan becomes obsolete during its lifetime.

The general way of updating the Plan will be to change the dates of a measure, and not the measure, but if a significant change occurs in the date when a threshold is expected to be reached, the choice between measures or between pathways (Options) may be reviewed, especially if an alternative pathway is more effective to manage flood risk under the new changed circumstances. Therefore, both the '*preferred options*' and the alternative options may be re-appraised, using updated (best) estimates of future change (and another Option may be chosen). This the reason why alternative Options (pathways) were included in the TE2100 Plan. The Options (and their measures) should be as adaptable as possible and avoid measures that might not be needed in the future (Ramsbottom and Sheppard 2017, p.13).

In synthesis, the TE2100 entails an ongoing monitoring of the world, and a review of decisions over time, as observations, new knowledge or updated projections arise (Reeder and Ranger 2011). A key-factor for the efficacy of the 'route-map' approach will be the development of long-term records of climate information and data on sea levels, so that changes can be detected and any necessary alterations to the plan (route-map) can be timely made (Reeder and Ranger 2011) (see Note 122).

The indicators must be monitored, and the Plan must be regularly reassessed and reviewed (based on the monitored indicators), to ensure that the Plan remains '*adaptable to change*', *flexible*, and '*fit for purpose*' over its lifespan, and responds adequately to changes (EA 2012, p.36,38, 39; EA 2016).

There are various ways to address changes, as these are monitored, or each time the TE2100 Plan is reviewed or updated (EA 2012, p.39), e.g. by adjusting the date of the 'implementation point' and 'decision point' of measures, or by shifting of measure (or pathway), or altering the measures themselves. Section 6.2 sums up how the TE2100 Plan is adaptable, i.e. the ways through which the Plan can be adapted to changes, as these are monitored, or when the Plan is reviewed.

Step 4: Implementation of the TE2100 Plan

The TE2100 Plan was published in 2012 (EA 2016; Ramsbottom and Sheppard 2017, p. 14). Once the TE2100 Plan was approved by Government, the work on the first actions and investments scheduled began (EA 2012, p.41). The implementation of the actions and activities recommended in the Plan commenced since the publication of the Plan. To streamline the implementation of actions[53], an organisation called *TEAM2100* (composed by EA staff and consultants) signed a 10-year contract to refurbish, improve and replace flood defences in the Estuary, namely TB and other barriers. Furthermore, new works on flood defences, port facilities and other developments, have been implemented in line with the Plan (Ramsbottom and Sheppard 2017, p.12,14-16).

Step 5: Conducting the monitoring and review programme

The regular monitoring of indicators was also initiated in 2012 and has occurred as required to allow the regular review and update of the Plan (Ramsbottom and Sheppard 2017, p13). The EA (together with the Met Office and others) has conducted this monitoring (TE2100 Appendix L 2009; Reeder and Ranger 2011; Lowe et al. 2009, p.90).

The first 5-year monitoring review report was published in 2016 (EA 2016). In general, it confirmed that the Estuary has been changing as expected by the Plan (EA 2016; London Councils 2018); the changes observed in the indicators, and the future projections, were, in general, consistent with those expected in the original Plan, thus, it was not necessary to modify the content nor the timing of actions; however, some indicators were refined (Ramsbottom and Sheppard 2017, p.13-15). The *implementation partners* with recommendations in the Plan must deliver their actions as planned (EA 2016; London Councils 2018). For more on the main findings of the monitoring (between 2012 and 2016), and per indicator, see Note 123.

[53] To facilitate the transition towards the implementation of actions, the TE2100 Team has worked with partners to define how actions should be taken forward, establish *implementation agreements, terms of reference* for partnership work, and *design frameworks* (EA 2012, p.41). https://www.gov.uk/government/publications/thames-estuary-2100-te2100/thames-estuary-2100-te2100#an-adaptive-plan-monitoring-and-adapting-to-change-in-the-thames-estuary

5. PLAN'S CONTENTS

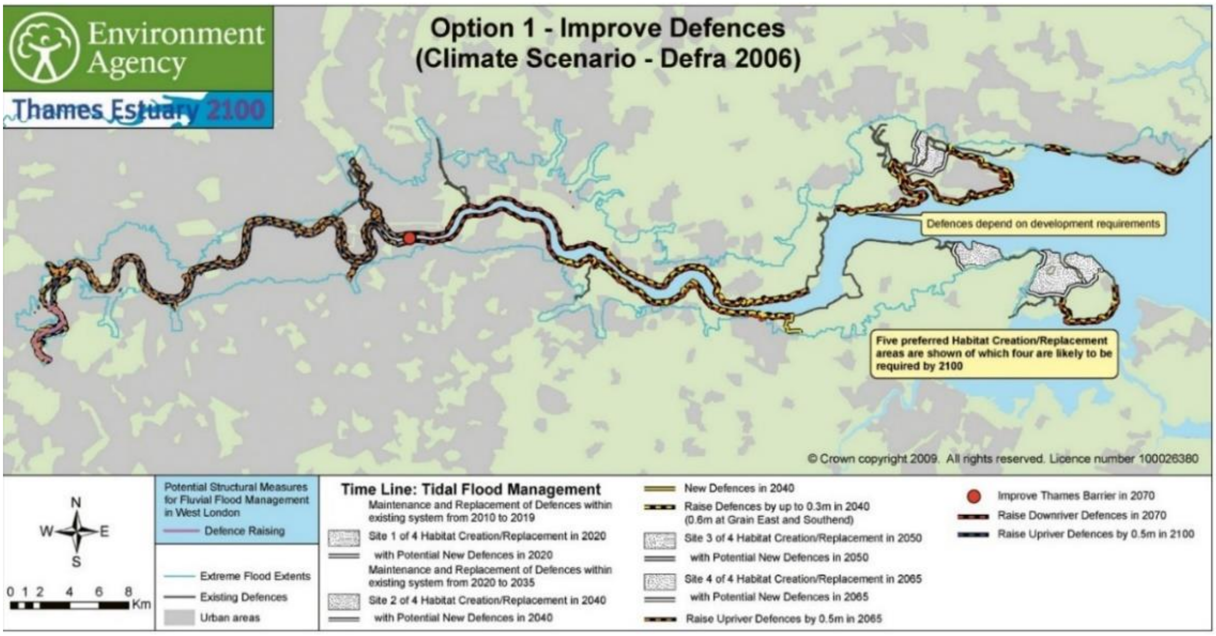
The TE2100 Plan is a flood risk management plan, developed by the UK's Environment Agency to manage tidal flood risk in the TE and London throughout this century, until 2100. Overall, the Plan defines a set of possible Options (pathways) to manage flood risk over this century and adapt to change at the estuary-wide level, but also the actions needed at local level. More specifically, it describes:

- the FRM policy allocated to each policy unit (a FRM policy, from P1 to P5, was attributed to each of the 23 'policy units') (EA 2012, p.6, 29, 44-45).
- The Options (pathways) that can be used to manage (reduce) flood risk over this century, at the estuary-wide level, so-called '*Estuary-wide Options*' (EA 2012, p.6, 35,30, 57-65).
- The actions required for each policy unit. Based on the FRM policy allocated to each policy unit, the Plan defines actions needed to achieve such policy, in 3 time-periods (Action Plan) (EA 2012, p.6).

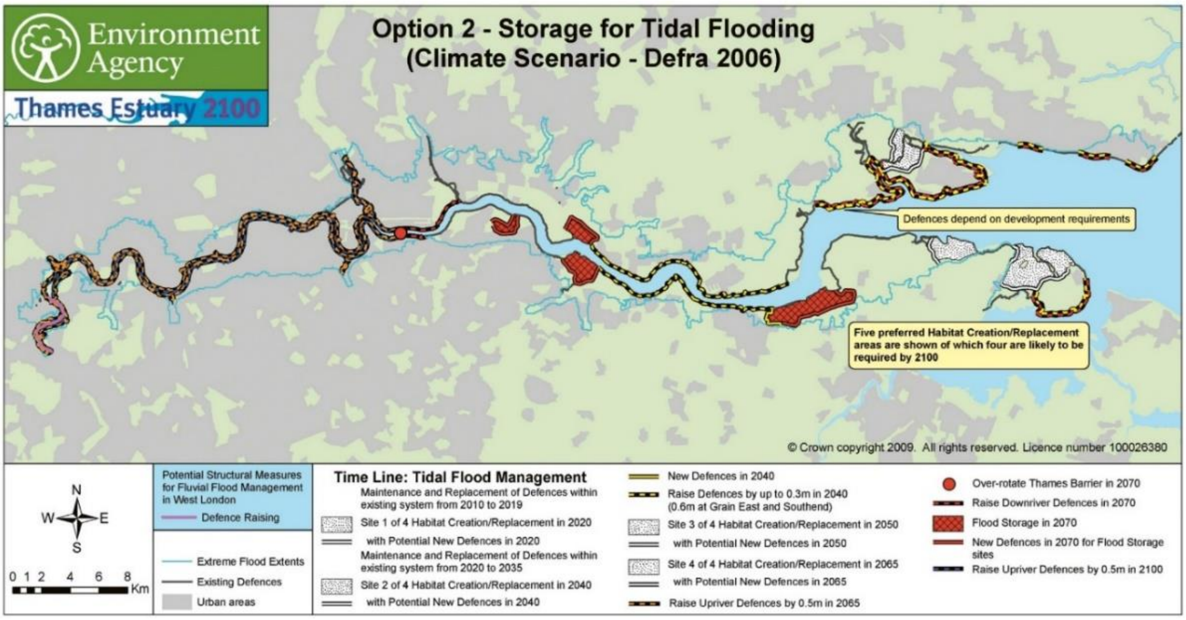
5.1. ESTUARY-WIDE OPTIONS (PATHWAYS)

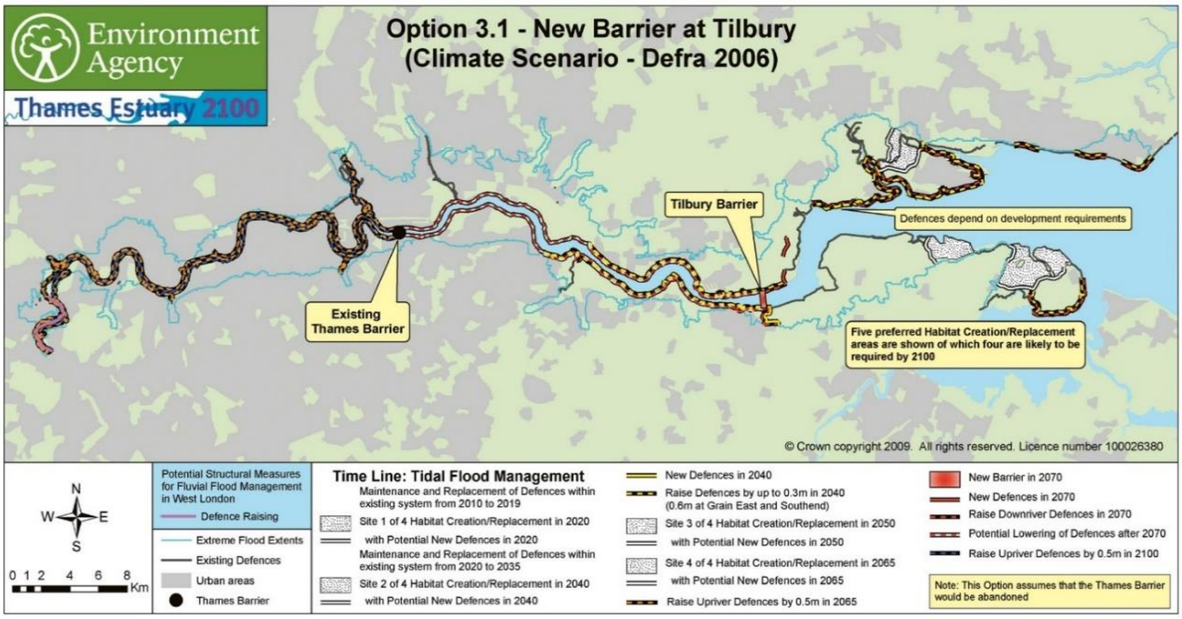
The Team designed four *Estuary-wide Options* (pathways) to manage and reduce flood risk throughout this century (EA 2012, p.30, 6); i.e. these *Estuary-wide Options* were developed to deliver the TE2100's *strategic vision* (the objectives of FRM in the TE), although they vary in the way of delivering it (EA 2012, p.35, 56).[54] The *Estuary-wide Options* (and their variations) are identified in Table 4 (for a detailed explanation see Note 115). Moreover, each Option was mapped out in a geo-referenced map in the TE2100 Plan (EA 2012, p.59-65), as shown in the maps of Figure 23.

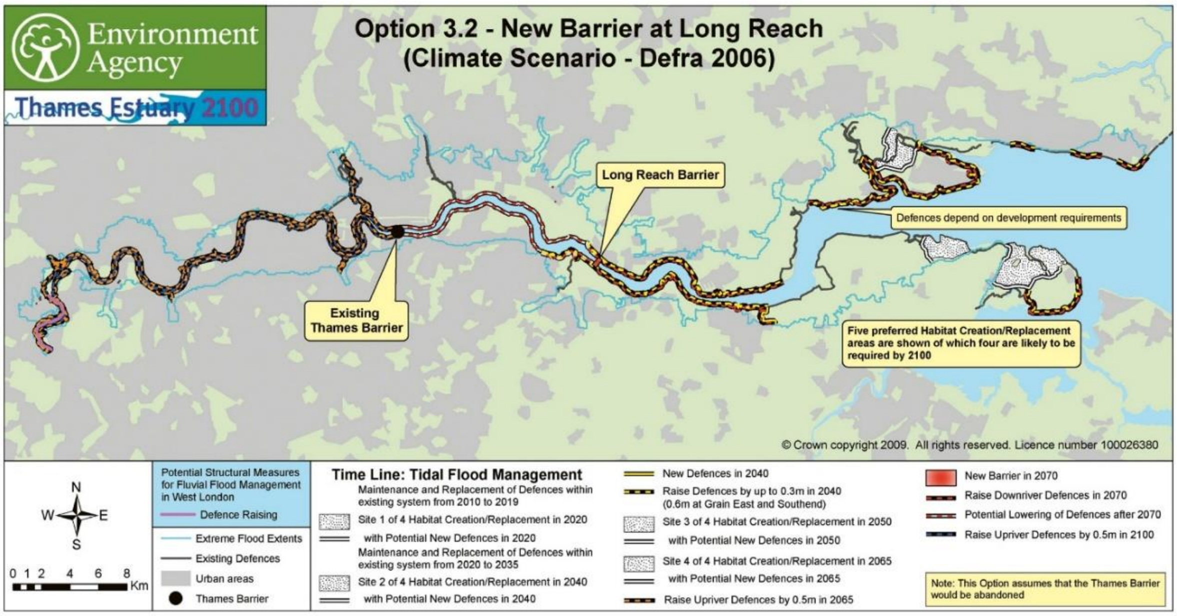
An option is a 'pathway' made of several actions sequenced and implemented over time. These maps show how each pathway was translated in space, in a map at the estuary scale, including the various measures (sequenced in time) that together will form such pathway.



[54] Furthermore, the *Estuary-wide Options* were designed to achieve the TE2100's FRM policies (EA 2012, p.30) (an 'option' is a pathway made up of several interventions sequenced and implemented over time that act together to achieve the recommended policy) (EA 2012, p.34). Each of the *Options* (pathways) presented in the Plan was appraised on its costs, benefits, and economic, social, and environmental impacts (in Step 2c) and two front-runner options were identified (EA 2012, p.30, 6).


Environment Agency
Thames Estuary 2100
Option 2 - Storage for Tidal Flooding
(Climate Scenario - Defra 2006)
Defences depend on development requirements
Five preferred Habitat Creation/Replacement areas are shown of which four are likely to be required by 2100
© Crown copyright 2009. All rights reserved. Licence number 100026380
N
W
E
S
0 1 2 4 6 8
Km
Potential Structural Measures for Fluvial Flood Management in West London
Defence Raising
Extreme Flood Extents
Existing Defences
Urban areas
Time Line: Tidal Flood Management
Maintenance and Replacement of Defences within existing system from 2010 to 2019
Site 1 of 4 Habitat Creation/Replacement in 2020
with Potential New Defences in 2020
Maintenance and Replacement of Defences within existing system from 2020 to 2035
Site 2 of 4 Habitat Creation/Replacement in 2040
with Potential New Defences in 2040
New Defences in 2040
Raise Defences by up to 0.3m in 2040
(0.6m at Grain East and Southend)
Site 3 of 4 Habitat Creation/Replacement in 2050
with Potential New Defences in 2050
Site 4 of 4 Habitat Creation/Replacement in 2065
with Potential New Defences in 2065
Raise Upriver Defences by 0.5m in 2065
Over-rotate Thames Barrier in 2070
Raise Downriver Defences in 2070
Flood Storage in 2070
New Defences in 2070 for Flood Storage sites
Raise Upriver Defences by 0.5m in 2100


Environment Agency
Thames Estuary 2100
Option 3.1 - New Barrier at Tilbury
(Climate Scenario - Defra 2006)
Tilbury Barrier
Defences depend on development requirements
Existing Thames Barrier
Five preferred Habitat Creation/Replacement areas are shown of which four are likely to be required by 2100
© Crown copyright 2009. All rights reserved. Licence number 100026380
N
W
E
S
0 1 2 4 6 8
Km
Potential Structural Measures for Fluvial Flood Management in West London
Defence Raising
Extreme Flood Extents
Existing Defences
Urban areas
Thames Barrier
Time Line: Tidal Flood Management
Maintenance and Replacement of Defences within existing system from 2010 to 2019
Site 1 of 4 Habitat Creation/Replacement in 2020
with Potential New Defences in 2020
Maintenance and Replacement of Defences within existing system from 2020 to 2035
Site 2 of 4 Habitat Creation/Replacement in 2040
with Potential New Defences in 2040
New Defences in 2040
Raise Defences by up to 0.3m in 2040
(0.6m at Grain East and Southend)
Site 3 of 4 Habitat Creation/Replacement in 2050
with Potential New Defences in 2050
Site 4 of 4 Habitat Creation/Replacement in 2065
with Potential New Defences in 2065
Raise Upriver Defences by 0.5m in 2065
New Barrier in 2070
New Defences in 2070
Raise Downriver Defences in 2070
Potential Lowering of Defences after 2070
Raise Upriver Defences by 0.5m in 2100
Note: This Option assumes that the Thames Barrier would be abandoned


Environment Agency
Thames Estuary 2100
Option 3.2 - New Barrier at Long Reach
(Climate Scenario - Defra 2006)
Long Reach Barrier
Defences depend on development requirements
Existing Thames Barrier
Five preferred Habitat Creation/Replacement areas are shown of which four are likely to be required by 2100
© Crown copyright 2009. All rights reserved. Licence number 100026380
N
W
E
S
0 1 2 4 6 8
Km
Potential Structural Measures for Fluvial Flood Management in West London
Defence Raising
Extreme Flood Extents
Existing Defences
Urban areas
Thames Barrier
Time Line: Tidal Flood Management
Maintenance and Replacement of Defences within existing system from 2010 to 2019
Site 1 of 4 Habitat Creation/Replacement in 2020
with Potential New Defences in 2020
Maintenance and Replacement of Defences within existing system from 2020 to 2035
Site 2 of 4 Habitat Creation/Replacement in 2040
with Potential New Defences in 2040
New Defences in 2040
Raise Defences by up to 0.3m in 2040
(0.6m at Grain East and Southend)
Site 3 of 4 Habitat Creation/Replacement in 2050
with Potential New Defences in 2050
Site 4 of 4 Habitat Creation/Replacement in 2065
with Potential New Defences in 2065
Raise Upriver Defences by 0.5m in 2065
New Barrier in 2070
Raise Downriver Defences in 2070
Potential Lowering of Defences after 2070
Raise Upriver Defences by 0.5m in 2100
Note: This Option assumes that the Thames Barrier would be abandoned

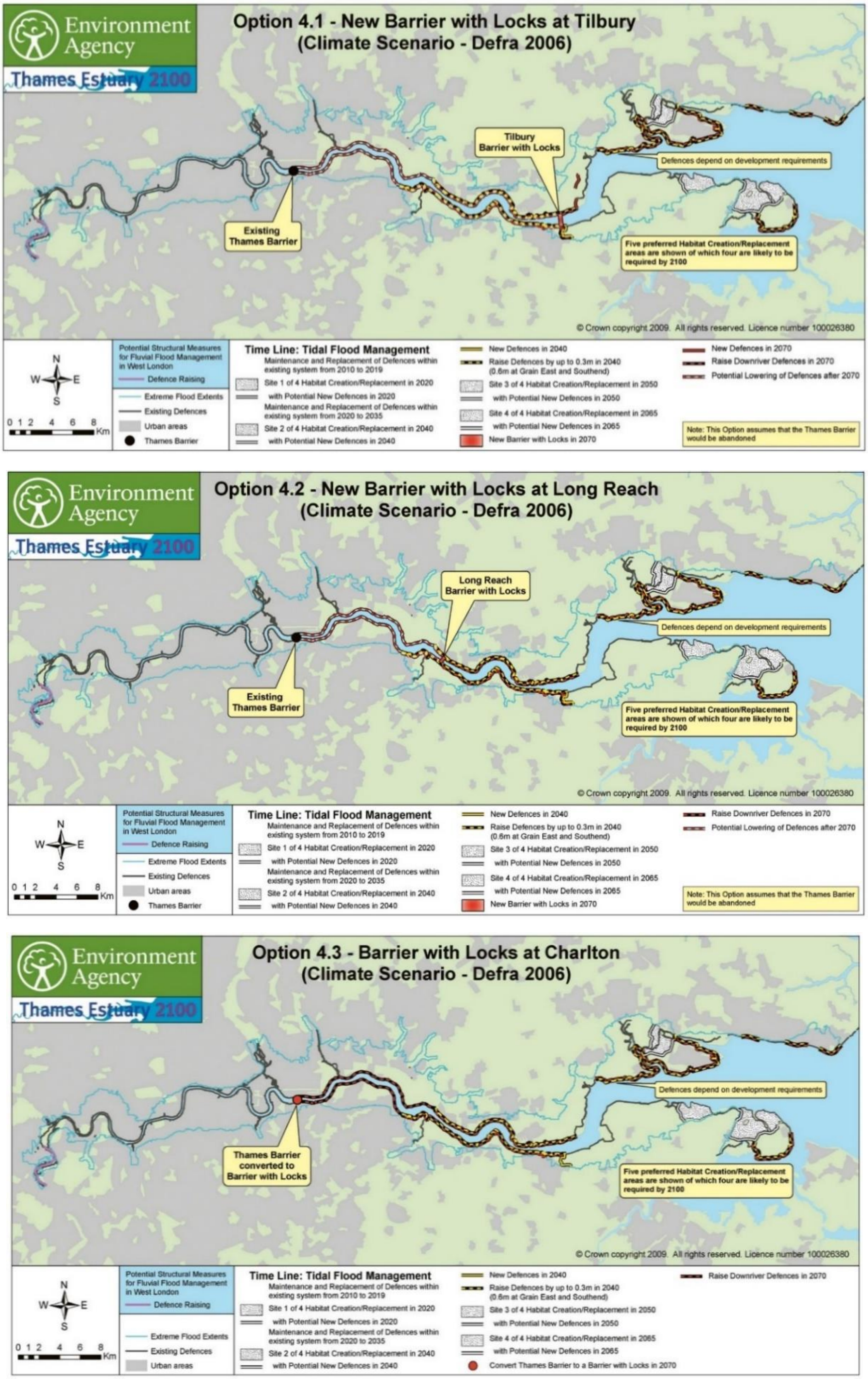


Figure 23. The four Options (pathways) designed in geo-referenced maps, under the *most likely* climate scenario (the Defra06 scenario) based on 2010 Government guidance. Each *option* is a pathway that contains several measures implemented in sequence (in a staged way). Source: EA 2012, p. 59-65.

6. What are the key-elements of the Adaptive Planning approach applied in the TE2100 Project

As mentioned, the TE2100 Project developed and used a '*Dynamic Adaptive Planning approach*' (also known as '*Iterative Risk Management'* or '*Managed Adaptive approach'*), which is based on *Dynamic Robustness* (Ranger et al. 2013, p.249-250, 254, 257-258; Ramsbottom and Sheppard 2017, p.1, 18). This '*Dynamic Adaptive Planning approach'* aimed to build a '*dynamic adaptive* ***plan / strategy***' that was '*robust*' and '*flexible*' (Ranger et al. 239, 233, 249). Robust means that the Plan / Strategy '*performs adequately well against a set of decision criteria under a wide range of possible future states of the world'* (Ranger et al.2013, p.247). *Flexible* (or '*dynamic robust'*) means that the Plan / Strategy (its measures, and their timing) can be changed over time as conditions change or new knowledge arises, thus, it is '*adaptable*' / adaptive (EA 2012, p.35-38; Ranger et al. 2013, p.233, 247, 249, 239).
As part of this '*Dynamic Adaptive Planning approach*', the TE2100 developed a new methodological approach to construct a 'dynamic adaptive plan / strategy': the 'Adaptation Pathways approach', also called 'Route-map approach' or 'Decision Pathways approach' (Ranger et al. 2013, p.249).

This Section identifies elements of the 'Dynamic Adaptive Planning approach' of the TE2100 that were essential to develop a *dynamic adaptive plan* (i.e. a *dynamically robust flexible plan*) and explains how these elements were applied in practice in the TE2100. Drawing on the prior analysis and on previous studies and work of other authors[55], it was possible to sum up the main elements of the Dynamic Adaptive Planning approach devised and applied in the TE2100 and fundamental 'ingredients' that make the Plan a dynamic adaptive plan. These elements and ingredients are identified in Table 5.

Table 5. Key-elements of the Adaptive Planning approach developed and used in the TE2100
Key-element 1: To consider a wide range of *plausible future scenarios* (different climatic, physical and socioeconomic scenarios), rather than a single probabilistic projection of the future, and use them namely to assess measures and strategies on their effectiveness (Jeuken et al. 2014, p.1,3, 23, 10; Jeuken and Reeder 2011, p.2, 6; Walker et al. 2013, p.969-970). This key-element consists of the consideration of a wide range of plausible future scenarios, and their use in the assessment of measures and strategies (pathways) regarding their effectiveness (Jeuken et al.2014, p.3, 10). It is necessary to consider various plausible futures to assess what measures can be used to achieve the objectives regardless of how the future unfolds (Walker et al. 2013, p.970). The scenarios should represent the main uncertainties about future conditions and changes. In the TE2100, this key-element implied: the generation of a range of plausible future scenarios of water level rise, and their use to test the effectiveness of measures, develop and appraise the pathways (Ranger et al. 2013, p.233, 239, 258).
Key-element 2: To identify critical thresholds (later called *Adaptation Tipping-points*), i.e. conditions under which the current or a proposed measure fails (ceases to be effective / meet the objectives), or the current system performs unacceptably, and a new measure is needed (Walker et al. 2013, p.970; Jeuken et al. 2014, p.17; Reeder and Ranger 2011, p.5; Ramsbottom et and Sheppard 2017, p.4). The TE2100 analysed 'what amount of change can the system cope with before it runs into trouble' (Jeuken and Reeder 2011, p.2). The Team identified thresholds in the vulnerability of the existing FRM system, which were the starting point for the planning of measures and pathways (Jeuken and Reeder 2011, p.3, 2; TE2100 Appendix L 2009, p.5).
Key-element 3: To develop and use a *'robust and flexible'* set of measures to deal with uncertain changes, through the 'Adaptation Pathways approach' (APs) (also called 'Route-map approach') (Jeuken et al. 2014, p.23, 1). In other words, this element consists of designing *robust flexible strategies* (with measures or actions that are *robust* and / or *flexible*), with the 'APs approach' (a strategy can be deemed a set of measures, a pathway) (Jeuken and Reeder 2011, p.2-3). According to Jeuken et al., one of the main elements of an Adaptive Planning approach is '*to respond to uncertain change with a robust and flexible set of actions'* (Jeuken et al. 2014, p. 23, 1). In an Adaptive Planning approach, measures / actions must be *robust* and *flexible* (Jeuken et al. 2014, p.3, based on Sayers et al. 2012). Measures should also be '*low/ no-regrets'* as much as possible (Jeuken et al. 2014, p.3). The development a *robust and flexible* set of measures requires considering and incorporating *robustness* and *flexibility* and low-regrets content when choosing measures and devising strategies (ibid, p.3).

[55] This Section builds on: (i) the prior analysis of the TE2100 Project and Plan, planning approach and process (sections 3, 4 and 5); the work of authors who examined the TE2100 case to extract essential elements of the methodological approach and of the 'adaptive plan' (e.g. Jeuken and Reeder 2011; Reeder and Ranger 2011; Ranger et al. 2013) or elements that lead to the classification of the TE2100 as a successful example of an Adaptive Planning to FRM (Ramsbottom and Sheppard 2017); studies that first identify elements of an Adaptive Planning and a dynamic adaptive plan, and then examine if these elements are present in diverse cases worldwide, e.g. TE2100 (Jeuken et al. 2014) (see Note 124).

According to Jeuken and Reeder, this element consists of designing *robust flexible strategies* (Jeuken and Reeder 2011, p.3, 2), and in the TE2100 this was done by using the 'Adaptation Pathways approach'. The 'Adaptation Pathways approach' (APs) is a methodological approach for '*exploring and sequencing a set of possible actions* (i.e. a set of possible measures) *based on alternative external developments over time*' (Haasnoot et al. 2012, p.485); and it is an Adaptive Planning approach. In the APs approach, a planner envisions short-term measures chained / articulated with long-term possible alternatives (options) and envisages possibilities for switching between them, through adaptation pathways (Jeuken et al. 2014, p.1). In the TE2100, this element involved the design of *robust flexible strategies*, with the 'Route-map / APs approach' (Jeuken and Reeder 2011, p.2-3). In other words, in the TE2100, the development of a '*robust and flexible*' set of measures – i.e. *robust flexible strategies* (a pathway / strategy is a set of measures) – required the design of pathways with the 'APs approach'. The TE2100's *Dynamic Adaptive Planning approach* contained an innovative method to construct a '*dynamic adaptive plan / strategy'* that was both *robust* and *flexible*: the 'Adaptation Pathways approach' (APs) (Ranger et al. 2013, p.249). In the 'APs approach', the Plan and its strategies are '*designed to be adjusted over time as more is learnt about the future*' or as changes occur (Ranger et al. 2013, p.249). The timing for new measures, and the measures themselves, can be modified (changed) over time, in this way, *flexibility* is built-in into the long-term strategy itself (Ranger et al. 2013, p.249). In the APs, measures are implemented iteratively over time to keep risk below the target levels, and, at the same time, keeping open options (alternatives) to manage future risk (Ranger et al. 2013, 247, 249, 239; Reeder and Ranger 2011, p.13). A pathway / route is a *package* of measures that are sequenced and implemented over time (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8). Each pathway, called *High-Level Option* (HLO) or *Option*, contains a set of measures (individual measures or portfolios) that are implemented in sequence to manage flood risk over time (Bloemen et al. 2018, p.7; Ramsbottom and Sheppard 2017, p.2, 5). Five pathways (HLOs) were designed in the TE2100's route-map. Each pathway is itself flexible (e.g. it is possible to move from a measure to other), and it is also possible to move from a pathway to another. The APs approach resulted in a *dynamic adaptive plan* that is: *dynamically robust* to uncertain future changes and *adaptable* to change (the pathways can be adapted as changes occur in climatic, physical or socioeconomic conditions) (EA 2012, p.1, 29, 35, 39; TE2100 Appendix L 2009, p.3; Ranger et al. 2013, p.239; Bloemen et al. 2018, p.12; Jeuken et al. 2014, p.2,4,19, 21).
Key-element 4: To continuously monitor relevant changes and new information, and reassess / review the Plan, and, adjust (adapt) it accordingly. This requires: a targeted monitoring of relevant changes (in external conditions, effects of measures) and continual evaluation of new information (e.g. updated scenarios); and the regular reassessment (review) of the Plan, and, in accordance, the adjustment of the Plan (i.e. updating, redefining or modifying policies, measures, pathways, and / or implementation plans, according to the monitoring outputs) (Jeuken et al. 2014, p.1, 23, 3; Sayers et al. 2012, p.282; Walker et al. 2013; Bloemen et al. 2018). This will allow the adjustment (adaptation) of the Plan and its strategies and measures. Important changes are continuously observed and foreseen through targeted monitoring and future scenarios are reassessed; and the Plan is regularly revaluated, and its policies, measures or pathways are appropriately adjusted / adapted (Jeuken et al. 2014, p.3; Sayers et al. 2012, p.282). The monitoring and reassessment system must be accounted for in the Plan itself. In the TE2100, this involved the definition of a monitoring system, which specifies indicators to be monitored and decision-points that trigger the implementation of measures based on the observation of indicators (Ranger et al.2013, p.233, 239, 258). The monitoring system keeps track of indicators, and the decision-points help to ensure that measures are timely taken and cost-effective (Ranger et al. 2013, p.233, 239, 258; Jeuken and Reeder 2011, p.6; Ramsbottom and Sheppard 2017, p.5, 12). The monitoring of local and global changes is necessary to examine if decisions should be taken earlier or postponed, revised or altered (Jeuken and Reeder 2011, p.6). This implies the capacity to alter (adapt) the Plan (its policies, measures, or the timing for applying measures), as new information and knowledge arise or as changes occur.
Key-element 5: the ongoing process of adaptive planning (which is also associated to the continuous process of iterative risk management and climate adaptation), and which involves several steps that allow the adaptation of the general Plan over time and under uncertain future conditions and changes. The TE2100 Project has followed a *decision-centred* planning process which entails an iterative risk management cycle with several steps: i) the assessment of risk and potential impacts; 2) identification of possible measures and development of strategies (pathways) considering a wide range of scenarios; 3) selection of Options (preferred pathway) and decision-making; 4) application; 5) monitoring of changes, measures applied, and new information; 6) reassessment of the Plan and, if necessary, its review (i.e. correct, alter, or change the Plan, its measures or their timing). This iterative process helps to ensure ongoing learning and safeguards the adaptability of the general Plan over time, so that it can better deal with change and uncertain future conditions.

Table 5. Key-elements of the *Dynamic Adaptive Planning approach* of the TE2100. Source: Own elaboration, based on: Jeuken et al. 2014; Sayers et al. 2012; Ranger et al. 2013; Jeuken and Reeder 2011, etc. Some elements correspond to steps of the planning process and address key issues e.g. *what to prepare for*, *how to respond*, *what to monitor* (Jeuken et al. 2014).

These are the main elements of the Adaptive Planning approach applied in the TE2100. These elements were essential to develop an *adaptive plan* and allow an Adaptive Planning. They are explained next.

6.1. How these key-elements were applied in the TE2100 Project

Key-element #1

The TE2100 Project developed and used a wide range of plausible future scenarios of water level rise until 2100, rather than a single '*most probable*' scenario (Jeuken et al. 2014, p.10, 11; Jeuken and Reeder 2011, p.6). Such scenarios were generated based on GCMs, RCMs, climate projections, modelling studies, past observation, expert judgement, and other sources (Ranger et al. 2013, p.233, 239, 258). The main climate parameters considered in the scenarios were SLR, storm surges and river discharges, but projections showed no trends in river discharges (Jeuken et al. 2014, p.11, 14), thus, the work focused on SLR and storm surge (Jeuken and Reeder 2011, p.6). The uncertainties around future climate change effects are reflected in the consideration of various plausible scenarios with a long temporal horizon (2100 or beyond it) (Jeuken et al. 2014, p.14; Jeuken and Reeder 2011, p.6). The range of scenarios includes e.g. '*high-impact, low-probability*' scenarios and *'moderate*' scenarios. Later in the Project, the '*most likely'* scenario was identified (Jeuken et al. 2014, p.10, 11). Moreover, socioeconomic scenarios were specifically developed for the TE (Jeuken et al. 2014, p.13).

The range of scenarios of water level rise was used to inform the exploration of possible measures and the development of Options (pathways). Initially, the High++ was used for exploratory purposes, and then other moderate scenarios were used for the appraisal detailed design of *Options*. Two climate scenarios (*Defra central* and *High+*) and two socioeconomic scenarios were used to appraise the *Options*, and, in this way, examine the long-term robustness of the Plan (Jeuken et al. 2014, p.10, 14).

The generation of a wide range of plausible future scenarios of water level rise, and their use to test the robustness of measures and develop and appraise the pathways, is deemed an innovative element of the TE2100 (Ranger et al. 2013, p.233, 239, 258; Reeder and Ranger 2011, p.7), which was crucial to develop a long-term adaptive plan able to deal with uncertain future change. The Plan was designed to cope with change (a changing climate), and the scenarios allowed the Team to measure '*how much adaptation will be needed for different scenarios*' (EA 2012, p.28), i.e. what measures will be necessary.

The scenarios generated were used to assess flood risk now and in future, to identify the limits of different measures, to set the long-term adaptation requirements (for the HLOs), and to develop the *Options* (pathways) and appraise them (Ramsbottom et and Sheppard 2017, p.7, 9).

Key-element #2

In the TE2100, critical thresholds were identified by analysing 'what amount of change can the existent system cope with before it runs into trouble' and specifically what increases in sea-level and in river discharge could lead to the failure or overtopping of the flood defence system (Jeuken and Reeder 2011, p.3, 2). The critical thresholds describe conditions under which the current system (with its current policies / measures), or alternative measures, might *fail* (Jeuken et al. 2014, p.17); they represent 'limits' that would be disruptive for the existing flood defence system (thresholds in the sensitivity / vulnerability of the system, e.g. values of SLR, limits of adaptation of the existing system, etc.) and which would require new measures (e.g. modifications to the existing defences) (Ranger et al. 2013, p. 242; Reeder and Ranger 2011, p.6). Thresholds correspond to conditions under which the current system (the current FRM measures / policy) will no longer meet the objectives and new measures will be needed (Jeuken and Reeder 2011, p.4; Bloemen et al. 2018, p.7, 8). The driver for taking action is not climate change *per se*, but (mainly) being unable to meet the objectives (Jeuken and Reeder 2011, p.4).

The analysis of thresholds was the starting point for the planning process (for exploring measures and pathways) (Jeuken and Reeder 2011, p.2-3; TE2100 Appendix L 2009, p.5). The thresholds were used to define '*acceptable flood probabilities*' (acceptable return periods for flood events) which were then translated into '*design criteria*' for flood defences (i.e. the FRM policies), in line with a *risk-based approach* (Jeuken et al. 2014, p.17; Sayers et al. 2012, 282, 285). To identify the thresholds, the Team examined physical and technical limits of the defence system, quantified its overcapacity, and, based on this and on projections, defined *design criteria* (Jeuken and Reeder p.6; Ramsbottom et and Sheppard 2017, p.4). The Team examined '*what are the thresholds where interventions will be needed*' (flood probability will increase until a certain threshold level is reached (e.g. the maximum acceptable flood probability) and new measures are needed to reduce such probability).[56] Modelling of future scenarios was undertaken *to determine the* (timing of) *thresholds when measures are needed to keep the flood probability within acceptable limits*, and investigate possible measures to manage flood risk (Ramsbottom et and Sheppard 2017, p.4,5).

The Team sought to identify key thresholds (major change points), such as the level of SLR at which the existing sea defences will fail, other limits to adaptation, limits of vulnerability to impacts (Reeder and Ranger 2011, p.5, 6). The definition of thresholds requires analysing '*what (amount of) change can the system handle before it runs into trouble*' (Jeuken and Reeder 2011, p.3). The starting point of the analysis is identifying thresholds in the vulnerability of the existing system. The TE2100 Project focused on determining the level of SLR, and the increase in river discharge, that could cause a technical failure or overtopping of the flood defence system (including its embankments, floodwalls, and the Thames Barrier) (Jeuken and Reeder 2011, p.3).

The identification of thresholds (and detection of their date in different scenarios) informed the development of *Options* (pathways) (TE2100 Appendix L 2009, p.5, 10, 12). The thresholds were used to sequence and assemble the possible measures into '*packages* of measures' (i.e. to design pathways) (Jeuken et al. 2014, p.17). The route-map shows the thresholds at which it is necessary to switch from a measure to another. The identification of thresholds helped to enhance the flexibility of the Plan (ibid).

This 'threshold analysis' allowed a more '*scenario neutral approach*', and it is deemed one of the main successes of the TE2100 (TE2100 Appendix L 2009, p.5, 10, 12). The Route-map approach is more *scenario neutral* because decisions do not require information about the likelihood of different scenarios (Ranger et al. 2013, p.254; Reeder and Ranger 2011, p.9).

Key-element #3

Other key element of the Dynamic Adaptive Planning approach of the TE2100 consisted of the development of a *'robust and flexible*' set of measures, to deal with uncertain future change, which was done by using the 'Route-map / Adaptation Pathways approach' (Jeuken et al. 2014, p.1, 23; Jeuken and Reeder 2011, p.2, 4; Ranger et al. 2013, p.249; Reeder and Ranger 2011; Ramsbottom and Sheppard 2017, p.5). In other words, this element involved the design of *robust flexible strategies* (a strategy, here, is itself a set of sequenced measures, a pathway).

Under uncertain future changes, planners should develop a '*dynamic adaptive plan*' that is '*robust*' and *flexible*'. To develop a '*dynamic adaptive plan*,' the TE2100 devised a new methodological approach: the 'Adaptation Pathways approach' (also called 'Route-map approach'), which is itself within the family of Adaptive Planning approaches (Ranger et al. 2013, p.249).

---

[56] It defined a maximum acceptable flood probability (represented by the 'Standard of Protection'), which is the level of protection provided by the flood defences expressed either as an annual flood probability (%) or a return period in years. This sets the threshold values of acceptable flood probability for the flood defence system that should not be exceeded. The Team identified the thresholds when the measures / portfolios of measures reached their maximum limit of flood risk (Ramsbottom et and Sheppard 2017, p.4-5).

In the light of the *Adaptive Planning paradigm*, in the face of deep uncertainty about future changes, a '*dynamic adaptive plan*', with '*robust policies/*strategies and '*adaptive policies* / strategies, is needed (Jeuken et al. 2014, p.2). 'Robust policies' / strategies are those '*perform well under a wide range of plausible futures*', whereas 'adaptive policies' / strategies '*can be adapted once the future unfolds differently than foreseen*' (Jeuken et al. 2014, p.2). According to Jeuken et al. (2014), one of the central elements of an 'Adaptive Planning approach' is '*to respond to uncertain change with a robust and flexible set of actions'* (Jeuken et al. 2014, p. 23, 1). This set of actions should: create a *robust* system, i.e. one that can cope with several plausible future scenarios, namely extreme scenarios, and remain *flexible* in relation to changes and uncertain future conditions (Jeuken et al. 2014, p.3). A *dynamic adaptive plan* must contain *robust* and *flexible* measures. In an 'Adaptive Planning approach', measures (or their set) must be: *robust* (i.e. effective under the widest range of plausible future scenarios), and *flexible*, e.g. not foreclose or unnecessarily constrain possible future measures (options) (Jeuken et al. 2014, p.3, based on Sayers et al. 2012). Moreover, measures should be '*low/no-regrets'* as much as possible (i.e. with properties like robustness, flexibility, reversibility, adaptability) (Jeuken et al. 2014, p.3). This implies considering *robustness* and *flexibility*, and *low-regrets' content*, when choosing measures and developing strategies (Jeuken et al. 2014, p.3).

To deal with uncertain future change, it is necessary to develop a '*robust and flexible*' set of measures (Jeuken et al. 2014, p.23, 1). To do this, the TE2100 Project devised and applied the 'Adaptation Pathways / Route-map approach' (Jeuken et al. 2014, p.10). The TE2100 Team designed a *robust and flexible* set of measures, with the 'APs approach' (Jeuken et al. 2014, p.23).

In the TE2100's Adaptive Planning approach, a 'dynamic adaptive plan / strategy' should be: *robust* (perform well under a wide range of plausible futures), and *adaptive* (the Plan and its measures can be changed over time as changes occur or as new information arises (Ranger et al. 2013, p.233, 239, 247, 249).

The TE2100's 'Dynamic Adaptive Planning approach' aimed at building a 'dynamic adaptive plan / strategy' that was robust: *robust* (i.e. '*performs adequately well against a set of decision criteria under a wide range of possible future states of the world*'), and *flexible* or '*dynamically robust*' (i.e. the Plan / Strategy, its measures, or their timing, '*can be changed over time as more is learnt or as conditions change*', thus, the Plan should be 'adaptable' (Ranger et al. 2013, p.247, 233, 239, 249, 254; EA 2012, p.35-38). The Team sought that the Plan was '*as robust as possible*' (e.g. to uncertainties about future water levels), '*adaptable to change'* (EA 2012, p.35-38; Ranger et al. 2013, p.239, 254).

This Dynamic Adaptive Planning approach (also called 'Managed Adaptive approach') included itself a new method to build a '*dynamic adaptive plan/strategy*': the 'Adaptation Pathways approach' ('Route-map approach') (Ranger et al. 2013, p.249). In line with the 'Dynamic Adaptive Planning approach', in the 'APs approach', the Plan, its strategies and measures '*are designed to be adjusted over time as more is learnt about the future*' or as changes occur (Ranger et al. 2013, p.249). In the 'APs approach', the timing of new measures, and the measures themselves, can be changed over time, in this way, '*flexibility is built into the long-term strategy itself'* (Ranger et al. 2013, p.249). In the 'APs approach', measures are implemented iteratively over time to maintain risk below the target levels (cost-effectively), while keeping open alternative measures (options) to manage future risk (instead of designing an optimal solution for given level of risk) (Ranger et al. 2013, 249, 247, 239; Reeder and Ranger 2011, p.13).

A pathway is a '*package*' of measures that are sequenced and implemented over time (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8; Jeuken and Reeder 2011, p.4; Jeuken et al. 2014, p.18). Each pathway, so-called '*High-Level Option*' (or '*Option*'), contains a set of measures (individual measures or portfolios) that are implemented in sequence over time to manage flood risk in a staged way (Bloemen et al. 2018, p.7-8; Ramsbottom and Sheppard 2017, p.2, 5). Four pathways were represented in the route-map of the TE2100 Plan; such pathways are expected to cope with the estimated plausible rises in water level until 2100 (providing a complete FRM solution during the Plan's life) (Bloemen et al. 2018, p.7).

BOX 3: Within its '*Dynamic Adaptive Planning approach*', the TE2100 developed a new methodological approach to construct a 'dynamic adaptive plan / strategy': the 'Adaptation Pathways approach' (APs), also called 'Route-map approach' or 'Decision Pathways approach'. In the APs approach, a planner explores possible measures and identifies their timing and sequencing, and in this way, designs possible pathways of adaptation over time under different scenarios. Each pathway is a package of measures sequenced and implemented iteratively over time to maintain risk below target levels (Ranger et al. 2013, p.249).

In specific, the 'APs approach' is a (methodological) '*approach for exploring and sequencing a set of possible actions* (i.e. a set of possible measures) *based on alternative external developments over time'* (Haasnoot et al. 2013, p.485). Haasnoot et al. (2012, 2013) and Walker et al. (2013) place the 'APs approach' within family of Adaptive Planning approaches. The APs offers a methodological approach for designing a '*dynamic adaptive plan*' that is *robust* and *adaptive* under uncertain future changes.

The development of *robust flexible strategies* with the 'APs approach' is one of the main elements of the Adaptive Planning approach of the TE2100 (Jeuken and Reeder 2011, p.2). This element involved the design of *robust flexible strategies* by using the 'Route-map / APs approach' (Jeuken and Reeder 2011, p.2,4). The TE2100 used the 'Route-map / APs approach' as a method of designing *robust flexible strategies*, where *robustness* to uncertain future change, and *flexibility*, are 'built-in' in the adaptation strategy itself (Jeuken and Reeder 2011, p.4, 2; Reeder and Ranger 2011, p.3, 8, 11).

In the TE2100, the 'APs approach' served to: identify possible (FRM/adaptation) measures, and explore their the timing and sequencing over time and under different scenarios of water level rise, and, in this way, develop various pathways to keep risk below acceptable levels while maintaining *flexibility* (Ranger et al. 2013, p.233, 239, 249, 258). The 'Route-map approach' allows the design of a route-map of pathways. In this approach, measures are implemented over time to continuously manage risk (adapt), while keeping open alternative measures (options) for the future, and, in this way, maintaining *flexibility* (Jeuken and Reeder 2011, p.4).

The 'APs approach' required the analysis of thresholds – i.e. points under which a measure no longer meets the predefined decision criteria (Kwadijk et al. 2010) and it is necessary to take a new measure or switch to other pathway – and examining under what conditions the Plan fails and preparing actions to guard against this (Ranger et al. 2013, p.250).

In the 'Route-map / APs approach', a planner envisions diverse possible measures and possibilities for switching between them through adaptation pathways, and short-term measures are chained with (*coupled with*) long-term possible alternatives (options) (Jeuken et al. 2014, p.1).

By using the 'Route-map / APs approach', the TE2100 Team designed four possible pathways, so-called *High-Level Options* (HLOs or '*Options*') (Jeuken and Reeder 2011, p.4). Each *HLO* / pathway is a '*package of measures'* sequenced and implemented over time, and the route-map shows four different possible pathways (HLOs) (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8; Jeuken and Reeder 2011, p.4; Jeuken et al. 2014, p.18). Each HLO is a pathway / route through the century that can be adapted (and adopted according) to the rate of change (water level rise) that is experienced (TE2100 Appendix L 2009, p.3; Reeder and Ranger 2011, p.9; Ranger et al. 2013, p.250; Lowe et al. 2009, p.89; Jeuken and Reeder 2011, p.5). Together, these HLOs were designed to span (cover) the estimated range of plausible future scenarios of water level rise in the TE until 2100 (i.e. up to 4,2m) (Jeuken and Reeder 2011, p.4; Ranger et al. 2013, p.250; Reeder and Ranger 2011, p.8). Each pathway (HLO) can cope with a certain level of water level rise; each pathway was tested under various scenarios, to assess its robustness (Jeuken and Reeder 2011, p.4).[57] All the pathways (HLOs) will remain under consideration, and a decision between them will only be made in the future when there is better information as a result of continued monitoring and new insights into SLR (Ranger et al. 2013, p.251).

The 'Route-map / APs approach' involves sequencing the implementation of diverse measures in a way that allows the system under consideration (the FRM system) to adapt to changes over time (e.g. SLR), and, at the same time, keeping alternatives (options) open to cope with plausible different future climate scenarios (Reeder and Ranger 2011, p.3). The approach '*focuses on sequencing a suite of measures in order to cost-effectively manage current risk while maintaining the flexibility to cope with the range of possible future sea level rise*' (Reeder and Ranger 2011, p.13).

To deal with uncertain future change, the TE2100 Team sought to *build-in* (embed) flexibility (i.e. *dynamic robustness*) into the Plan and its measures (Ranger et al. 2013, p.249). This was done with the 'Route-map / APs approach'. By using the 'APs approach', the TE2100 sought to safeguard the *robustness* and *flexibility* of the Plan (Jeuken et al. 2014, p.10). In the TE2100, the robustness and flexibility of the Plan was safeguarded by using the 'Route-map / APs method'; this approach allows for switching between different measures or pathways in the future (Jeuken et al. 2014, p.10). The 'Route-map approach' helped to incorporate (*build-in*) and enhance the *robustness* to uncertain future conditions and *flexibility* to deal with change, into the plan itself and its *strategies* (pathways).

In the 'APs approach', *dynamic robustness* / *flexibility* is *built-in* and ensured in the following ways:

- **Through pathways' flexibility** (Ranger et al. 2013, 249). In the 'Route-map / APs approach', the Plan's strategies are designed to be adjusted as changes occur or more is learnt about the future (Ranger et al. 2013, p. 249, 233, 227). In specific, the timing of new measures, and the measures themselves, can be changed (adjusted, adapted) over time, in this way, *flexibility* is built-in into the long-term strategy (Ranger et al. 2013, p.249).
  Importantly, in the APs approach, each HLO (pathway) is itself *flexible* (e.g. it is possible to move from a measure to another), and it is also possible to move from a HLO (pathway) to another depending on the rate of change that actually occurs (TE2100 Appendix L 2009, p.4; Reeder and Ranger 2011, p.9; Lowe et al. 2009, p.89; Jeuken and Reeder 2011, p.4; Jeuken et al. 2014, p.18). The route-map contains various pathways (HLOs) (Jeuken and Reeder 2011, p.4; Jeuken et al. 2014, p.18). The 'Route-map approach' allows the switching between different measures, but also between different HLOs (pathways) (Jeuken and Reeder 2011, p.4; Jeuken et al. 2014, p.18). In the 'Route-map approach', it is possible to switch from a measure to a different measure, but also to switch from one HLO (pathway) to another. The TE2100 Plan provides various pathways and allows the switching between different alternatives in the future (Jeuken et al. 2014, p.18). It is also possible to adjust the timing for implementing a new measure, as new information emerges.
- **APs allow switching from a measure to a new one (within the same pathway) or switching to te different pathways, but also adjusting (adapting) the pathways or measures, if necessary.** In the Route-map approach, it is possible to adjust (adapt) a given measure, or switch to other measure, if new information or knowledge arise. The Plan explains how the planned measures can be adapted, or new measures adopted, if critical indicators (e.g. SLR rate) change significantly (or differ from the estimate assumed in the Plan) (Jeuken et al. 2014, p.18, 6). In addition, the TE2100 Plan identifies different possible *Options* (pathways) that can cope with different levels of SLR, and the thresholds

[57] With the APs approach, it was possible to make the plan more robust to deep uncertainties about future climate. The APs offered a way of incorporating robustness to climate change uncertainties into the adaptation Plan / Strategy itself. To assess the robustness of the pathways, the Team tested the suitability of each pathway under different scenarios (Jeuken and Reeder 2011, p.4).

at which these *Options* will be needed (HM Treasury 2009, p.13); such *Options* can cover a water level rise until 4,2m (Ramsbottom and Sheppard 2017, p.16).

- The 'APs approach' involves a **stepwise implementation of measures** and **keeping open the possibility to switch to other (alternative) measures** (Jeuken et al. 2014, p.18). In this approach, flood risk is managed (reduced) iteratively: the approach displays short-term measures and possible future measures (alternatives), which fosters flexibility (Ranger et al. 2013, p.248-249). In the APs, measures are implemented stepwise over time. Instead of taking a decision now on the 'best' measure for given future scenario (which could result in maladaptation if this scenario did not occur), the 'APs approach' encourages planners to reflect on *what if* scenarios and adopt a 'more flexible approach' where decisions and measures are taken over time to continuously adapt while maintaining as much flexibility as possible about future measures (options) (Jeuken and Reeder 2011, p.4; Isoard and Winograd 2013; Ranger et al. 2013, p.250).[58] One way of building-in *'flexibility*' is keeping open options (alternatives available) to manage future risk (Ranger et al. 2013, p.249), not foreclosing or constraining possible future measures unnecessarily (Jeuken et al. 2014, p.3; Sayers et al. 2012). This implies finding measures that do not block further measures that might be needed in the future and avoiding irreversible investments as much as possible (Jeuken and Reeder 2011, p.2; Ramsbottom and Sheppard 2017, p.5). The possibility of implementing certain measures or pathways should not be prematurely closed-off, e.g. by actions of third parties (HM Treasury 2009, p.28).

  The outcome of the 'Route-map / APs approach' was a 'dynamic adaptive plan' that provides a suite of sequenced measures to manage current risk while '*maintaining the flexibility to cope with the range of possible future SLR'* (Reeder and Ranger 2011, p.13). The TE2100 Plan proposes various possible pathways (series of sequenced measures to manage flood risk until 2100) which *can cope with large ranges of change* if necessary (Zevenbergen et al. 2018).

- By using **a wide variety of measures**, which also improves the system's resilience (Jeuken et al. 2014, p.1). The Plan contains different types of FRM measures to cope with plausible future changes, e.g. defence works, managed realignment, local resilience measures, etc. (Jeuken and Reeder 2011).

- By using **'no-/low-regret' measures**[59] in the route-map, in the near-term (Ranger et al. 2013, p.248-249; Reeder and Ranger 2011, p.6, 9, 11; Ramsbottom and Sheppard 2017, p.5). In the TE2100, some pathways contain *low-regrets* early measures, e.g. improving / upgrading existing defences[60] (ibid). This measure will cost-effectively reduce risks and, at the same time, leave '*open the possibility to scale up action in the future*' and 'buy time' to monitor and learn before making a major investment (Ranger et al. 2013, p.248-249). The Team strategically placed 'low-regret measures' early in the route-map (Reeder and Ranger 2011, p.9). For example, the measure '*raising other defences in the TE*' (present in several HLOs) is a low-regret measure that helps to extend the lifetime of the existing defence system and 'buy time' before it is necessary to take a more irreversible decision on the long-term measure (instead of taking an more 'inflexible' decision now) (Reeder and Ranger 2011, p.9, 11; Ranger et al. 2013, p.255). All the *Options* (pathways) designed include small

58 The adaptive approach is reflected in the way of managing flood risk - the *managed adaptive approach* – where several measures are introduced over time (at different moments) to keep risk below the target level, and alternatives are kept open to manage future risk (Ranger et al. 2013, 247-249; HM Treasury 2009, p.22; EA 2012, p.34; Ramsbottom and Sheppard 2017, p.3). The TE2100 is an *example of a well-founded decision to postpone* a major 'irreversible' action; the APs approach showed that there is still time before making a major intervention (Jeuken et al. 2014, p.18). Instead of rushing into the construction of major engineering defences, the TE2100 applied an adaptive approach (Penning-Rowsell et al. 2013, p.1383). In the APs approach, '*large-scale decisions can be made robust in the face of deep uncertainty over future climate* (Jeuken and Reeder 2011, p.4).

59 Low-regrets measures are measures that *work through the whole range of change* (Reeder and Ranger 2011, p.6). In the TE2100, 'low-regret measures' were those that reduce risk immediately and cost-efficiently under a wide range of SLR scenarios. They are 'low-regret' rather than 'no-regret' because they may involve some opportunity cost (in Ranger et al. 2013).

60 The measure 'upgrade existing flood protection infrastructure' was detailed in the 40-year investment plan (Reeder and Ranger 2011, p.9).

incremental measures in the near-term (e.g. upgrades to existing defences) and leave irreversible measures as far as possible into the long-term future, to make the best use of information that will arise (HM Treasury 2009, p.13, 27-28). *Flexibility* was available, in part, because the TB was designed to provide a high standard of protection up to 2030 (adaptation is not urgent) and cost-effective *low-regret* measures were available (Ranger et al. 2013, p.255). Delaying a major investment is justified when its benefits are highly uncertain now (Ranger et al. 2013, p.255). Hence, using low-regrets measures, and avoiding irreversible investments as much as possible, are important sub-elements of this key element of Adaptive Planning (Ramsbottom and Sheppard 2017, p.5).

- Through **'structural / engineered flexibility'**. This type of flexibility was incorporated in several measures. Structural flexibility can be delivered, e.g. by over-rotating the TB in case of greater SLR than predicted, by using 'safety margins' (over-engineering infrastructures to cope with greater change than predicted), by purchasing land to construct FRM measures in the future, etc. If structural / engineered flexibility is considered, flood defence structures can be adjusted or improved in the future at limited additional costs. Including structural flexibility is effective where the additional cost is low (Ranger et al. 2013, p.248-249).
- **By seizing of opportunities to integrate** the proposed measures with other agendas or multi-objective investments (Jeuken et al. 2014, p.1), and mainstreaming climate adaptation into works for maintaining or improving defences (Ramsbottom and Sheppard 2017, p.5).
- **By having the possibility to alter the timing for implementing measures**. In the APs approach, a measure can be postponed or advanced in time, according to changes and new information that arises.

These were the main ways of incorporating and enhancing the robustness and flexibility into the general Plan, its pathways and measures. However, in a FRM plan, *flexibility* tends to be limited by the *nature* and *lifespan* of measures already applied, namely flood protection structures (e.g. barriers) which are implemented for many decades. The pathways of the TE2100 are apparently flexible into the future, in part, because new large-scale structural measures could be postponed. Other types of measures (e.g. soft protection, flood-proofing buildings), which can be applied in small steps, only contributed partially to the Plan, it contains mostly measures to improve the existing defence system (Jeuken et al. 2014, p.18).

BOX 4: incorporating *flexibility* (*dynamic robustness*) into a Plan, its pathways, and measures

Some of the main ways of incorporating ***flexibility* (*dynamic robustness*)** into a Plan, or its measures, are (Note 125):

- Using measures that are suitable over a broad range of plausible future scenarios, i.e. robust measures (e.g. early-warning systems) (Reeder and Ranger 2011, p.3).
- Designing a measure in a way that allows it to be adjusted (adapted, changed) over time (e.g. a seawall with large foundations that, in the future, can be raised instead of replaced). Yet, this type of flexibility might mean higher costs (e.g. larger foundations). In many cases, such costs are compensated by the benefits, but in others, this flexibility may not be feasible due to costs or constraints or may not solve the whole problem (Reeder and Ranger 2011, p.3).
- Building-in (embedding) flexibility into the broader adaptation strategy / plan (rather than in individual measures), by sequencing the implementation of diverse measures over time in a way that allows the system under consideration to adapt to changes over time (SLR) and, at the same time, keeping alternative measures (options) open to cope with plausible different future climate scenarios – which implies using the 'Route-map / APs approach' (Reeder and Ranger 2011, p.3). This was the approach devised and used in the TE2100 Project. The idea underlying the 'Route-map approach' ***is to design 'packages' of adaptation measures that can be implemented over time'*** (Reeder and Ranger 2011, p.8). The approach allowed the design of several adaptation pathways '*that are appropriate to cope with the plausible range of climatic changes that could be seen by 2100*' (Reeder and Ranger 2011, p.5).
- Including '*no / low-regrets'* measures and *win-win* measures in the route-map (e.g. resilient urban development, emergency plans); such type of measures helps to increase the *robustness* of the overall plan and its strategies (pathways) (Reeder and Ranger 2011, p.11-12; Ramsbottom and Sheppard 2017, p.5; Ranger et al. 2013, p.255). Applying *low-regrets* measures first is a cost-effective way of 'buying-time' before making 'more irreversible' decisions or investments (e.g. a new expensive barrier); it helps to gain time to monitor, learn and make better decisions (Reeder and Ranger 2011, p.11-12; Ranger et al. 2013, p.248-249, 255). This is related with avoiding irreversible decisions as much as possible (Ramsbottom and Sheppard 2017, p.5).
- Using measures that reduce risk and increase resilience (e.g. emergency plans) (Reeder and Ranger 2011, p.12).

In synthesis, the development of *robust flexible strategies* with the 'Route-map / Adaptation Pathways approach' (APs) is one of the main elements of the *Dynamic Adaptive Planning approach* of the TE2100 (Jeuken and Reeder 2011, p.2, 4). To deal with uncertain change and future conditions, the TE2100 Project decided to develop a '*dynamic adaptive plan*' that was *robust* and *adaptive*, and, to construct such plan, it devised the 'Route-map / APs approach'. The Team sought to *build-in* '*dynamic robustness'* (*flexibility*) into the Plan and its measures, and the 'APs approach' was essential to achieve this. Such '*dynamic adaptive plan'* should include a '*robust and flexible*' set of measures.

The production of '*flexible adaptable Options*', i.e. pathways, and the analysis of thresholds that it implied, were essential to develop a plan (manage flood risk until 2100) that was '*adaptable* / *adaptive*' and '*dynamic robust*' in the face of change and uncertain future conditions. *Dynamic robustness* (*flexibility*) and *adaptability* are basic properties of the Plan (TE2100 Appendix L 2009, p.2-4, 10, 199). The adoption of the 'APs approach' to design possible pathways (of adaptation / FRM) is one of the main and most innovative elements of the TE2100 (Ranger et al. 2013, p.233, 239, 258). The development of adaptation pathways (*Options*) is one of the essential elements of the *Adaptive Planning approach* of the TE2100 (Ramsbottom and Sheppard 2017, p.5). The development of *robust flexible strategies*, which was done by using the 'APs approach', is one of the main elements of the Adaptive Planning approach of the TE2100 (Jeuken and Reeder 2011, p.2).

In sum, this element consisted of developing a '*robust and flexible*' set of measures to deal with uncertain changes, with the 'Adaptation Pathways approach' (APs). This required searching for measures that are *robust* and / or *flexible* and preparing a '*robust flexible*' set of measures. The set of measures should contain the following properties: *robustness* (ability to achieve the objectives despite how the future unfolds and be effective under a wide range of future scenarios), *flexibility* (ability to be changed over time as changes occur or as new information arises, and keep options open / not foreclose future options), and be *no / low-regret* whenever possible (with properties like *reversibility*, adaptability, etc.). By using the 'Route-map / APs approach', it was possible to design of several packages of sequenced measures, i.e. pathways. Each pathway can be deemed a *strategy*, i.e. a set of measures sequenced and implemented over time to manage changing risk; and several pathways were designed. Together, the various pathways form a *robust* and *adaptive* plan.

Key-element #4

The TE2100 Plan has defined a monitoring and review system, including the indicators to be monitored and 'decision-points' (that can be identified based on the observation of certain indicators). This monitoring and review system constitutes other key-element of the TE2100's Adaptive Planning approach (Ranger et al. 2013, p.233, 239, 258). The TE2100 Plan accounts for the monitoring of local and global changes, and for its own reassessment and review. It identifies the main indicators that must be monitored, specifies important decision-points, and explains how to estimate them (it defines a trigger-value for certain indicators, which will trigger a decision) (Jeuken et al. 2014, p.10, 22). The reassessments of the Plan must be informed by the monitoring results (thus, monitoring and the creation of long-term records should be a priority) (Reeder and Ranger 2011).

The decision-points will help to ensure that measures (to manage changing risk) are timely taken and cost-effective (Ranger et al. 2013, p.233, 239, 258). The TE2100 Team has estimated decision-points (which precede critical thresholds); to this end, several scenarios were used to assess when it will be necessary to adapt at earliest and at latest, considering the lead-time required for designing and constructing a certain measure; and then, based on monitoring results, it will be possible to see if decisions should be postponed or taken earlier (Jeuken and Reeder 2011, p.6).

Two factors are deemed essential for the effectiveness of the 'Route-map approach' and of TE2100 Plan as an *adaptive plan*: (1) the monitoring of local changes, of the progress of climate change at global

scale (as it is experienced and forecast) and of new scientific insights; and (2) the periodic review of the Plan, and adapting the Plan and the physical system to changes early in time (as time progresses) (Met Office 2012; TE2100 Appendix L 2009, p.10; Jeuken and Reeder 2011, p.6). Ongoing monitoring is, and will be, crucial to ensure that changes are timely detected and any necessary alterations to the Plan or its *Options* are made (Reeder and Ranger 2011). For example, monitoring and the review of Plan are essential to see if a switch to other action / measure, or to another HLO (pathway), is needed, in light of changes observed in the indicators and new information. Such a switch will be possible with no significant wasted investment in the early decades of the Plan (HM Treasury 2009, p.27-28). Moreover, the adaptive approach of the TE2100 implies a careful monitoring of drivers of risk to ensure that FRM authorities are not taken by surprise and forced into emergency measures (Wong et al. 2014, p.388).
Since the Plan's publication, the monitoring programme has been conducted, and has kept track of changes in the indicators, and the indicators have been refined (Ranger et al. 2013, p.233, 239, 258). The TE and flood risk will change over time, but the Plan *'can accommodate future change and can be adjusted when the rate of change is either faster or slower than originally predicted*. *This flexibility was included to ensure that the actions in the Plan remain appropriate and are implemented at the right time'* (EA 2016, p.15). The ongoing monitoring of local and global changes, and the regular re-appraisal and review / update of the Plan, ensure that the plan remains 'adaptable' (Ramsbottom and Sheppard 2017, p.5, 12-13), and constitute a key-element of the *Adaptive Planning approach* of the TE2100.

Key-element #5
To develop a long-term *dynamic robust adaptive plan* (a FRM plan) in the face of uncertainties about future changes, the TE2100 Project has followed a 'decision-centred' planning process with several steps, which is associated to continuous and iterative risk management (ongoing process of Adaptive Planning / Managed Adaptive approach). This continuous and *decision-centred* process is deemed one of the main innovations of the TE2100, and an innovation in the field of climate adaptation and FRM (Ranger et al. 2013, p.233, 239, 258). The *Dynamic Adaptive Planning approach* of the TE2100 presupposes an ongoing, iterative, learning-oriented planning and decision-making process, which allows that the Plan (and its strategies) are refined iteratively, incorporating new data over time – and thus, adapted (Ranger et al. 2013, p.257).

In synthesis, the main elements found in the TE2100's planning approach that were essential to develop an adaptive plan under uncertain future changes and conditions, were:
1. The generation of a wide range of plausible future scenarios of SLR, and their use to test robustness of measures and pathways. Climate projections were generated during the development of the Plan.
2. The identification of 'thresholds' (which implied a 'threshold analysis').
3. The creation and use of the 'Route-map / APs approach') to develop *robust flexible strategies*, i.e. pathways (sets of sequenced measures to manage flood risk).
4. The definition of a monitoring programme, including indicators and decision-points.
5. The *decision-centred* process associated to the approach of *iterative risk management* (also called *Managed Adaptive approach* or *Dynamic Adaptive Planning approach*) (Ranger et al.2013, p.233, 239, 258; TE2100 Appendix L 2009, p.3,4).

The TE2100 has been largely quoted as a leading example of how a major long-term planning project should address the emerging risks and challenges associated with climate change and climate adaptation: developing an *adaptable plan* able to manage changing risk. The elements mentioned were essential to develop an *adaptive plan* to manage flood risk in the TE until 2100 (TE2100 Appendix L 2009, p.3). Such elements are interrelated and constitute the main innovations of the TE2100, and arose from a long process of public engagement and learning (Ranger et al. 2013) (Note 126).

6.2. How the Plan is '*adaptable*'

The TE2100 Plan is an *adaptable plan*. It was devised to be '*adaptive*' to change and uncertain future conditions. The TE2100 Plan itself, and some authors, have explained how the Plan is *adaptable* to a changing future environment (changing climatic and socioeconomic conditions that may arise in the next 100 years). Table 6 shows how the Plan is *adaptable*: it identifies the main ways through which the Plan can be adapted and forms of addressing change and an uncertain future over time.

Table 6. How the TE2100 Plan is adaptable: ways through which the Plan can be adapted

The pathways (HLOs) are themselves flexible	In the 'APs approach', each pathway (*HLO / Option*) is itself flexible, e.g. it is possible to shift from one measure to another (TE2100 Appendix L 2009, p.3; Lowe et al. 2009, p.89; Reeder and Ranger 2011, p.9; Jeuken and Reeder 2011, p.4; Jeuken et al. 2014, p.18). Each *Option* (pathway) contains several sequenced measures (actions) and shows when each measure ceases to be effective (and a new measure is needed) (EA 2012, p.38, 39). Each *HLO* / pathway is a '*package'* of measures sequenced and implemented over time, and the route-map shows 5 different possible pathways (*HLOs*) (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8; Jeuken et al. 2014, p.18).
Ability to change (switch) from a pathway to another	In the 'APs approach', not only are the *HLOs* (pathways) themselves *flexible*, but it is also possible to move from one HLO (pathway) to another depending on the rate of change that actually occurs (TE2100 Appendix L 2009, p.4; Lowe et al. 2009, p.89; Reeder and Ranger 2011, p.9; Jeuken & Reeder 2011, p.4; Jeuken et al. 2014, p.18). The 'APs approach' allows switching from one *Option* (pathway) to another. If the rate of change requires so, it may be necessary to switch to another *Option* that can cope with the new conditions (EA 2012, p.39). Thus, it is beneficial to consider higher (worse scenarios) in terms of robustness analysis (TE2100 Appendix L 2009, p.3).
Having various pathways	More than one pathway (*Option*) is available to manage flood risk over the century (EA 2012, p.38, 39). The Plan contains various *Options* (pathways) to cope with the plausible future increases in water level in the TE (from the current level until 2100, under different SLR scenarios) (EA 2012; in Bloemen et al. 2018). The Plan identifies different *Options* (pathways) to cope with different levels of water level rise and indicates the thresholds at which each *Option* will be needed (HM Treasury 2009, p.13). Together, the *HLOs* were designed to span the estimated range of plausible future scenarios of water level rise in the TE until 2100 (up to 4,2m) (Jeuken and Reeder 2011, p.4; Ranger et al. 2013, p.250; Reeder and Ranger 2011, p.8).
Stepwise implementation of measures + Keeping options (alternative measures) open	In the APs, measures are implemented iteratively over time to maintain risk below target levels (stepwise), while keeping options (alternative measures) open to manage future risk (Ranger et al. 2013, p.249). *Keeping options open* is a way of maintaining *'flexibility*' to cope with possible future change (ibid; Jeuken and Reeder 2011, p.4). Given the uncertainty about future water levels, it would be risky to commit to a given pathway or measure for the long-term based on the 'best' projections of SLR available at a certain moment (the choice would be highly sensitive to the existing projections) (Reeder and Ranger 2011, p.9; Ranger et al. 2013, p.250). As the future conditions are not exactly known, the choice of the '*end of the century option'* (the pathway for the long-term) will be made around 2050 in a review of the Plan based on the then-existent conditions (EA 2012, p.38, 39). The HLOs that were designed do not diverge significantly until SLR reaches 50-60cm, and then, it is possible to shift between pathways apparently at low costs (Ranger et al. 2013, p.250). The route-map (general strategy) is designed a way that, in an early period (when uncertainties are higher), there are virtually no costs of switching of pathway (ibid).
Possibility of adjusting / adapting pathways over time	The Plan / Strategy can be changed over time: the pathways are designed to be adjusted over time or as more is learnt about the future or as conditions change (Ranger et al. 2013, p.249, 247, 233). The timing of measures, and the measures themselves, can be changed over time (Ranger et al. 2013, p.249). Each HLO / *pathway* can be adapted *to the rate of change* that is experienced over time (TE2100 Appendix L 2009, p.3; Reeder and Ranger 2011, p.9; Ranger et al. 2013, p.250; Lowe et al. 2009, p.89; Jeuken and Reeder 2011, p.5).
Changing the timing of new measures	When an action ceases to be effective, a new action must be implemented, but the decision to do this must be made some years before. The timing of actions may be altered as new climate scenarios arise or changes occur over time; thus, the 'decision date' and the 'implementation date' may be advanced or postponed according to the changes observed (EA 2012, p.38, 39). The 'APs approach' allows for changing (modifying) the timing of new actions, according to the rate of change observed. If conditions change faster, actions are brought forward; if they change slower, actions are delayed (ibid). In the Plan and its route-map, the timing of actions can be brought forward if the rate of SLR comes closer to the maximum projected; e.g. the implementation of a 'new barrier' may be *brought forward or pushed back if monitoring of conditions in the TE suggests climate change is occurring at a faster or slower rate than currently projected* (EA 2016, p.18).
Adaptability / Flexibility to be adapted to changing	The TE2100 Plan is *adaptable to change* (changing climatic and socioeconomic conditions that may develop over the next 100 years), e.g. the *Action Plan* can be adapted to changes observed in the indicators. The Plan can be adapted in the following ways: by adjusting the timing envisaged for a new measure (the 'implementation point' and 'decision point'); by switching to a new measure or to another pathway; or by modifying / changing a measure itself (within a given HLO). These are the main ways to address and respond to changes as these are monitored and identified, or each time the TE2100 Plan is reviewed or updated (EA 2012, p.35, 36, 39). The Plan can be adapted

conditions over time	to changes over time: it is possible to adjust the timing of measures, as well as the measures (shift from a measure to another, or from a pathway to another) as conditions change (Ramsbottom and Sheppard 2017, p.19). The Plan *'can accommodate future change and can be adjusted when the rate of change is either faster or slower than originally predicted; this flexibility was included to ensure that the actions in the Plan remain appropriate and are implemented at the right time'* (EA 2016, p.15). To ensure that the Plan remains *adaptable* and *fit for purpose* (EA 2012, p.36, 38), indicators will be monitored throughout the Plan's lifetime. A re-appraisal (review) of the Plan must be conducted every 10 years at least and must be informed by the monitoring results. Certain values in the indicators may act as triggers of changes and require the anticipation or postponing of a measure (EA 2012, p.39). The monitoring and revaluation system is crucial to allow the adjustment of the Plan, e.g.: if monitoring indicates that SLR is happening faster / slower than predicted, then a decision-point may be anticipated / delayed. Moreover, the Plan is reassessed as new information emerges, and measures may be brought forward or postponed (HM Treasury 2009, p.13). The monitoring, and Plan's reviews, are essential to see if a switch to another action or HLO is needed, in the light of changes observed in the indicators and new information (HM Treasury 2009, p.27-28). In addition, the Plan is *flexible* enough to deal with accelerating / decelerating effects of climate change in relation to current predictions, due to its adaptable programme of measures (the *Action Plan*) (London Councils' TEC 2007).
Diversity / variety of measures	The Plan seeks to manage flood risk through diverse measures (Lowe et al. 2009, p. 86). The Plan (and its preferred *Options*) contain diverse FRM *measures* (actions), e.g.: measures to adapt the existing flood defence system (phased modification of the TB), improving existing flood defences, building new defences, 'making space for water', local flood defences, building-resilience measures for new and existing urban development, flood warning systems and forecasting, emergency preparedness (EA 2012; Bloemen et al. 2018; Ramsbottom and Sheppard 2017, p.19; Lowe et al. 2009, p. 86). The Plan contains (mostly) measures to reduce the probability of flooding (e.g. protection / defence measures), but also measures to reduce the impacts of an eventual flood for existing and new spatial development and to make the floodplain safer (considering the protection provided by existing defences and their risk of failure or overtopping) (EA 2012, p.36; London Councils' TEC 2007). The Team sought to provide new ways of managing flood risk sustainably beyond building higher and higher walls, e.g. allowing undeveloped areas to flood (managed realignment) or store flood water (London Councils' TEC 2007), spatial planning-related measures (EA 2012, p.36).
Inclusion of low- / no regrets measures	The Plan proposes 'low-regret' measures for the near-term. The route-map includes *low-regrets measures* (measures that work through the whole range of change) (Reeder and Ranger 2011, p.6). The Team strategically defined early actions that are *low-regret* in the route-map (Reeder and Ranger 2011, p.9, 11). In the TE2100, 'low-regret measures' are those that reduce risk immediately and cost-efficiently under a wide range of climate scenarios (they are 'low-regret' rather than 'no-regret' because they involve some opportunity cost) (Ranger et al. 2013). A low-regret measure is '*improving (raising) existing defences around the TB*'; this will cost-beneficially reduce risks and, at the same time, leave open '*the option to scale up action in the future'* and 'buy time' to monitor and learn before making a major investment (Ranger et al. 2013, p.248-249).
Incorporating structural / engineered flexibility; adaptation of engin. structures	Engineering structures may be designed so that they can be adapted to changing conditions, e.g. by constructing foundations of new defences able to withstand higher flood water loadings, or by designing barriers or defences that can be modified in the future; though the initial cost of adaptable structures is often higher than structures that do not allow future adaptation, this can lead to significant cost savings over the structure's lifetime (EA 2012, p.39). The Plan has measures involving adaptation of engineering structures. Incorporating 'structural / engineered flexibility' allows that defence structures are adjusted or improved in the future at limited additional costs. Structural / engineered flexibility is present in some measures, e.g.: over-rotating the TB in case of greater SLR, designing 'safety margins' (over-engineering structures to cope with greater change than predicted), or purchasing land to build FRM measures (Ranger et al. 2013, p.248-249).
Safeguarding land for future FRM measures	Some FRM measures will require land (e.g. new or enlarged defences, new barriers, areas for habitat creation or flood storage). The allocation of land through the spatial planning system must be informed and guided by the requirements of the TE2100 *Options*, to guarantee that these *Options* remain viable (EA 2012, p.39). Spatial development in areas that will be needed for future FRM measures (e.g. for defences, flood storage, or managed realignment) could hinder such measures, therefore, the TE2100 Plan recommends the safeguarding of land via land-use planning. This measure entails '*opportunity costs'* but provides '*options value*'. If the *opportunity cost*s are minimized, the value of maintaining options available can be large and justified (HM Treasury 2009, p.28).
Adaptation of new infrastructure / projects (main-streaming)	Some projects and infrastructures projected for the TE have major implications for future FRM *Options*, e.g. new port infrastructures (the London Gateway Port at Shell Haven, which will require free access to navigation) and new transport links (e.g. a new crossing over the TE that might be combined with a new flood barrier). These projects must be used as opportunities to integrate adaptation / FRM actions. Some actions envisioned in the TE2100 may be brought forward, if this is justified by synergies and funding opportunities from other stakeholders (EA 2012, p.39). The Plan considers the possibility of bringing forward some of its Options and actions in order to seize the momentum of new infrastructure developments.

Table 6. The main ways through which the TE2100 Plan is adaptable. Source: own elaboration, based on EA 2012; Lowe et al. 2009, p.89; Reeder and Ranger 2011, p.9; Bloemen et al. 2018; Ramsbottom and Sheppard 2017, p.19; EA 2016.

7. CURRENT STATUS OF THE TE2100 PLAN

7.1. INTEGRATING THE TE2100 PLAN'S RECOMMENDATIONS INTO OTHER SPATIAL PLANS AND POLICIES

After the publication of the TE2100 Plan (in 2012), the 'implementation partners' should deliver their recommended actions (London Councils 2018). Since 2012, the Local Boroughs have been asked to carry out two main actions, in short- and medium-term:

- Include a reference to the TE2100 Plan in their policy documents, e.g. in the Local Plan, Economic growth / regeneration Strategy, and Riverside Strategy; in order to ensure that developers know that local policy requires them to take the TE2100 Plan into consideration. In January 2018, most of the affected boroughs had included a reference to the Plan into their policies or plans. The EA has worked with Boroughs, to improve these references when Local Plans are updated (London Councils 2018).
- Plan riverside areas by giving space for improving and raising flood defences and floodwalls, providing more access to the river and enhancing riverside environment. This has been carried out in Greenwich (Charlton Masterplan). In the next years, several defences and floodwalls will need to be raised. The definition of requirements for constructing new homes that allow defence raising, and safeguarding public space for new defences, will enable cost savings (London Councils 2018).

Besides, the EA has worked with the Greater London Authority to include references to the TE2100 Plan in the *Environment, Housing and Transport Mayoral Strategies* and *London Plan*. This facilitates the inclusion of TE2100's recommended actions in Boroughs' plans (London Councils 2018). In 2012, some policy documents already identified the TE2100 Plan as helping to deliver their objectives (e.g. the *Climate Change Adaptation Strategy* of the Greater London Authority and the *Thames Gateway Eco-Region Prospectus* of local governments) (EA 2012, p.2). The TE2100 Plan is also linked to adjacent Catchment Flood Management Plans (CFMP) which address non-tidal flood risk management, and the Shoreline Management Plans (SMP) of Kent and Essex which address coastal flood and erosion risk management (EA 2012, p.5). The TE2100, CFMPs and SMPs had to work well together (ibid).

7.2. THE 2016 MONITORING REVIEW

In December 2013, the Thames Estuary experienced the most significant storm surge of the latest 60 years, which served as a test for the local defences, namely the TB (which recorded the highest tide since the 1994).[61] Moreover, during the winter of 2013/2014, record levels of rainfall were registered in many parts of the Thames River catchment, relevant floods occurred in areas upstream of London, and the TB closed several times to reduce flood risk in areas of west London (EA 2016, p.4).

Through its monitoring and review programme, the TE2100 Team has identified (physical and socioeconomic) changes that have occurred in the Estuary (EA 2016, p.5). The 2016 Monitoring Review Report of EA (EA 2016) describes the changes that took place in the Estuary between 2010 and 2015 and expected in the future (based on the 10 indicators) and explains how changing conditions (that influence flood risk) have been monitored (EA 2016, p.15). Essentially, the 2016 Monitoring Review process assessed: what physical and socioeconomic changes occurred in the TE (during 2010-2015), if the broader objectives of the Plan are being met, whether the recommended action have been taken in line with the Plan, and whether the flood defences are being managed as recommended by the Plan. In particular, it assessed whether there were any changes occurring the Estuary that suggested that the Plan's Recommendations should be reviewed earlier than planned (EA 2016, p.16).

The first 5-year Monitoring and Review Report (of 2016) provides the latest monitoring results (see Note 127 as well as Note 123). In general, the changes observed during 2010-2015 are in line with the

[61] The surge of 5-12-2013 was the most significant in the UK in the last 60 years, with highest tide since the completion of the TB in 1984.

expectations of the (2012) Plan (EA 2016). The 2016 Monitoring Review Report presents the results for each of the 10 indicators. More specifically:

- During 2010-2015, the changes in the physical environment (that affect flood risk) happened as the Plan expected, hence, the type and timing of the FRM actions defined in the Plan remained right in 2016. For instance, SRL in the Estuary is occurring in line with projections.
- Between 2012 and 2016, the number of people living and working in the Estuary floodplain, and the number and value of assets and infrastructures, have increased as the Plan expected, and this is projected to continue. Thus, flood risk to people, businesses, assets and ecosystems continues to rise. The EA has worked with the stakeholders responsible for managing flood risk and for implementing the actions recommended in the Plan (implementation partners) and will continue to do so.
- The conditions and reliability of most flood defences remain high. The number of closures of the TB did not increase over time, despite the large number of closures in 2013/ 2014.
- The scenarios and models used in the Plan remain valid, and the course that was envisaged to manage the flood risk until 2100 is still right.
- The FRM measures (actions) have been in accordance with the Recommendations of the Plan, and the standards of protection remain high. The '10-year asset management programme' (for the flood defence system) has ensured that the standards of flood protection in the Estuary remain high and in line with the Plan's recommendations (EA 2016).

The 2016 Monitoring Review Report shows that, although there were changes in the TE between 2010 and 2015, in general these changes were in line with the projections of the Plan (changes occurred as expected in the Plan). Hence, in 2016, there was no need to revise the recommended policies and actions; the Team considered that the actions (taken and planned in the Plan) remained adequate. The nature and timing of the FRM actions defined remain the right choices at the 2016's review (EA 2016).[62]

The EA Team will continue to monitor changes in the TE, and the monitoring results will inform the next review of the Plan (scheduled for 2020). The Team will also continue to review the Plan – its recommended policies, *Options*, and actions – using the latest science and lessons learned (EA 2016).

8. Effects and outcomes of the TE2100 Plan

8.1. Positive outcomes and advantages of the Route-map approach

In practice, the TE2100 Project demonstrated that, by using the 'Route-map approach', it is possible to make decisions more 'robust' under deeply uncertain future conditions and changes (namely decisions involving high-stakes) (Reeder and Ranger 2011, p.2, 4; Jeuken and Reeder 2011, p.5).

The Route-map approach constituted a way of incorporating and designing ***dynamic robustness*** (*flexibility*) into the adaptation plan itself and its strategies (pathways), in the face of deep uncertainties about future (climatic and socioeconomic) conditions and changes (Reeder and Ranger 2011, p.8). Instead of making a potentially irreversible decision now about the 'best' measure(s) to manage future risk based on a given scenario (which could lead to maladaptation if the expected scenario did not occur), the 'Route-map approach' encourages user to consider 'what if' scenarios and take more flexible stance regarding climate adaptation (Reeder and Ranger 2011, p.8; Ranger et al. 2013, p.250, 258). In the Route-map approach, diverse measures are implemented over time, and alternatives (options) are left

[62] In general, the 2016 monitoring results were aligned with the projections of the Plan, hence, these results did not trigger an earlier review of the Plan. The 2016 Monitoring Review Report provides recommendations for improving the understanding of the Estuary and the monitoring programme. The 2016 Report contains proposals for further work on each indicator, and this should start in the short- and medium-term to ensure that relevant data is available for the next review and update of the TE2100 Plan (in 2020) (EA 2016).

open to cope with plausible (different) future conditions (Reeder and Ranger 2011, p.3). Therefore, *decisions are made over time to continuously adapt while maintaining as much flexibility as is desirable about future options'* (Reeder and Ranger 2011, p.8). The APs approach seeks to build-in *dynamic robustness* (flexibility) in the general plan as a way of dealing with an uncertain future and change.

Moreover, the 'Route-map approach' seeks to ensure that whatever short- / mid-term measure is taken, it is set within a framework (pathway) that will not result in maladaptation if climate change progresses at a different rate from what was predicted as 'the most probable future' when the Plan was designed (Reeder and Ranger 2011, p.8; Ranger et al. 2013, p.255) (e.g. the initial High++ scenario (4,2m) was revised (to 2,7m), which made no difference to the short-term investment plan). It also promotes an adaptive approach regarding climate adaptation that is more cost-effective and avoids *maladaptations* since the outset of the Plan (Reeder and Ranger 2011, p.13; Jeuken and Reeder 2011, p.4).

The Route-map approach reduces the dependence of decisions on any climate scenario, therefore, stimulating a *more robust planning* (Reeder and Ranger 2011, p.13; Jeuken and Reeder 2011, p.4). The approach, and the resulting plan, are more '*scenario neutral*': decisions are not so dependent on information about the likelihood of different climate scenarios (Reeder and Ranger 2011, p.9; Ranger et al. 2013, p.254). This does not mean adapting to the worst-case scenario now, but having flexibility to deal with it, if necessary, in the future (Ranger et al. 2013, p.254).

The Route-map approach provided a way forward to tackle decision-making in the face of incomplete or 'imperfect knowledge' – i.e. deep uncertainty about future conditions and changes (Reeder and Ranger 2011, p.13). The TE2100 used this approach for FRM / adaptation planning purposes, and to deal with deep uncertainties that challenged planning (e.g. about future climate change effects on flood risk) (Reeder and Ranger 2011, p.2-3). The approach for developing the Plan explicitly addressed uncertainties around the projection of future climate, physical and socioeconomic changes in the TE (Lowe et al. 2009, p.86). The adaptive planning approach of the TE2100 is deemed a sensible way of moving forward in face of uncertainties about future conditions and changing risk, and it can cope with a '*large range of change*' if needed (Lowe et al. 2009, p. 85).

The Route-map approach developed and used in the TE2100 Project presented several advantages:

- It provides clear information on the timing and effectiveness of measures, by assessing under what conditions a measure could fail, and on what timescale (Ranger et al. 2013, p.255).
- In this approach, adaptation over time is not only determined by what is anticipated now, but also by what will be observed and learnt as time unfolds (Ranger et al. 2013, p.255).
- The approach helps in identifying low-regret measures and opportunities, but also potential in lock-ins (Ranger et al. 2013, p.255).
- The APs approach is robust to various sources of uncertainty, e.g. uncertainties about climate change, socioeconomic developments, resulting from lack of data, etc. (Ranger et al. 2013, p.255). It also encourages the user to take a more flexible approach to climate adaptation (Ranger et al. p. 258).
- It is simple, easy, and quick to apply (Jeuken and Reeder 2011, p.4). The APs approach does not need to take a lot of time or intensive studies. The 'route-map' and 'decision points' can be developed via a higher-level assessment using expert and stakeholder judgement (Ranger et al. 2013, p.257). Although there are complex 'scenario modelling tools' and 'computational tools' that can be used to assist the APs approach, in the TE2100, the APs involved a simple method (there was one dominant driver of risk relevant for the decision, and the economic justification for protecting London was so great that each Option was deemed 'low-regret') (Ranger et al. 2013, p.256). Moreover, the 'decision-centred' planning process, including the Route-map approach, presented several benefits: it did not take much time nor intensive studies, it helped to get an idea of the adaptation needs and

types of measures and options that are relevant, and identify information gaps; and the exercise can be repeated several times, with growing detail (Reeder and Ranger 2011).
- The Adaptive Planning approach of the TE2100 proved to be instrumental: it helped decision-makers to grasp the range of measures available, and how these can be assembled and sequenced into 'decision pathways' that provide a set of measures through the century (Zevenbergen et al. 2018).

Other important 'success factors' of the TE2100 Project were:
- The in-depth understanding of the Estuary and its processes, of the existing flood defence system, and the existing and future flood risk.
- The wide range of measures considered, the development of Options (pathways), and their appraisal to ensure that the selected options were feasible and adequate in terms of technical, economic, environmental and social criteria.
- The long-term perspective. It was possible to plan options for plausible conditions in the long-term future. The options envisioned cover a SLR up to 4 metres (Ramsbottom and Sheppard 2017, p.17).
- Clear communication of Project outcomes, e.g. the draft and final Plan, the list of actions needed to undertake it, information on the works needed, defence crest levels, etc.) (ibid).
- The involvement of stakeholders from the TE and London was crucial for the success of the TE2100, especially to ensure that the final Plan was compatible (as far as possible) with different interests concentrated in the TE. The ongoing dialogue with a broad range of actors and sectors, alongside with the large study programme undertaken, allowed a deeper understanding of issues that were critical to develop and assess the pathways (Lowe et al. 2009, p. 87).

8.2. National and international relevance and applicability

Until 2018, there has been no new example of implementation of an adaptive plan in the UK (of the scale of the TE2100). However, the value of the TE2100's Adaptive Planning approach and its potential applicability, are increasingly recognised. This approach has been discussed in several projects and initiatives in the UK. The principles underlying this Adaptive Planning approach were incorporated into guidance on FRM developed by the EA and *Lead Local Flood Authorities*. Moreover, the TE2100 experience led to a wider application of the APs' approach in the UK (Bloemen et al. 2018).[63] In theory, the Adaptive Planning approach of the TE2100, and its way of dealing with uncertain future conditions and changes, can be used in other situations of deep uncertainty and complexity about future climate change-related risks and natural hazards. Adaptive planning methods seem to be even more essential in contexts where various natural hazard risks overlap (Ramsbottom and Sheppard 2017, p.19).

8.3. Barriers, difficulties in, and disadvantages of, applying an Adaptive Planning approach

Some of the main barriers to, and difficulties found in the TE2100 in, applying an Adaptive Planning approach, namely the Route-map approach, are outlined next. These barriers have hindered the use of an Adaptive Planning approach in the TE2100, and / or the application of an adaptive plan.
- The use of a broad range of scenarios is more acceptable in the exploratory phase of the process (Jeuken et al. 2014, p.1).
- The identification of thresholds for some systems can be problematic if there is insufficient knowledge. In the TE2100, it was difficult to determine thresholds for impacts on local ecosystems.

---

[63] For example: the 'Coast Communities 2150 project, which developed an indicative long-term adaptation plan for Newhaven (South coast of UK), the *London Climate Change Partnership* which advocates the use of APs, and the London Assembly which asked the Mayor to prepare adaptation measures grouped into 'pathways of linked adaptation'. The 'Infrastructure Plan of the Mayor of London' calls for the use of APs in the development of water resource plans; the 'Thames Water' company and other water companies in the South East have investigated and designed APs; and the applicability of the APs in the fields of surface water flooding and heat waves has been explored (Bloemen et al. 2018).

Even though, it is possible to advance, by gradually postulating such thresholds and then subjecting them to more detailed modelling. The identification of thresholds is difficult for some systems (e.g. ecosystems), yet, if a threshold is potentially critical, it can be further researched and monitored, so that the route-map can be adjusted (e.g. a threshold is postulated and subjected to sensitivity analyses). Provided that the APs approach accounts for *potential surprises* and ongoing learning, it allows for adjustments to be planned in (Reeder and Ranger 2011, p.12; Ranger et al. 2013).

- In the 'formal appraisal' of pathways, a potential drawback is that the decision analysis methods used in it are often resource intensive. However, when high stakes are involved, a careful assessment (considering vulnerabilities and uncertainties) is usually justified (Reeder and Ranger 2011).
- During the public consultations, many stakeholders felt that it was difficult to comment on measures for the late century and easier to plan decisions for the near- and mid-term (EA 2012, p.9).
- Some structural flood protection measures taken in the past do constrain future options and choices. In part, the flexibility of the Plan (its pathways) was constrained by the nature and lifespan of some pre-existent measures (e.g. barriers that are in place for many decades) (Jeuken et al. 2014, p.1, 18).
- Though the TE2100 Plan was developed with input from stakeholders, the public awareness of the Plan remains low. This is explained, in part, by its distant timeframe in the future. Nevertheless, by including references to the Plan and taking the recommended actions, local Boroughs can better plan riverfronts throughout the next century (London Councils 2018).
- A disadvantage of the Route-map approach (as other approaches that seek to build in flexibility into the adaptive plan) is related to its greater overall costs. For instance, delaying a measure (e.g. the construction of a defence) can leave people temporarily exposed to storm surges, or imply expensive repairs to existing defences (as in the TE2100 case). Such trade-offs should be carefully assessed in during the Options' appraisal. In addition, the APs often requires detailed information about the local system (the FRM system, ecosystems), namely for identifying thresholds (Reeder and Ranger 2011).
- The monitoring and review (e.g. the reappraisal of Options) are complicated by the fact that the trends in some variables cannot be easily detected (Jeuken et al. 2014, p.1). The TE2100 case suggests that it is necessary to shift from probabilistic modelling to a greater focus on monitoring and observation, on an improved understanding of historical climatic variability, physical systems and processes, their representation in models, in order to improve projections / scenarios (Ranger et al. 2013, p.234).

Besides this, although the TE2100 Plan is relatively recent and has not been fully tested by time, experience has shown some barriers to its full application and to the adoption of some measures, e.g.:

- Difficulties in ensuring that land will be available for creating new intertidal habitat areas. It has been difficult to obtain land for this purpose; in some areas this will require managed realignment (breaching and realigning existing flood defences). Agreement on the availability of land is needed.
- The data produced in the TE2100 is not fully integrated with existing data sets, e.g. the EA's database on flood defence assets. Such database does not contain the best available and most updated data.
- The Plan proposes some that defence improvements form part of the *riverside landscape strategies* developed by local planning authorities, but the partnership work required for this has not occurred.
- The scarce 'integration' of studies about different sources of flooding: tidal and fluvial flood risk have been examined in detail in the TE2100; while studies focused on surface water and groundwater. However, their results have not been fully 'joined up'. The TE2100 Plan has not been linked with drainage plans for the defended areas (Ramsbottom and Sheppard 2017, p.17).

These are issues that need to be improved and which require further research and work. As the climate changes, it will be necessary to change the ways through which flood risk is managed. The TE2100, and its *Dynamic Adaptive Planning approach*, provided greater certainty about the current and future FRM measures and pathways available and the arrangements necessary to implement them (EA 2012).

CASE II – DELTA PROGRAMME (DP)

1. EXISTING FLOOD RISK MANAGEMENT SYSTEM AT THE BEGINNING OF THE DP

This section presents a description of the existing FRM system when the DP was initiated.

The historical background of Dutch flood risk management (FRM) is briefly outlined in Figure 24.

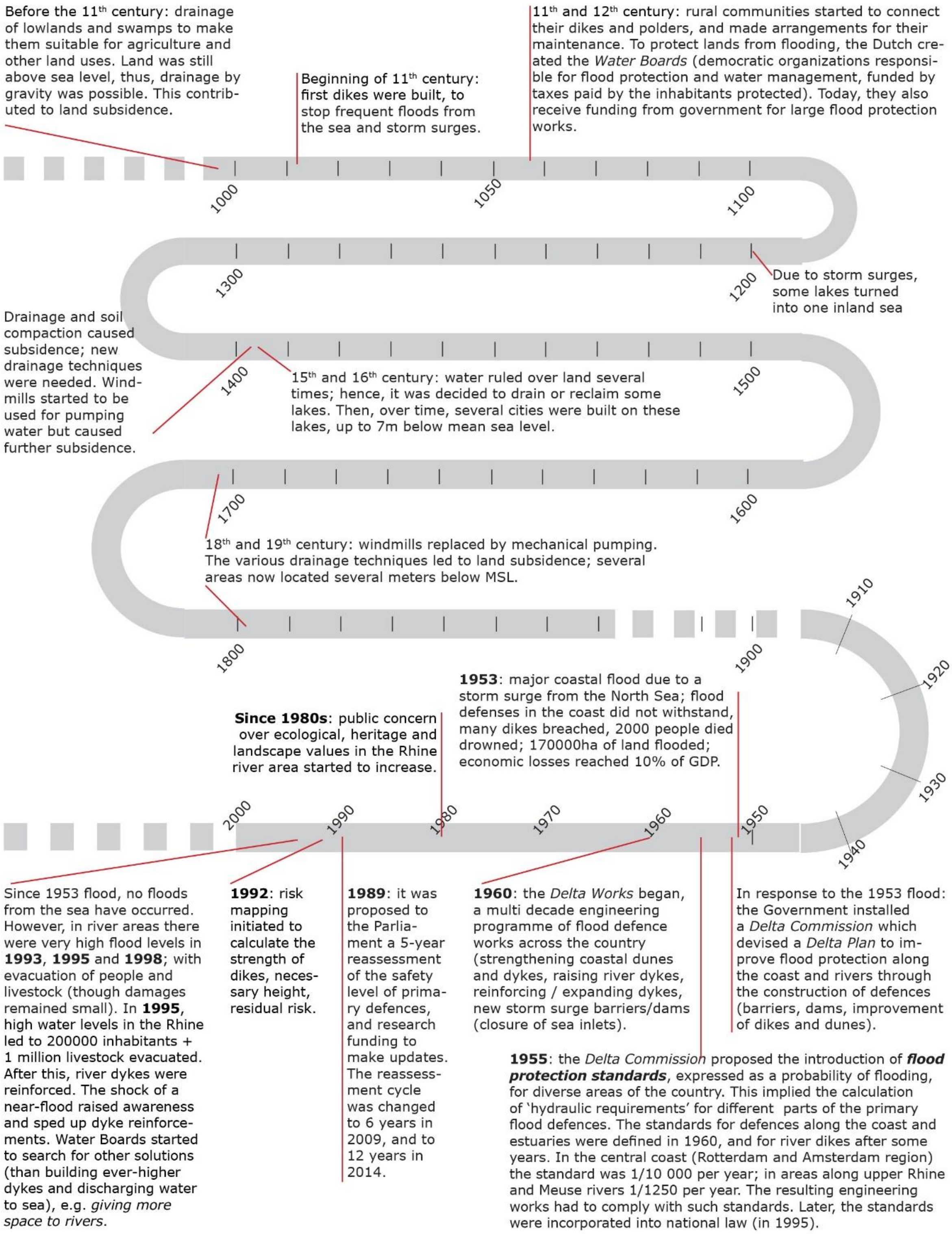


Figure 24. Chronology of the main facts in Dutch flood risk management (FRM).

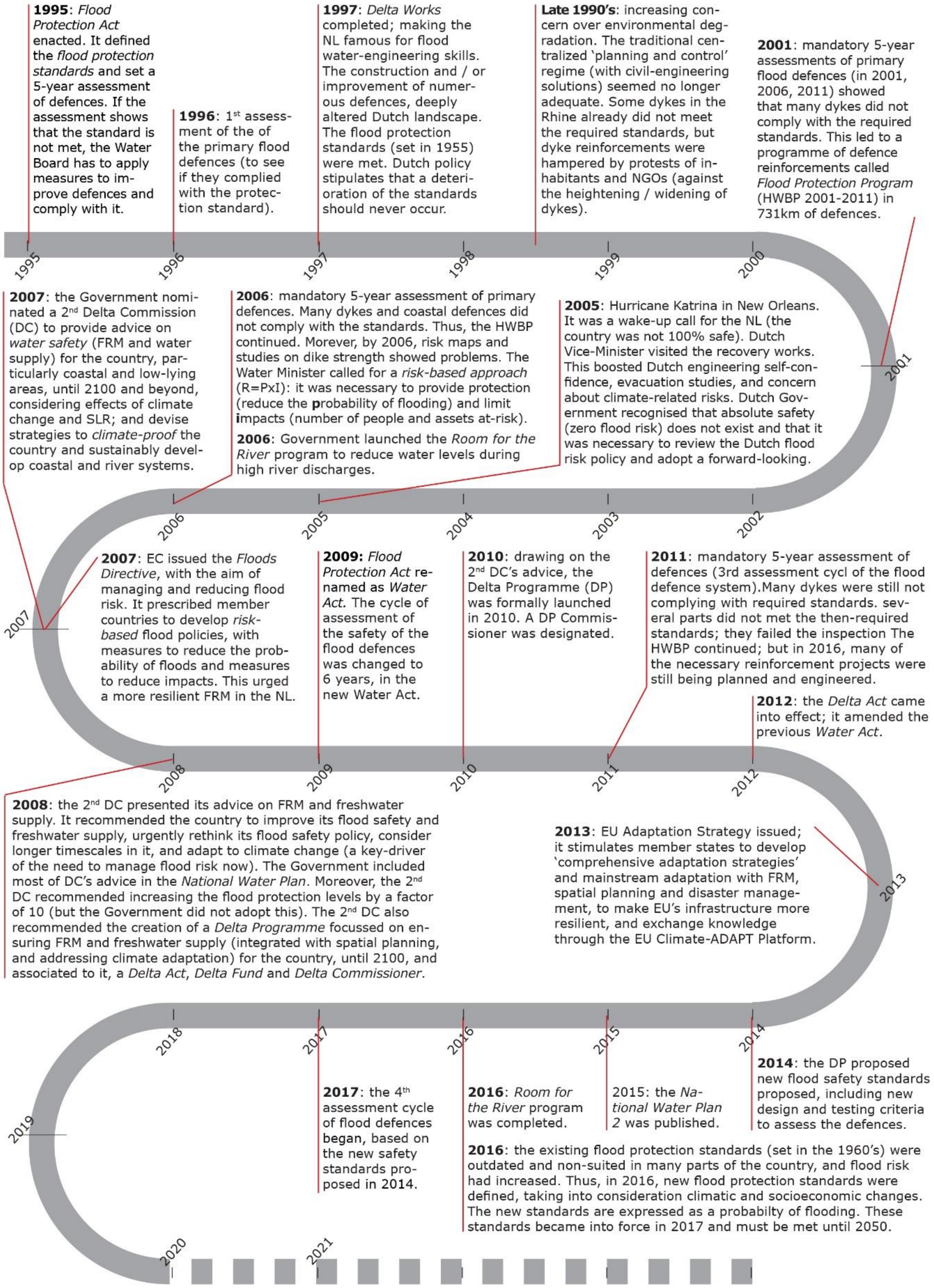


Figure 24 (continuation). Chronology of the main facts in Dutch flood risk management. Source: own elaboration based on Haegen and Wieriks 2015; Ritzema and Steensma 2018, p.2; Alphen 2015; Haegen 2014; Kabat et al. 2009; Petersen and Bloemen 2015; Buuren et al. 2016; Seijger et al. 2017; Restemeyer et al. 2017, p. 925; Jeuken et al. 2014, p.8; Marchand and Ludwig 2014, p.7; Klijn et al. 2016; DC (Delta Commission) 2008; Werners et al. 2016; Vink et al. 2013; DP 2013, 2014. For a detailed description see Note 200.

After the 1953 flood, the Government installed a *Delta Commission* (DC) to devise a *DeltaPlan* to improve flood protection along the coast and river floodplains through the construction of protection works, e.g. storm surge barriers, dams and large-scale improvements of dykes. In 1960, the *DeltaWorks* began – an engineering programme to construct and improve defences across the country, completed in 1997. In addition, in 1955, the DC proposed the introduction of *flood protection standards* for different parts of the country, expressed as a probability of flooding (Alphen 2015; Kabat et al. 2009; Haegen and Wieriks 2015; Ritzema and Steensma 2018; Petersen and Bloemen 2015).[64] The standard defined for the central coast (Rotterdam region and Amsterdam region) were 1/10000 per year. The resulting engineering works had to comply with these standards (Kabat et al. 2009; Alphen 2015).

These *flood protection standards* were incorporated into national law in 1995. In this year, the *Water Defence Act* was enacted (renamed *Water Act* in 2009): it set the legal basis for the *standards* (defined in 1955), and it mandated a 5-year assessment of the safety of defences by the Water Boards[65], to see if defences comply with their standards (Alphen 2015; Peterson and Bloemen 2015; Haegen and Wieriks 2015). If the assessment showed that a standard is not met, the Water Board had to apply measures to improve defences and comply with it (Alphen 2015). The standards require a minimum height and strength in dykes and defences around a certain area, to protect it from flooding from the sea, rivers or lakes; the area protected (enclosed) by dykes is called a *dyke ring* (Haegen and Wieriks 2015).

Dutch policy stipulates the *flood protection standards* must be maintained and that a deterioration of the safety levels should 'never occur' (Peterson and Bloemen 2015). Nevertheless, still in the 1990's, some defences in Rhine River did not meet the then-existing standards (Ritzema and Steensma 2018, p.5). The mandatory 5-year assessments of flood defences occurred in 2001, 2006 and 2011, and showed that many dykes (also called embankments) did not comply with the required standards (Klijn et al. 2016; DP 2013, p.20, 44; Kabat et al. 2009). This led to the creation (in 2001) of a multi-year programme of reinforcements comprising 731km of defences called *Flood Protection Programme* (HWBP); however, in 2016, many reinforcement projects were still being designed and engineered (Klijn et al. 2016).

Between 1134 and 2006, there were 337 extreme weather events which resulted in 1735 dyke failures due to storm surges and river floods; after such disasters dykes were usually heightened or strengthened. Worth mentioning, in 2006**,** the Government launched the 'Room for the River' program, with the aim of reducing water levels during high river discharges, by creating extra storage space along rivers (Ritzema and Steensma 2018, p.3-4). This marked a paradigm shift in Dutch FRM towards a more resilient approach (Buuren et al. 2016). It was completed by 2016 (Note 201).

In addition, in 2006, risk mapping exercises and studies on dyke strength revealed problems in dykes, and progressive insights about the design of dykes suggested that uncertainty was large. This led the Water Minister to call for a '*risk-based approach*', where *Risk* results from the multiplication of a *probability of flood* by the *potential impacts*, that is, R = P x I. In the light of this approach, it is necessary to provide flood protection (to reduce the increasing probability of flooding), but also to limit the potential impacts of floods (deal with the number of people and assets at-risk) (Buuren et al. 2016).

In 2007, the Government nominated a *2nd Delta Commission* to advise on FRM (or flood safety) and freshwater supply, for the country until 2100 and beyond, accounting for climate change and SLR effects. The 2nd DC published its advice in 2008, which recommended the Government to:

[64] After the 1953 flood, the Government decided to establish 'flood protection standards'. A standard expressed the *'exceedance frequency of the design flood level'* (Alphen 2015). It was assumed that a failure resulted from overtopping, and that a flood covers an entire dyke ring. Defences had to be designed and maintained according to the standard set (Alphen 2015; Kabat et al. 2009, p.451) (Note 202).

[65] The Water Boards are democratic organizations responsible for flood protection and water management. They were initially funded by taxes paid by the inhabitants and landowners protected. Now, they may receive additional funds from the central government (Alphen 2015).

- improve flood risk management (FRM, i.e. flood safety) and freshwater supply (FS) of the country, rethink its flood risk policy, consider longer timescales in it, and adapt to climate change (this was one of the main drivers from managing flood risk and water supply on the Dutch Delta now).
- increase the existing '*flood protection standards'* (in all dyked areas) by a factor of 10.
- create a *Delta Programme* (DP, a national policy programme for ensuring FRM and FS, and an associated *Delta Act*, *Delta Fund* and *Delta Commissioner* (Klijn et al. 2015, 2016; Vink et al. 2013; Seijger et al. 2017; Petersen and Bloemen 2015; Kabat et al. 2009; Ritzema and Steensma 2018; DC 2008; Alphen 2015; Werners et al. 2016; Buuren et al. 2016) (Note 203 and Note 204).

The Government integrated most of the DC's advice in the National Water Plan and decided that the protection standards would be updated later (Alphen 2015). Based on this, the DP was initiated in 2010.

1.1. The Dutch FRM system in 2010

The Netherlands is one of the best protected deltas in the world, especially since the construction of the *DeltaWorks*. Without the existing dykes, dunes and dams, more than half of the country would be regularly submerged. Nearly 60% of the country surface consists of low-lying areas vulnerable to floods from sea, rivers and lakes. 9 million people live, and 70% of the GDP is produced, in flood-prone areas (DP 2013, p.32; DP 2014, p.16; Klijn et al. 2015, p.846). Many areas lie at an elevation where they would be rapidly and deeply submerged in case of flood (DP 2014, p.65) (Figure 25) (Note 205).[66]

Around 65% of the area of the country is protected from flooding by dykes and dunes (Ritzema and Steensma 2018, p.1-2; Haegen and Wieriks 2015). In built-up areas inside dykes, nearly 75% of buildings can be damaged if the primary defence system is breached; in areas outside dykes there are also buildings; vital functions (e.g. hospitals, power plants) are often not flood-proof (DP 2014, p.30).

Over time, to protect low-lying areas from flooding, the Dutch built primary dykes along the coast and main rivers, and secondary dykes. The 2010 flood protection system was comprised of: the primary flood defence system which includes nearly 3700 km of primary defences (dykes, dunes, seawalls, dams and storm-surge barriers, along the sea, main rivers and lakes, which prevent and protect from flooding); and the secondary flood defence system (nearly 14000km of secondary dykes that prevent flooding from regional water courses) (Ritzema and Steensma 2018; Alphen 2015; Peterson and Bloemen 2015; DP 2013, p.32; Klijn et al. 2015, p.859). The FRM system includes several types of measures, namely dykes, storm surge barriers, seawalls, dune / beach nourishment, and, more recently, 'room for the river' measures (floodplain excavation, side channels, bypasses, dyke realignment) (Alphen 2015) (Figure 26).

Dutch flood policy has traditionally focused on reducing the probability of flooding via protection measures, e.g. strengthening or heightening dykes. To provide flood protection, the Dutch divided the country into dyke rings (areas protected by a closed system of dykes, dunes, dams, barriers and natural high ground); this is the 'polder approach': it involves the protection of low-lying areas through defences and their drainage through pumps and canals) (Ritzema and Steensma 2018, p.2,5,12). The country has 53 dyke rings and other small embankments, managed by Water Boards (Haegen and Wieriks 2015).

The Netherlands largely owes its existence to its flood defence infrastructure and drainage network, built over centuries, which requires constant maintenance, improvement, and adaptation to change (Klijn et al. 2016). The comprehensive system of flood defences ensures a high level of protection. The country is one of the best protected deltas with a highly advanced FRM system, but it will have to continue to work to ensure its safety. This Thesis focusses on the Rhine-Meuse Delta, Rotterdam region (Note 206).

[66] Nearly 40 % of the country's surface lies below mean sea level (Klijn et al. 2015, p.846). The west is 0 to 5m below MSL and most areas are only relieved by coastal dunes; the lowest point is north Rotterdam (7m below MSL) (Ritzema and Steensma 2018) (Note 205).

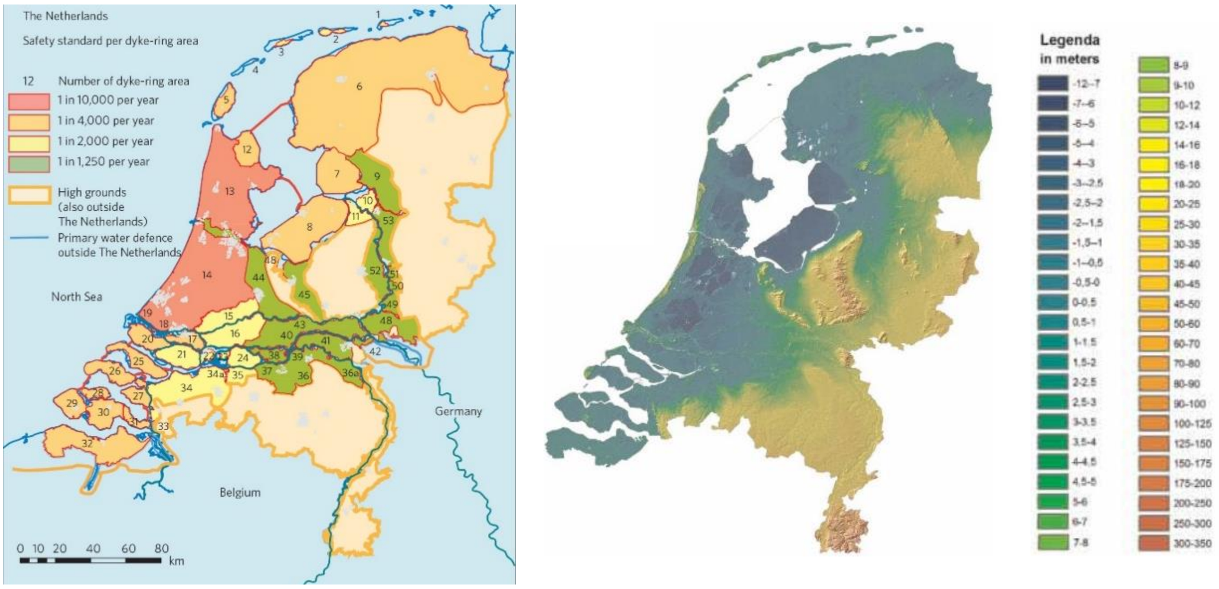


Figure 25 (left). The *flood protection standards* per dyke ring in 2009. Source: Kabat et al. 2009, p.450. The standards were: 1/10 000 per year in the western part of the country (coast, densely populated, where flood risk is mainly related with storm surges on the coast); 1/4000 per year in the southwest and northeast; 1/1250 per year around main rivers (Ritzema and Steensma 2018; Alphen 2015; Kabat et al. 2009). **Figure 25 (right):** Height of the surface area, showing the flood-prone and embanked parts. Dark blue areas are the deepest polders (reclaimed from lakes and sea). Source: Haegen and Wieriks 2015.

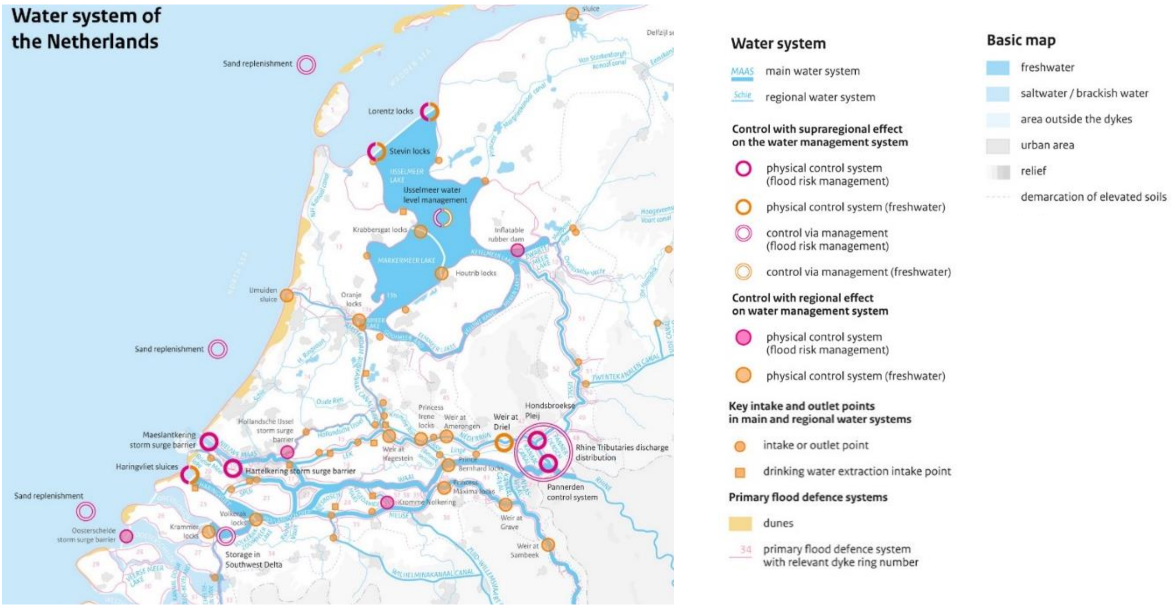


Figure 26. Dutch water system, including the flood risk management (FRM) system and freshwater supply system. The main water system includes (main) 'primary controls' and (regional) secondary controls. Source: DP2014, p.151.

Flood protection standards

In the Netherlands, flood safety has traditionally been expressed in standards – i.e. a probability per year that a critical water level occurs – which are laid down in law for every dyke ring (Haasnoot et al. 2013, p.491; Kabat et al. 2009, p.450). Until 2014, the Dutch legislation defined the *flood protection standard* that each dyke ring must withstand expressed as an *allowable exceedance probability for the water level* (i.e. a frequency) (Ritzema and Steensma 2018, p.2) (Note 207). The system of defences (dykes, dunes, dams, barriers) is designed and maintained at high safety standards enshrined in law. Nevertheless, in recent years, in the Netherlands, flood risk has been re-defined as the product of the 'probability of flooding' multiplied by the 'adverse impacts of flooding' (thus, risk increases if there is an increase in the frequency of extreme events, and / or in the number of people and assets affectable by floods) (Haegen and Wieriks 2015; Buuren et al. 2016; Bloemen et al. 2018). In the early 2000's, it has become clear that the existing *flood protection standards* no longer reflected the number of people and the value of property behind dykes, and by 2014, many dykes did not yet meet the required statutory standards (defined in 1960), and some were susceptible to '*piping*' (a phenomenon in which water flows underneath and carries sand) (DP 2014, p.53). Due to the ongoing growth of value to be protected, expected climate change effects, and the improved understanding of the existent flood risk, it was necessary to increase the level of protection provided by defences in many areas (DP 2014, p.50, 53; Haegen and Wieriks 2015). By 2014, it was decided that the *level of protection* provided by some flood defences would be increased (DP 2014, p.50, 53). In 2014, the DP proposed new flood protection standards (with new design and testing criteria for defences) (Petersen and Bloemen 2015).

Institutions responsible for FRM

In the Netherlands, FRM falls within public responsibility, and this is laid down in the Constitution: the State must ensure flood protection and justify the allocation of money for it (Restemeyer et al. 2017, p.936). There are long-established strong institutional arrangements on flood safety (Alphen 2015). The institutionalization of the FRM system began after the 1953 flood. The Dutch FRM system has a strong institutional basis (Buuren et al. 2016; Brugge and Roosjen 2015):

- Responsibilities for flood protection (and water management) are allocated to specific (public) organizations: the national agency of public works (Rijkswaterstaat) and the regional Water Boards.
- There is a funding scheme (legally anchored) to keep the dykes up to the level of binding flood protection standards. This cost is shared by the National Treasury and regional Water Boards.
- Associated to the flood protection standards, there is a statutory assessment, design and technical guidelines for flood defences. The *Expertise Network for Flood Protection* provides advice to the Ministry of Infrastructure and Environment, which is almost always adopted.

1.2. Factors that motivated the development of the DP: drivers of change and risk

In recent years, the risk of flooding has increased significantly in the Netherlands (as other European countries): the frequency of floods, but also the damage caused by flooding, have increased (Haegen 2014; Haegen and Wieriks 2015). Various drivers of change are exacerbating flood risk, increasing the frequency and potential impacts of water-related disasters and aggravating hydro-meteorological extreme events. Flood risk is increasing mainly due to socioeconomic development, and it expected to continue so due to further socioeconomic development and climate change; thus, more floods and flood damage are expected in the future (Note 208). The main drivers of change that have exacerbated flood risk in the Netherlands, and that urged the country to manage it and develop the DP, were:

- Demographic, socioeconomic and spatial development. Over the past 70 years, major socioeconomic changes have occurred in flood-prone zones, namely population growth, rapid urbanization, economic growth, increase in built assets and economic value, and, in some situations, inadequate spatial, land and water management, which have all contributed to increase flood risk (DP 2013, p.32, DP 2014, p.65; Haegen and Wieriks 2015; Haegen 2014; Klijn et al. 2016; Deltares). From 1960 to 2010, the number of people and the value of property that needed to be protected from floods has increased significantly (intensively in Rotterdam metropolitan area) and vital infrastructures (ports, airports, transport routes) were deployed in flood-prone areas (Kabat et al. 2009, p.450; DP 2013, p.6). In the future, further urban growth is expected: while during the 20th century, the urban area in flood-prone zones along the coast and rivers increased six-fold, projections estimate an increase of 30% in urban areas in flood-prone zones for 2100 (in a scenario of low economic growth) up to 125% (in a scenario of high economic growth) in relation to 2000 (Haegen and Wieriks 2015).

- Climate change and its effects, namely SLR and changing river discharge regimes. Several climate change effects are expected for the Netherlands, namely SLR, higher river discharges in winter and lower river discharges in summer, changes in precipitation, saltwater intrusion, rising temperatures, drier and wetter periods (DP 2013, p.32; DP 2014, p.71, 65; Ritzema and Steensma 2018; Haegen and Wieriks 2015; Haegen 2014; Klijn et al. 2016; Deltares). Some of these effects are already being felt: sea level is rising, salinization is increasing, the country is getting drier (DP 2013, p.6-7). In addition, it is not clear if storm surges will increase in frequency and intensity. Moreover, water levels in rivers are expected to rise during extreme conditions (peak discharges in the main rivers are expected increase, while SRL will affect downstream areas of rivers) (DP 2014, p.50, 53; Haegen[67] and Wieriks 2015). SLR, in particular, is expected to exacerbate flood risk and put additional challenges to the existing flood defence system. Despite the protection provided by existing defences (dykes and dunes) to lowlands, SLR is projected to increase flood risk, leaving these areas at greater risk of flooding (Kabat et al. 2009, p.450).[68] SLR will make it more difficult to discharge water from the lakes to the sea by gravity (DP 2014, p.50). Built-up areas are expected to suffer more problems caused by floods, heat and extreme drought (which in the past were not considered in spatial planning and construction methods) (DP 2014, p.30; 2013, p.32). Yet, the main threats that climate change poses to Dutch coastal and deltaic cities are SLR and increasing extreme river discharges (Deltares).
- Land subsidence. Land has been subsiding (due to soil compaction, oxidation, and oil, gas and salt exploration) (Klijn et al. 2016; DP 2013, p.6; DP 2014, p.65; Haegen and Wieriks 2015; Deltares).
- Outdated *flood protection standards* and the delay in the maintenance of the existing flood defence system (in 2010), which led to the need to update such standards (in line with a new FRM approach). In the early 2000's, the existing 'flood protection standards' were mostly outdated: such standards dated back to 1955 and 1960, and were based on the statistical likelihood (probability) of overtopping of dykes as assessed in the 1960's (Kabat et al. 2009, p. 450, 451); they had been established according the existing population and investments at that time (Bloemen et al. 2018 p.10). These standards were outdated, and there was also a delay in the maintenance of the existing defence system – these were important reasons for investing in the improvement of flood protection (Bloemen et al. 2018).[69] The level of protection provided by defences had to be increased in several areas: the DP 2014 proposed new flood protection standards (DP 2014, p.50). All the previous factors led the DP to define, in 2014, new 'standard specifications' for flood defences, along the coast and rivers (DP 2014, p.65).
- The growing concern over climate change, and recent near-flood disasters, were key drivers of the DP.

In sum, the past and the expected socioeconomic growth, and at the same time, the current and future effects of climate change and SLR, and land subsidence, have contributed to increase flood risk. These factors urged the country to manage its increasing flood risk and led the Government to develop the DP. The recognition of an increasing flood risk, and its drivers, led to the need to develop a programme to ensure 'water safety', i.e.: flood risk management (FRM) and freshwater supply (FS), integrated with spatial planning and climate adaptation (Klijn et al. 2015; Werners et al. 2016).

---

67 Melanie Van Haegen was the Dutch Minister of Infrastructure and Environment between 2010 and 2016.

68 In the early 2000's, the Government recognised the increasing vulnerability of low-lying lands, and the need to reshape the FRM system and 'climate-proof' the country (Kabat et al. 2009, p.450). The SRL pushed for sustainable FRM solutions in coastal and riverine areas.

69 The 2006 mandatory 5-year assessment of the primary defence system showed that some defences did not yet met the statutory requirements (DP 2013, p.20; Klijn et al. 2016). In 2006, 24% to 56% of the coastal defences did not meet the required standards. In 2011, the 3rd assessment of the primary defence system showed that some parts did not meet the statutory standards (nearly 30% of the system) (DP 2013, p.44, 32). Along the coast, the main factors that motivated the definition of new standards were: SLR and related changes in wave heights and patterns, and the necessary management and maintenance of the 'basic coastline' and flood defences. Along rivers, the great natural variability in river discharges, and the long lead-time needed for dyke projects, led the DP to assume *fixed values* for peak discharges (DP 2014, p.75, 65).

2. PRESENTING THE DELTA PROGRAMME (DP)

2.1. OBJECTIVES AND AREA COVERED

The Delta Programme (DP) is a Dutch policy programme focused on flood risk management (FRM) and freshwater supply (FS), which was initiated in 2010. Its main objective is to ensure FRM (also called flood safety) and sufficient FS (*water safety*) to the country, now and in future generations (DP 2013, p. II, 6, 133) (see Note 204). Its specific goal is to ensure '*a sustainable and robust flood risk management and freshwater supply in 2050'* and make the country a 'robust country' able to '*withstand the (greater) climatic extremes in a resilient manner'*, i.e. '*a safe and robust delta that is resilient enough to withstand the extremes of nature*' (DP 2014, p.6, 8). The DP aims to provide '*a sound way of dealing with water*' in the future, which is essential to the Dutch physical safety and economy (DP 2013, p.6).

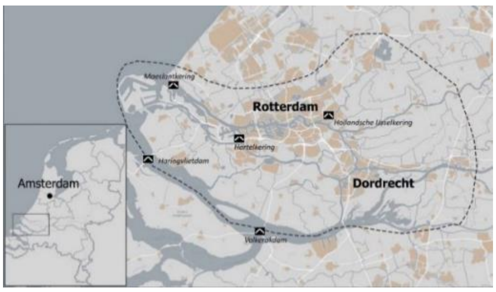
The DP addresses 3 key-areas: FRM, FS, and water-robust spatial planning (i.e. spatial adaptation) (DP 2014, p.6). Importantly, the DP was created with the purpose of developing decisions and strategies for sustainable FRM and FS under changing conditions (namely climate change) and with the time-horizon of 2100 in mind. Thus, it should address, in specific, the risks of flooding and drought (Jeuken et al. 2014) and develop policies to '*climate-proof'* the water-land system (Jeuken and Reeder 2011). The aim was to ensure FRM and FS bearing in mind the uncertainty about future climatic and socioeconomic changes and addressing the need for climate adaptation (Brugge and Roosjen 2015).

The DP is a national programme in which the national government, provincial authorities, Water Boards, and municipalities, are involved and work together; and knowledge institutions, social organizations (public) and business community collaborate. It is yearly elaborated by these national, regional and local authorities, who jointly develop 'Decisions' and 'Strategies' on FRM and FS (different actors and governance levels work together on FRM policy) (DP 2013, p.II, 133; Bloemen et al. 2018; Zevenbergen et al. 2018; Gersonius et al. 2016; Werners et al. 2016; Alphen 2015; Restemeyer et al. 2017).

The national programme is subdivided in 9 subprogrammes: 3 nation-wide subprogrammes on specific topics and 6 regional subprogrammes. The nation-wide subprogrammes address critical themes generic to the country, i.e.: (a) flood safety, (b) freshwater supply, (c) new urban development and restructuring. The regional subprogrammes address: the Rhine Estuary-Drechtsteden; the Southwest Delta; the Ijsselmeer Region; the Rivers; the Coast; and the Wadden Region (Figure 27) (Note 209). This research focusses particularly on the area of the Rhine Estuary-Drechtsteden and the Coast of Rotterdam region.

Figure 27, left. The 6 regional subprogrammes of the DP, and 3 generic subprogrammes (listed in the upper left corner). Source: DP 2010, p.3; DP 2011, p.III. The Subprogramme for the Rhine Estuary-Drechtsteden encompasses the most urbanised region, i.e. Rotterdam city and port, and it addresses tidal and fluvial flood risks.

Figure 27, below. The Rhine Estuary-Drechtsteden region, and its main flood barriers (Restemeyer et al. 2017). All subprogrammes are directed by the Ministry of Infrastructure and Environment, except the subprogrammes for the Wadden Sea and South-Western Delta (directed by the Ministry of Economic Affairs) (Alphen 2015).



The DP is institutionally substantiated in five Ds: the *Delta Act*, the *Delta Commissioner*, the *Delta Fund*, the DP Report, and the *Delta Decisions* (see Note 210).

The ***Delta Act*** is the legal basis (*statutory foundation*) of the DP: it assures that there is a Delta Fund for financing measures proposed, and a Delta Commissioner (specifying his responsibilities and roles), and it requires the presentation of an annual DP Report (DP 2013, p.44, 6; Haegen and Wieriks 2015; Restemeyer et al. 2017; Alphen 2015; Werners et al. 2016; Buuren et al. 2016). The Delta Act stipulates that: the DP must be updated yearly and it must report on the implementation of *strategies* of FRM and FS; a Delta Fund of €1 billion / year is available for these strategies; and a Delta Commissioner must coordinate the DP and prepare its annual progress reports (Seijger et al. 2017).

The ***Delta Commissioner*** is the public officer responsible for steering the elaboration, implementation and update of the DP (in the name of the Dutch Government), overseeing and reporting on the progress of the implementation of all the 'programmed measures' (DP 2013, p.6, 113, 133; 2014, p.148; 2017, p.5; Werners et al. 2016; Vink et al. 2013; Alphen 2015). The Commissioner must issue a DP Report every year reporting on the DP progress to the Cabinet. Since 2014, the Commissioner steers the implementation of the *Delta Decisions* and *Preferential Strategies* (submitted to the Cabinet in 2014) (Restemeyer et al. 2017) and ensure the consistency of the adaptive approach used by the DP (DP 2014).

As stipulated in the Delta Act, every year, the **annual DP report** contains the DP's proposal and the Cabinet's response, and it presents all *programmed measures* in the field FRM and FS, in a programme of measures detailed for the first 6 years, indicative for the next 12 years, and with a general look up to 2050 and beyond (i.e. the so-called *Delta Plan on FRM* and *Delta Plan on FS*) (DP 2013, p.6, 12, 86; 2014, p.8, 86, 146). This report is presented to the House of Representatives for approval in the next year's national budget.

The **Delta Fund** is the main financial source of the DP, it comprises resources to fund the programmed FRM and FS measures of national importance, and management and maintenance costs. It provides the resources to implement the *Strategies*. The *Delta Act* assured that there is a Delta Fund of 1 billion € per year of public funding, at least until 2028, to implement FRM and FS measures (Restemeyer et al. 2017; Alphen 2015). Yet, the DP has other sources, as other partners share financial responsibility, e.g.: Water Boards, government funds earmarked for dyke improvements, provinces, municipalities, social organizations. In 2014, the allocation of costs of FRM measures was: 50% Government, 40% all Water Boards, 10% of the implementing Water Board (DP 2013, 2014).

The ***Delta Decisions*** consists of the main decisions and choices on FRM and FS until 2100. In 2014, the DP issued its 5 *Delta Decisions* (prepared from 2010 to 2014); since 2015, they have been embedded in policy instruments (e.g. *National Water Plan*) (Restemeyer et al.2017; Werners et al.2016).

2.2. Drivers of the need to use an Adaptive Planning approach and develop an *adaptive programme*

The main factors that led the DP to use an Adaptive Planning approach to devise an adaptive plan were:

- Proactiveness about flood risk. Dutch flood policy was traditionally drawn up in response to floods (reactively). With the DP, the Government aimed to change this and proactively prevent future flood disasters. Given the uncertainty about future conditions, an *adaptive and flexible approach* was needed; the options of doing nothing, little or later was deemed too risky, and it was necessary to be ready in a timely way (DP 2013, p.6). The recognition that risk, if not adequately managed in advance, could lead to flood disasters, and a sense of urgency to act now on increasing climate-related water risks, led to the need for a *proactive* but *flexible* approach to plan the DP (Haegen and Wieriks 2015). Proactive FRM payed-off in flood-prone urban areas and anticipating climate change in decision-making was required to *future-proof* decisions / investments in flood defences, infrastructures and built environment. Recent floods and concerns on climate change led scientists to call for improved long-term FRM policies that should be *adaptive* to deal with uncertain changes (Restemeyer et al. 2017).

- Deep uncertainty about the effects of climate change, spatial, and socioeconomic developments, their magnitude and rate over the next decades. Despite the growing scientific evidence of climate change effects in the country (e.g. increasing temperatures, SLR, increasing precipitation, etc.), it was not known how rapidly these will develop during this century. Besides, the socioeconomic development of the last 50 years substantially changed the scene of flood safety. In addition, more knowledge was acquired about the strength of dykes as well as new methods to assess risk and potential flood impact (DP 2013, p.32). Yet, future changes in climate, sea levels, river discharges, precipitation patterns, and also socioeconomic development and soil subsidence, were deemed very uncertain (DP 2012, p.81, as noticed in the DP (2011, p.8), '*it is hard to predict the effects accurately for between fifty and a hundred years ahead*'. Coping with uncertain future conditions and change demanded an *adaptive planning*. Though it would be logical to *'defer decision-making until any uncertainties have been greatly reduced'* (as the *'system is complex and knowledge of many parts* (and of the future) *is, by definition, incomplete'), 'waiting until the uncertainties have been resolved is not an option; uncertainty is unavoidable, but can be made manageable'* (DP 2010, p.68). It is uncertain how exactly the climate will develop, and this will largely depend on global developments; for this reason, the country should '*take an adaptive stance in responding to changing insights and developments regarding the climate*' (DP 2017, p.117). As Haegen and Wieriks (2015, p.55) note, '*uncertainties are no excuse for inaction'*, but *'inherent in long-term planning and should be accounted for in a comprehensive, flexible and adaptive approach*'. The ADM approach was developed with this in mind.
- Despite the existence of significant uncertainties about the future changes and conditions, it was necessary to make decisions and investments in expensive coastal and riverine water-related infrastructures in the short-term (in some cases, there was an urgent need to invest in flood defences). Alongside the above-mentioned uncertainties, there was uncertainty about whether FRM investments should be made now or postponed, and whether forthcoming investments in spatial planning and urban infrastructure maintenance or renovation could be used to reduce flood risk. This uncertainty, and the complexity of the Delta, challenged the planning of FRM: decisions and investments had to be sustainable in the long-term and '*climate-proof*'. The deep uncertainties about future conditions and changes, and, on the other hand, the need to make short-term decisions and investments in flood defences, called for an *adaptive approach* to support planning and decision-making (Deltares; Zevenbergen et al. 2018; Brugge and Bruggeman; Brugge and Roosjen 2015). The Water Boards faced a dilemma between 'long-term uncertainties' and the need to make 'urgent decisions'.
- Weaknesses of existing planning approaches that led to the need to create a new planning approach. The DP clearly felt the need to develop new planning methods that were missing, thus, together with the scientific community, it devised and employed a new planning approach (Werners et al. 2016). In traditional planning approaches, there is scarce inclusion of long-term uncertain effects and consequences into planning decisions. Some authors noticed that traditional planning approaches were not fully up to the task of handling uncertainty about water systems, especially problems characterized by the unpredictability of future changes in such systems, variability and non-linear causality, which further complicated planning, thus, decided to develop a new planning approach that was able to deal with uncertain and complex problems, and which operationalized *adaptiveness* to *handle* uncertainty: the *Adaptive Delta Management* (ADM). ADM is an 'adaptive planning approach' that emerged in the context of complex quotidian planning practice where '*environmental issues, fraught with uncertainty, interrelate with conflicts between values and stakes'*; it seeks to handle uncertainty and complexity in FRM through *adaptiveness* and *planned anticipation* (Zandvoort et al. 2018, p. 185, 192-195).

2.3. Requisites for the planning approach: an Adaptive Planning and Management approach

Adaptive Delta Planning and Management

In 2010, the DP Commissioner underlined that one of the main challenges of DP was '*dealing with uncertainties in the future climate, but also in population, economy and society. This requires a new way of planning, which we call adaptive delta planning'* as a '*new way of planning that seeks to maximize flexibility; keeping options open and avoiding 'lock-in''* (Kuijken 2010 *in* Haasnoot et al.2013 p. 490; Werners et al. 2016).[70] The deep uncertainties about future developments, and, on the other hand, the need to make responsible financial investments, demanded a more '*flexible and realistic approach'*, which gave rise to the DP's *Adaptive Delta Management* (ADM) approach (Rhee 2012 *in* DP 2014, p.138; DP 2011, p.48). Given uncertainties around future climatic and socioeconomic changes, an '*adaptive approach*' was needed, which should be '*flexible*' but also '*down-to-earth*' (DP 2013, p.6; 2011, p.16, 70). The DP would contain decisions and strategies for FRM and FS now and in the future, and this implied a planning approach that took into account and was able to deal with deep uncertainties about future (climatic, environmental and socioeconomic) changes and conditions: the DP used an *adaptive way of planning* (Alphen 2015). As Brugge and Brugeman (p.1) explain, such an '*adaptive approach*' had to be *flexible* enough to adapt the plan / strategy to changing and unforeseen future conditions, and at the same time, devise short-term measures and investments under uncertainty. ADM responds to these two aspects: it is *adaptive* and deals with uncertainties about the future (Deltares). The DP devised ADM as an *adaptive planning approach* to cope with uncertain future conditions and changes. With ADM, Dutch policy on FRM has shifted towards a more *adaptive* form of planning and management (Ritzema and Steensma 2018).

Anticipatory, with long temporal horizon

In recent years, Dutch flood policy has shifted from its traditional reactive approach where policy development and implementation occurred after floods, towards a more proactive approach that aims to prevent floods and *climate-proof* the country and, thus, anticipates future climatic and socioeconomic changes (Haegen and Wieriks 2015; Haegen 2014). The DP broke with the past tradition (and vicious cycle) in which major interventions were often *reactions* to floods and new flood policy was elaborated after the occurrence of floods: with the DP, the Government sought to proactively avoid flood disasters, and, under uncertainty about the future, a '*flexible and adaptive approach*' was required (DP 2013, p.6; Petersen and Bloemen 2015; Ritzema and Steensma 2018). Dealing with climate change demanded *proactive plans* (Ritzema and Steensma 2018), and a '*more flexible approach with a long-term horizon'* (Haegen and Wieriks 2015). From the outset, it was decided that the DP would have long temporal horizon (Zevenbergen et al. 2018; Vink et al. 2013, p.96) (Note 211). The DP was formally charged of devising strategies to ensure sustainable FRM, FS and spatial adaptation throughout this century, considering climatic and socioeconomic changes (Klijn et al. 2015). The leading thought was that the country must anticipate possible changes in the climate, society and economy, and their possible effects on flood risk and drought risk instead of simply responding to floods or droughts (as this was economically preferable), and be prepared in time for future conditions to avoid water-related hazards (DP 2014, p.47, Klijn et al. 2016, p.846). This demanded an *anticipatory adaptive planning* that allowed gradual adaptation and kept options open for more drastic changes that may happen in the future – this should be a basic principle in the planning approach of the DP (Klijn et al. 2016). A long-term view was needed to make *future-proof* decisions and investments (Alphen 2015). This *forward-looking* considers the long-term and inherent uncertainties, and it required a *flexible adaptive approach* (Haegen 2014).

[70] DP Commissioner Kuijken's speech at the *Deltas in Times of Climate Change* conference, Rotterdam, 2010. The need of a new planning approach was driven by a new understanding of FRM and adaptation challenges, more focused on coping with the limits of the FRM system under climate change (Werners et al. 2016). This Adaptive Delta Planning is quite similar to the DAPP approach of Haasnoot et al. 2013.

Devising *robust flexible strategies*

To ensure a *'sustainable and robust FRM and FS'* and cope with climatic extremes, the country should be '*prepared for various scenarios*', and measures and strategies should provide *flexibility* to respond to new insights and changing conditions, either by '*stepping up measure*s' or '*changing of strategy*' if necessary (DP 2014, p.6).[71] Due to uncertainty about the rate of climate change, the DP decided to work with several possible future *Delta Scenarios* and draw up strategies for them (DP 2013, p.6). The DP's *flexible adaptive approach* values flexibility mainly in terms of possible strategies and possible timing of implementation (Haegen and Wieriks 2015; Zevenbergen et al. 2018), i.e. possibility of switching to other measures (or modifying a measure) and anticipating / delaying measures (Vink et al. 2013, p.92).

Using a *risk-based approach*

The DP marked the introduction of a new '*risk-based' approach* that considers both the probability of flooding and the potential impacts of a flood in the calculation of flood risk (DP 2013, p.32; Zevenbergen et al. 2018; Haegen and Wieriks 2015, Ritzema and Steensma 2018) (Note 212).[72] With this *risk-based approach*, there has been a shift from flood policy almost exclusively focused on prevention measures (to reduce the probability of floods, mostly protection measures) towards a more *integrated* FRM that includes not only protection measures, but also vulnerability reduction and impact mitigation measures (Haegen 2014; Marchand and Ludwig 2014). The planning of diverse FRM measures pays off in terms of reduced loss of life, avoided damage and economic stability. The '*risk-based approach*' led to the need to set new *flood protection standards* and entailed new FRM tasks and measures (DP 2013, p.32).

Integrated: Linking FRM / adaptation with planned investments (*mainstreaming*)

The DP's *adaptive approach* (ADM) seeks to 'link' different investment agendas (of diverse policy fields and authorities) and mainstream (integrate) FRM, FS or spatial adaptation measures into planned investments, long-term plans and agendas, to create synergies and ensure a truly *integrated* FRM (Haegen and Wieriks 2015; Zevenbergen et al. 2018). The enhancement of integrated FRM was an important goal of the DP. The uncertainties about future changes and multi-scalar complexity inherent to the Dutch Delta called for a *flexible adaptive approach* with *integrated and adaptive policy frameworks* and institutional capacity at different levels and zones to address interacting risks and apply measures, avoid negative outcomes and create synergies (Zevenbergen et al. 2018).

In synthesis, the DP's planning and management approach must be a proactive (*anticipatory*), *flexible adaptive* approach, adopt a *risk-based approach* to FRM, and ensure a more *integrated* FRM. Over the recent years, since the DP was launched with its ADM approach, the Dutch FRM approach has been through a fundamental process of change, a paradigmatic shift, towards a more adaptive planning and management approach (Marchand and Ludwig 2014; Ritzema and Steensma 2018; Haegen and Wieriks 2015; Haegen 2014; Klijn et al. 2016) (Note 213).

---

71 The 2nd DC already called for more flexibility: the modification of existing defences, or the creation of new ones, should be made in a stepwise fashion, and should be designed so that they could be *readily upgraded if scenarios for future SLR change* (Kabat et al. 2009 p.452).

72 The emerging understanding of flood risk (R = P x I) and concerns over the effects of climate change and socioeconomic growth in flood-prone zones, led the Government to adopt a *risk-based approach* (Haegen and Wieriks 2015). With the 'risk-based' approach, Dutch FRM has gradually shifted from *fighting against water* to *living with water* (Haegen 2014). Climate change and environmental degradation in the 1990's, showed that the traditional centralized '*planning and control'* regime dominated by civil-engineered responses was no longer adequate: a *more adaptive approach* was emerging focused on increasing the delta resilience and adaptivity (Marchand and Ludwig 2014) (Note 212). Dutch FRM has traditionally focused on reducing the probability of flooding through protection / defence measures, namely by strengthening or heightening dykes; and the Dutch legislation defines the *flood protection standard* that each dyke ring must withstand (as an allowable exceedance probability of a water level, a flood frequency) (Ritzema and Steensma 2018). In the past, after flood disasters, dykes were usually heightened or strengthened. However, in early 2000's, projections of future climate change and socioeconomic development called into question the existing *protection standards*. As a consequence, the Government decided to reformulate its FRM policy approach. The DP, and its risk-based approach, marked a paradigm shift in the Dutch FRM. Instead of focusing solely on prevention (i.e. reducing the probability of flooding), the new approach focusses on this but also on the reduction of potential flood impacts (Ritzema and Steensma 2018).

3. THE ADAPTIVE PLANNING APPROACH OF THE DP: *ADAPTIVE DELTA MANAGEMENT* (ADM)

Since 2010, the Delta Programme (DP) has developed and used its own adaptive planning approach – a conceptual and methodological approach called '*Adaptive Delta Management*' (ADM) (DP 2010, p.4; 2012, p.88; 2013, p.102; 2016, p.11, 59; 2017, p.117). The approach was developed based on the DAPP approach developed by *Deltares Knowledge Institute* and *TU Delft* and presented by Haasnoot et al. (2013), and it was also inspired by the planning approach of the TE2100 Project (*in* Haasnoot and Jeuken; DP 2011, p.48, 55; Marchau et al. 2019) (Note 214).[73] ADM can be placed within the family of Adaptive Planning approaches (Jeuken et al. 2014; Restemeyer et al. 2017). ADM was introduced in the DP 2010 and further developed in the following years (DP 2011, p.48; 2014, p.7).

The ADM approach was developed for the DP (DP 2014, p.7), by the DP staff and Deltares. Deltares led its development and offered guidance for its application in the DP (Deltares). The national DP staff provided to the regional subprogrammes an *ADM Implementation Guide* (Rhee 2012) to support the application of ADM (Werners et al. 2016; Zandvoort et al. 2018).[74] The DP Team closely cooperated with Dutch and UK scientists who developed the APs' method, and the *ADM Implementation Guide* recommends the use of scenarios, Tipping-points and Adaptation Pathways (Restemeyer et al. 2017).

The ADM approach is fundamental to the DP: it is the heart of the DP (DP 2012; 2014; 2011; 2016; 2017). The DP's approach for FRM is also based on ADM (DP 2014, p.7). The DP has used ADM to specifically address the issue of FRM (and FS) under uncertainty about future conditions and changes; and ADM differs from the traditional Dutch FRM practice because it requires an *adaptive flood risk management* (Klijn et al. 2015, p.848). By using ADM, the DP seeks to manage risks and respond to potential problems '*in a timely and adaptive manner*' (DP 2018, p.14).

ADM provides a clear way of taking into account and dealing with deep uncertainties about future changes and developments within policymaking and decision-making on FRM and FS (namely uncertainties about the future effects of climate change and socioeconomic developments, their magnitude and rate) in complex dynamic socio-ecological systems (DP 2011, p.48, 70; 2012, p.88; 2014, p.139; Gersonius et al. 2016; Marchand and Ludwig 2014; Brugge and Bruggeman; Deltares; Zevenbergen et al. 2018). It is an '*operating approach designed to transparently include uncertainties around future developments in the decision process*' (DP 2011, p.70). Overall, ADM is deemed an adaptive approach that supports planning and decision-making under deep uncertainty in the fields of FRM and FS (water policy), spatial planning and infrastructure (Deltares). ADM has been embraced by DP actors as a practical way of dealing with uncertain future change and developments, i.e. future changes about which there are uncertainties (DP 2012, p.88, 2017). With ADM, the DP can '*continue to make progress, while acknowledging the uncertainties regarding climate change and socioeconomic trends*' (DP 2017, p.7). Moreover, with ADM, the DP aims to remain '*adaptable*' to changing climatic, physical, and socioeconomic conditions (Restemeyer et al. 2017, p.921).

---

[73] Deltares is a knowledge partner of the DP who led the development of ADM and offered guidance for its application in the DP. It is a research institute in the field of water and infrastructure based in Delft and Utrecht (Deltares) (Note 215). ADM was developed based on the DAPP approach developed by TU Delft and Deltares and presented by Haasnoot et al. (2013) (DAPP was created to support the development of an adaptive plan that is able to deal with changes and deep uncertainty) (*in* Haasnoot and Jeuken). The '*adaptive delta planning*' mentioned by the DP Commissioner in 2010 (later renamed *Adaptive Delta Management*) *corresponds well with* the DAPP; the DP offered a study-case to test its applicability (Haasnoot et al. 2013). Yet, ADM was developed in the policy context of the DP (Buuren et al. 2016). The scientific basis of ADM lies in *Adaptive Planning* (Kwakkel et al. 2012; Ranger et al. 2013), namely in *Adaptation Pathways* and *Adaptation Tipping-Points* (Werners et al. 2016; DP 2011, p.48,70). ADM differs from the traditional Adaptive Management.

[74] In 2011, the *ADM Implementation Guide* became clear, providing the principles for policymaking to the DP (Note 216). Moreover, guidelines for the identification of ATPs and design of APs (Linde and Jeuken 2011) were provided to the DP (Werners et al. 2016). The DP staff promoted the application of ADM in the subprogrammes but did not dictate anything, the subprogrammes could hire two external advisors (one involved in the *ADM Guide*) to help them apply ADM (Restemeyer et al.2017). There is a national research network on ADM (Note 215).

3.1. Principles of ADM

The four main guiding principles of ADM are:

1. Linking short-term decisions with long-term tasks (*tasking*)[75] around FRM and FS.
2. Incorporating flexibility into possible '*solution strategies*'[76] (and their measures), where effective.
3. Working with '*multiple strategies that can be alternated between*', i.e. designing and using *adaptation paths* (pathways) between which it is possible to switch depending on developments.
4. Linking FRM and FS measures with other investment agendas (DP 2012, p.88, 83; 2013, p.102; 2014, p. 95, 47; 2016, p.5; Gersonius et al. 2016; Marchand and Ludwig 2014; Zandvoort et al. 2018; Brugge and Bruggeman; and, based on Rhee 2012, Werners et al. 2016; Klijn et al. 2016, 2015).

Principle 1 consists of linking short-term decisions with long-term tasking (DP 2011, p.49; 2012, p.83), i.e. connecting short-term decisions, investments and measures with long-term tasks and challenges around FRM and FS (Marchand and Ludwig 2014, p.8). This implies linking *short-term decisions with long-term objectives*' (Bloemen et al. 2018, p.12; and Klijn et al. 2016, 2015, based on Rhee 2012). Short-term decisions should be linked with *'long-term planning around FRM and FS*' and consider uncertain future climatic and socioeconomic changes (Werners et al. 2016, based on Rhee 2012).

One way of dealing with uncertain future change is linking short-term decisions with *options for adaptation* in the long-term. Investment decisions must take into account and 'anticipate' uncertain future conditions and developments in order to take cost-effective decisions and avoid measures that become obsolete or make certain options impossible in the future (Brugge and Bruggeman, p.2). ADM seeks to connect current decision-making to future choices (Deltares, p.2). In ADM, a planner should '*create a strategic vision of the future, commit to short-term actions, and establish a framework to guide future actions*' (Haasnoot 2013, *in* Marchand and Ludwig 2014, p.2, 11); and such vision must have a long time-horizon (e.g. a century) so that long-term climatic changes can be captured.

In line with this principle, it is necessary to link long-term tasks to short-term decisions (DP 2011, p.49; 2012, p.83). This requires looking ahead into the long-term future and connecting future tasks to short-term decisions, factoring in possible future developments in the choice of measures (DP 2016, p.5). Tasks to be tackled in the long-term must be linked to decisions that need to be taken in the short-term (DP 2017, p.22). Measures for the short- should *agree with* the tasks for the long-term (DP 2013, p.102).

This principle also implies looking at tasks into the future and using this insight to plan and implement cost-effective measures in good time (DP 2014, p.7, 95), i.e. *'looking into the distant future of long-term tasking and using that knowledge to take the right steps at the right time*' (DP 2013, p.102; 2012, p.88), that is, taking adequate measures when they are actually needed to achieve the objectives (Zandvoort et al. 2018). ADM seeks to ensure that '*the right decisions are taken at the right time*' and that decisions taken now are '*robust under a changing and uncertain future*' (Gersonius et al.2016, p.14).[77]

Principle 2 requires the incorporation (embedding) of flexibility into strategies (and / or their measures) to deal with change and new insights that might arise over time (Marchand and Ludwig 2014; Brugge and Bruggeman, p.2). Flexibility can be delivered in several ways, for example:

---

75 'Tasks' or 'tasking' refers to eventual policy shortfalls in the current or future situation regarding current or future objectives for FRM and FS (DP 2011, p.70). In the DP, it can be understood as a specific need or problem that needs to be addressed.

76 A 'Strategy' sets the objectives at which it is targeted, measures to meet them and the associated 'adaptation paths'; it indicates the time for implementing measures; it can also be a *policy alternative* (DP 2011, p.70; 2013, p.56; Rhee 2012 *in* Zandvoort et al. 2018) (Note 217).

77 Taking the right short-term actions under an uncertain future is complicated, it required an approach that considers uncertainties and dependencies in decision-making (Haegen and Wieriks 2015). Moreover, planners should make short-term decisions bearing in mind their possible long-term consequences on the system (Zandvoort et al. 2018, p.191).

- The possibility to switch to other measures (having alternatives available) (Brugge and Bruggeman).
- By incorporating flexibility in the strategy itself, or in the individual measures that compound a strategy (e.g. sand replenishments on the coast are a flexible measure); and / or by keeping options open. Flexibility can be incorporated into solutions themselves (e.g. solutions / measures that allow their adjustment in the future, or which are inherently flexible) (DP 2013, p.102; DP 2014, p.90).
- By keeping options open for the future (DP 2013, p.102; 2014, p.90).
- By having a variety of measures (DP 2014, p.90).
- By ensuring the flexibility of the strategy itself (as a pathway made of sequenced measures) (DP 2014, p.90).
- The possibility of a stepwise implementation over time, as changes are observed or as new knowledge emerges (Werners et al. 2016, based on Rhee 2012).
- By allowing altering the timing of implementation of measures, e.g. anticipating / postponing measures in time (Brugge and Bruggeman, p.2) (i.e. possibility to speed up / slow down measures) (Klijn et al. 2015, p.848; 2016, p.2, based on Rhee 2012; Werners et al. 2016, based on Rhee 2012).
- By linking agendas (DP 2014, p.90).

These types of flexibility can help to prevent the risks of over- or under-investment or underperformance (Klijn et al. 2015; 2016; based on Rhee 2012; Brugge and Bruggeman, p.2). With its flexible adaptive approach, the DP sought to ensure the possibility of anticipating / delaying measures, or shifting to other measures, or modifying them, and ensure that *'not too many measures, nor too few, and not (…) too early, nor too late*' were taken (Vink et al. 2013, p.96-97).

ADM also implies staying *flexible* to be able to act on new conditions, knowledge and insights (i.e. able to adapt) (DP 2014, p.7). Thus, having '*alternative measures*' available for the case they are necessary in the future (DP 2014, p.7), without '*ruling out future options*' (DP 2011, p.8; 45), is a sub-principle of Principle 2. A key aspect of ADM is having the possibility (options) '*for switching between strategies*' (DP 2013, p.77). As the DP 2013 refers, '*when deciding on the short-term measures, it is important to keep options open for the long-term, so that it is possible to switch to another strategy if future socio-economic developments or climate change should give rise to that* (DP 2013, p.95).

This principle requires '*looking at tasking ahead of us, using that insight to put in place (cost)-effective measures in good time and remaining flexible to be able to act on new opportunities, insights and circumstances*', and, thus, '*alternative measures are available should they be necessary in the future*' (DP 2014, p.7, 150). This implies looking ahead to the future tasks, and '*taking the most cost-effective step-by-step measures based on those insights*, and *leaving options open to be able to respond in a flexible manner to new insights and developments* (DP 2014, p.47) (Note 218).[78] ADM implies staying '*practical, alert and prepared*' to deal with uncertain future change (ibid, p.7, 47, 150).

A planner should seek and value flexibility both in individual measures and in comprehensive strategies, and this requires identifying and appraising flexibility in measures / options and pathways (Rhee 2012, *in* Klijn et al. 2015; 2016 and Werners et al. 2016). Principle 2 implies developing flexible strategies (Bloemen et al. 2018, p.12).

Principle 3 consists of developing and working with multiple strategies that can be implemented alternatingly depending on developments, i.e. with 'adaptation pathways', known as 'adaptation *paths*' in the DP (Marchand and Ludwig 2014; Gersonius et al. 2016; Rhee 2012 *in* Werners et al. 2016). ADM

[78] ADM involves *'responding to developments in the climate and society step by step, making sure that plans for new (and larger) interventions are ready and keeping enough options open for future interventions*', and '*taking currently needed decisions now, bearing in mind the steps that may be necessary in the long term'* (DP 2014, p.12).

builds on the idea of developing diverse trajectories – pathways – that the dynamic system might follow as time unfolds (Zandvoort et al. 2018, p.190). A pathway is a sequence of actions over time to achieve the defined objectives (Marchand and Ludwig 2014, p.2, 13, based on Haasnoot 2013). This principle requires the design of *adaptation pathways* as '*multiple strategies that can be alternated between*', and actively timing decisions and the implementation of measures (Werners et al. 2016, Rhee 2012). According to this principle, adaptation pathways should be identified with successive policy actions (and successive decision-points to allow adaptations) over time, rather than a final solution defined for a certain point in the future (*blue-print planning*) (Rhee 2012, *in* Klijn et al. 2016, 2015). This principle involves using the method of Adaptation Pathways (APs) to design the strategies (Brugge and Bruggeman). The APs allow the switching between measures and / or pathways, if necessary, as climatic or socioeconomic changes occur (it is possible shift from a measure or pathway to another) (Haegen and Wieriks 2015; Bloemen et al. 2018).

In the DP, the 3rd principle of ADM is reflected in the design of 'adaptation paths' in each Preferential Strategy (DP 2014, p.47). In line with this principle, an '*adaptation path*' was designed in each Strategy proposed in the DP (DP 2012, p.81; 2011, p.48). Each Strategy presents a map of adaptation pathways, *so-called 'adaptation paths'*. These *paths* contain diverse measures sequenced over time which can be implemented alternatively according to the changes that occur (Marchand and Ludwig 2014, p.8).

Principle 4 consists of linking (FRM and FS) measures with other investments and agendas of other policy actors or sectors (Marchand and Ludwig 2014; Gersonius et al. 2016). This requires an active search for possibilities to connect the measures envisioned to ongoing and planned investments of public and private actors, and other to other objectives and investment agendas of other policy fields (e.g. urban planning, environment, etc.), and looking for opportunities to integrate / mainstream measures with other initiatives (DP 2010, p.69-70; 2011, p.49; 2014, p.47; 2016, p.5; Zandvoort et al. 2018; Klijn et al. 2015, 2016, and Werners et al. 2016, based on Rhee 2012).[79] By interlinking agendas and investments, measures can become cheaper and easier to implement (by sharing costs or reducing impediments), yield added value and reduce regret (as other benefits are achieved) (Marchand and Ludwig 2014; Brugge and Bruggeman; Klijn et al. 2015, 2016). This can contribute to more innovative, efficient and sustainable solutions (DP 2010, p.69-70; 2011, p.49; 2014, p.47; 2016, p.5) (Note 219). The DP indicates which measures can be connected to other investments and agendas (DP 2017, p.22)

These four principles are core values at the heart of ADM.[80] The principles of ADM, alongside the DP objectives, have substantiated the *Delta Decisions* and *Preferential Strategies*, and have guided their implementation (DP 2016, p.7). Importantly, although the four principles of ADM seem obvious, their practical application in the DP was not simple nor without intricacies. To support their application, two methods were used: Adaptation Tipping-Points (ATPs) (Kwadijk et al. 2010) and Adaptation Pathways (APs) (Haasnoot et al. 2013; Haasnoot 2013). The ATPs and the APs were applied for FRM and FS.

[79] This implies the consideration of the objectives of other domains than FRM and FS, e.g. agriculture, nature, shipping, recreation, during the phases of planning, assessment and design of measures (Brugge and Bruggeman). ADM requires addressing FRM, FS and spatial adaptation, and different regions, in an integrated way, to ensure *a consistent and efficient approach*, at regional and local levels (DP 2016, p.59).

[80] In sum, the core values of ADM are: 1) interconnectivity between the short- and long-term (related with *inter-generational justice* and sustainability); 2) *flexibility* which is delivered through 3) the use of Adaptation Pathways to deal with future changes that are uncertain but anticipated now; and (4) *integration* of FRM and FS measures with other investment agendas of other actors (DP 2014, p. 95; Zandvoort et al. 2018, p.189). ADM combines knowledge from scenario development, flexibility, and mainstreaming (of climate adaptation) (Zandvoort et al. 2018). It is also an integrated approach based on Dutch experience in integrated water management (Deltares).

Other basic principles of ADM

Robustness and flexibility

The 2nd and 3rd principle of ADM are related to *robustness and flexibility* (DP 2013, p.103). ADM aims at developing strategies that are *robust* (i.e. that can deal with multiple futures), and *flexible* or *adaptable* (Marchand and Ludwig 2014). Robustness involves '*performing satisfactorily under a wide variety of futures*', and flexibility is related with the capacity of being '*easily adapted to changing or unforeseen future conditions*' (Haasnoot 2013, *in* Marchand and Ludwig 2014, p.8). The *ADM Implementation Guide* claims that strategies should be both *robust* and *flexible*: a robust strategy is one that '*works in all plausible futures*', while flexibility means that '*depending on the contextual circumstances - you can cut one strategy off and switch to another one*' (DP Staff member, *in* Restemeyer et al. 2017, p.930). According to the Guide, to find or develop *robust flexible strategies*, it is necessary to identify tipping-points and design adaptation pathways (Restemeyer et al. 2017). The design of *robust flexible strategies* requires exploring various possible measures under a range of plausible futures and searching for those that are *robust* and *flexible* (Marchand and Ludwig 2014).

Consequently, the DP has assumed that the strategies developed should be *robust and flexible* (DP 2013, p.103). The DP defines a *robust strategy* as one that is *future-proof* and provides a solution for the tasks arising in all the scenarios considered, while a *flexible strategy* is one that can be relatively easy accelerated or delayed, or that allows a switch to other strategy (a shift from a strategy to another) (DP 2013, p.103).[81] The DP aims to ensure that FRM and FS will be sustainable and that measures can cope resiliently with greater climate extremes (DP 2016, p.9). The ultimate goal is that the FRM system meets the requirements '*at all times*' (all scenarios), which requires solution '*able to adapt to new insights and circumstances*' and '*sufficient options to remain open in the future to take the required measures*' (DP 2013, p.102). The DP searched for short-term measures that are adequate in the long-term and enhance the system's robustness and flexibility, making it suited for diverse scenarios (DP 2010, p.69).

The DP has used ADM to devise *robust flexible strategies*. Flexibility is needed to deal with uncertain future conditions and change, and, at the same time, make responsible investments. Flexibility can be delivered in several ways, e.g.: by designing each strategy as an *adaptation path* (pathway), by using solutions that are 'flexible' *per se*, by using various pathways, by linking agendas, etc. These types of flexibility create added value in terms of cost reduction, feasibility, and benefits (DP 2014, p.90, 139).

Overall, ADM is a new planning approach adopted by the DP to achieve *robust flexible pathways* to manage flood risk and ensure water supply in the Dutch Delta (Werners et al. 2016). ADM itself employs an adaptive (methodological) approach for designing strategies under different future scenarios and changes: the 'Adaptation Pathways approach' (APs) (Haegen and Wieriks 2015, p.56, 54-55, 48).

In the light of ADM, it advisable to (see Note 220):

- **Keep options open for the future** (i.e. measures not needed now) (DP 2011, p.8; 2014, p.47; 2018, p.13). This means having *'alternative measures*' available for the case they are necessary in the future (DP 2014, p.7). The DP has used ADM as an '*adaptive way of planning* that aims at '*maximizing flexibility, keeping options open, and avoiding lock-ins*' (and, in this way, deal with uncertainty and

[81] One of the goals of the DP is to make the country 'robust' to withstand *greater climatic extremes* and, thus, '*prepared for various scenarios'*; and strategies should provide flexibility to respond to change, by '*stepping up measures*' or '*changing strategy*' if necessary (DP 2014, p.6). The DP 2010 defines a *robust system* as '*one that can withstand extreme events and accommodates different future developments*', and a *flexible system* as '*one that can easily adapt or be adapted to changing circumstances*', e.g. 'giving room to rivers' is a measure that increases robustness, while sand replenishment is a measure that maintains flexibility (DP 2010, p.69). Strategies should ensure '*flexibility'* (also called *'adaptability'*) and '*robustness*' (also called *resistance to extreme events*) (DP 2010, p.4).

change) (Alphen 2015; Zandvoort et al. 2018).[82] ADM requires the identification and announcement of possible measures for the long-term in policy plans, i.e. of options that must be left open for a future decision (DP 2014, p.49). This implies the proactive planning of measures that may be needed in the future, namely more drastic measures (DP 2011, p.8, 16; 2012, p.83). Thus, in ADM, initial decisions must '*take into account conceivable future decisions*', which entails '*the art of leaving the decision-space open for later choices and to maintain or increase flexibility of the water- and spatial system*' (Rhee 2012, Zandvoort et al. 2018, p.191). Keeping options open (namely options to deal with more drastic changes that might occur) is a basic tenet of ADM (Klijn et al. 2016).

- Have flexibility in measures and strategies to address tipping-points in the system, and, in the planning of measures, account for uncertainty to allow timely flexible responses (DP 2011, p.16, 49). Work with strategies that offer *chances to switch to other strategies*, and / or measures that allow their later adjustment or expansion (DP 2011, p.8); and search for *'measures that can be relatively easily accelerated or decelerated up to the implementation stage*' (DP 2010, p.70). A basic thought of ADM is to choose strategies and measures that ensure 'flexibility' in the way they respond to new measurements and insights, e.g. by intensifying efforts if necessary or by changing strategy, and at the same time, already having possible future measures envisaged (Petersen and Bloemen 2015).

As seen, ADM seeks to ensure that the right measures are taken at the right time (DP 2013, p.102; 2012, p.88; Gersonius et al. 2016; Zandvoort et al. 2018). In ADM, the first steps – i.e. those measures clearly needed in the near-term – must be taken, and, at the same time, '*sufficient flexibility must be incorporated to make adjustments if necessary*' (DP 2012, p.83). ADM seeks to ensure that the necessary measures are taken, whilst, at the same time, keeping open options that may be required in the future (Rhee 2012; Werners et al. 2016). ADM is about '*doing what is necessary (…) without ruling out future options*' (DP 2011, p.8; 45). This requires doing *'what is required now'* and knowing '*what measures can be taken if the situation changes'*, and implementing measures '*neither too early or too late, too much or too little'* (DP 2014, p.49; 2011, p.16, 8, 45; Klijn et al. 2015; Vink et al. 2013). The DP has sought to ensure that measures can be implemented when needed, in a cost-effective and flexible way (e.g. the first measures are often *no-regrets measures*) (DP 2012, p.88).

ADM implies staying *flexible* to be able to act on new conditions and insights (able adapt to change) (DP 2014, p.7). This not only requires '*looking ahead to the taskings that are facing us, setting down the measures required in concert*', but also '*persistently checking whether we are working at the right pace and in the proper direction*' (DP 2017, p.7; 2018, p.13; 2016, p.6). ADM involves '*keeping options open and, if need be, adjusting our strategies in time*' (DP 2018, p.13). ADM implies adjusting the course if necessary, as changes occur or new knowledge arises (DP 2016, p.5). As an adaptive planning approach, ADM is *flexible* enough to adapt the plan / strategy to unforeseen or changing conditions and opportunities that might arise, and, at the same time, able to support the planning of investments in the short- and mid-term under uncertainty (Brugge and Bruggeman).

Overall, the DP adopted a flexible approach regarding the possible strategies, valuing flexibility in terms of allowing the switch between measures and / or strategies (through Adaptation Pathways) and in terms of altering the timing for implementing measures. A flexible approach should allow switching between strategies through APs and seek to keep options open, and this requires ongoing monitoring and evaluation (Zevenbergen et al. 2018).

[82] The Commissioner called for an *Adaptive Delta Planning* that fosters flexibility by *keeping options open and avoiding lock-in* (Kuijken 2010).

Avoidance of over- and under-investment

ADM aims to avoid the risk of *over- and under-investment* in FRM and FS (DP 2010, p.70; 2011, p.8; Haegen and Wieriks 2015; Brugge and Bruggeman). It avoids doing too much / too little, and too early / too late (DP 2014, p.49; 2011, p.16, 8, 45; Klijn et al. 2015; Vink et al. 2013). ADM proposes a flexible and integrated approach to FRM and FS (including land and water management) in order to reduce risks, but also to avoid over- and under-investment (Marchand and Ludwig 2014; Zevenbergen et al. 2018; Brugge and Bruggeman). The 4th principle of ADM is crucial to this: it promotes an *integrated approach* to tasks and measures with a view to reduce the risk of *over*- or *underinvestment* (DP 2010, p.70; 2012, p.88). Moreover, according to the 1st principle of ADM, it is necessary to address tasks for the short-, and long-term in an integrated way, to minimize regret and maladaptation: short-term decisions should avoid an unnecessary increase of long-term costs, and agreements should be made on how measures can be cost-effectively linked to long-term options (Zevenbergen et al. 2018; Gersonius et al. 2016; DP 2011, p.48). Future developments (foreseen / unforeseen) may influence the cost-efficiency of measures in the long-term, e.g. in terms of use of space (Zevenbergen et al. 2018) (Note 220).

Ongoing monitoring, revaluation, and adaptation

ADM requires a continuous monitoring of external conditions (namely of climatic and socioeconomic changes), and of implemented and planned strategies, and (re)evaluation of the strategies followed (applied or planned) to check if they are proceeding as expected or if it necessary to adjust such strategies (their pace or content) (DP 2017, p.7; 2018, p.13; 2016, p.6; 2014, 149). It may be necessary to adjust the strategies, as new knowledge and insights into climatic, socioeconomic and technological changes arise (DP 2016, p.6). Moreover, to detect when an ATP may be reached it is also necessary to keep track of external changes and effects of measures through monitoring (Restemeyer et al. 2017, p.931).

As an adaptive approach, ADM not only requires anticipating future circumstances when choosing *what, when* and *where* measures should be implemented, but also '*adjusting strategies periodically'* based on new knowledge and insights (e.g. on the evolution of climate change), which implies '*monitoring and studies*'; it entails a '*constant alertness*' and '*a clear view of the possibilities for the future at all times'* through ongoing monitoring and evaluation (DP 2014, p.13). This does not mean waiting until new insights become available, but being 'continuously alert' and implement *'cost-effective measures at the right time*', i.e. '*intervening at the right time, rather than waiting and seeing*' (DP 2016, p.6). It requires the monitoring of '*what is being done and with what effects*', of changes / developments and of new insights, and, in accordance, properly acting on this information and regularly revaluate the strategies followed (DP 2016, p.6; 2014, p.149). Moreover, in ADM, the development of knowledge and research (e.g. on future changes), policymaking, and the implementation of measures, should be conducted at the same time and influence each other (DP 2014, p.149) (Note 221).

Flexibility depends on the '*capacity of decisionmakers to learn from the arrival of new information and their willingness and ability to revise investment decisions based upon that learning*' (Alphen 2013 *in* Zevenbergen et al. 2018). Thus, ADM implies the definition of clear policy goals with corresponding indicators and thresholds to assess the performance of system's components.

In sum, ADM follows an *adaptive* approach to be able to '*temporize*' (speed up / postpone) measures, or to change of measure or strategy, if the actual or expected rate of climatic and socioeconomic developments indicates that this is necessary (Dessai and Sluijs 2007; Buuren et al. 2013; *in* Marchau et al. 2019). It is also *integrated*: it seeks to address the interconnected fields of water management (FRM and FS) and physical developments in dynamic urbanized deltas (Marchau et al. 2019).

3.2. ATPs AND APs IN THE ADM APPROACH

ADM implies the design of adaptation pathways. In specific, the 3rd principle of ADM requires developing and working with adaptation pathways. ADM itself uses the methods of Adaptation Tipping-Points (ATPs) and Adaptation Pathways (APs).

ATPs are '*points where the magnitude of change due to external pressures such as SLR or peak discharges is such that the current strategy will no longer be able to meet the objectives and thus the measure is no longer adequate'* (*in* Zevenbergen et al. 2018, based on Kwadijk et al. 2010). In ADM approach, ATPs are understood as '*points where the magnitude of change due to socioeconomic developments, climate change or sea-level rise is such that the current strategy* (measure) *will no longer be able to meet the objectives*'; an ATP indicates conditions under which a given measure fails and other measure is needed (e.g. a level of SLR at which a storm surge barrier ceases to function) (Haegen and Wieriks 2015). Overall, tipping-points refer to conditions under which a given measure or action ceases to be acceptable or effective and a new measure is required (Rhee 2012, *in* Zandvoort et al. 2018, p.190).

The APs approach, as applied in ADM, is an adaptive planning method to design *flexible robust strategies* – i.e. pathways (Haegen and Wieriks 2015, p.54, 46). The APs approach (applied in ADM) was developed based on the 'Route-map approach / APs' of the TE2100 Project. This APs approach involved: mapping the measures available, identifying their tipping-point (the degree of change under which each measure begins to perform inadequately) and analysing when this might occur at the earliest and the latest, and assessing whether it is necessary change / adjust the existing measure or shift to other measure (Klijn et al. 2015, p.849).

A pathway is a sequence of actions over time to achieve the defined objectives (Marchand and Ludwig 2014, p.2, 13, based on Haasnoot 2013). Adaptation pathways offer '*coherent sequences of measures and potential options, which may be triggered before an ATP occurs*' (Zevenbergen et al. 2018, based on Haasnoot et al. 2012, 2013). Once a tipping-point is in sight, a switch to a new measure is needed, and, in this way, a pathway arises (Figure 28 and Figure 29). The various pathways provide possible trajectories to achieve the objectives (Haasnoot et al. 2012, *in* Zandvoort et al. 2018, p.191). In ADM, adaptation pathways are like '*successions of measures over time*' towards the future *'in a changing environment*', which are explored under many plausible transient scenarios of climate change and socioeconomic developments (Haegen and Wieriks 2015, p.50).

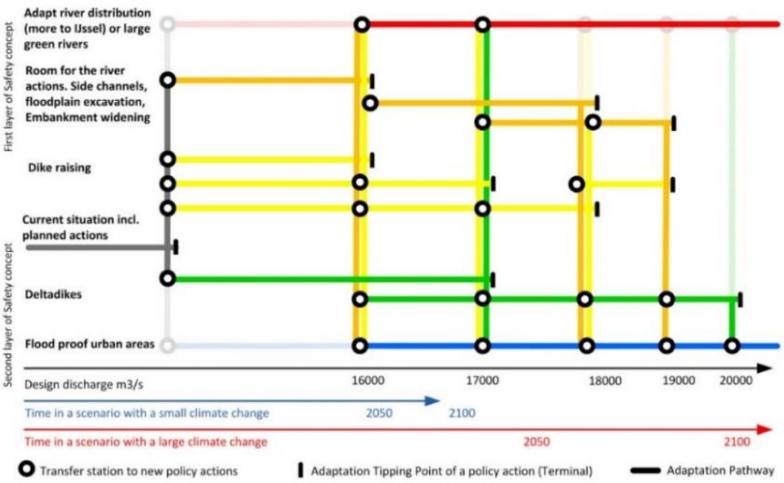


Figure 28 (top left). Map of adaptation pathways for FRM, developed by Haasnoot 2013) for the River Rhine, Waal Branch. Source: Haasnoot 2013 *in* Jeuken et al. 2014, p.17. The current policy with its measures (grey line) will become insufficient to manage flood risk in the future. There are 5 options:

- giving more space to rivers (orange line).
- dyke raising (yellow line) either with a large increase at once or in successive small steps.
- *Delta dykes*, i.e. unbreachable dykes (green line).
- Flood-proofing urban areas (blue lines).
- major interventions in the river to adapt it distribution (red line), but this solution is not likely to be selected now, thus, in the beginning it is transparent.

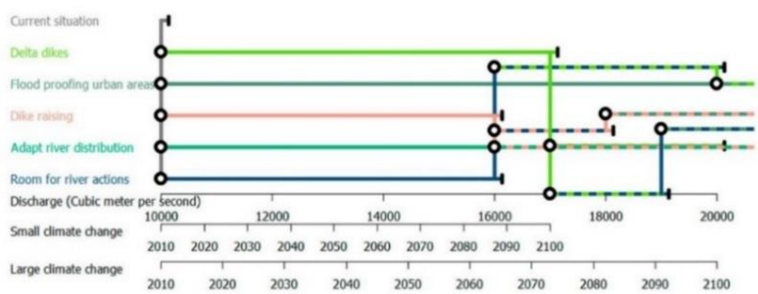


Figure 29. Map of adaptation pathways developed for *Delta Decision on the Rhine-Meuse Delta*. Source: map generated with Pathways Generator, Deltares 2015 *in* Zevenbergen et al. 2018, p.5.

The 3rd principle of ADM has translated into the design of 'adaptation paths' in the Preferential Strategies of the DP (DP 2012, p.81; 2011, p.48; 2014, p.47). In the DP 2014, a map of adaptation path(s) is presented in each of the Preferential Strategies, and in most of the Delta Decisions. Each DP's Preferential Strategy contains a map of 'adaptation path(s)', which shows the pathway (or pathways) to be followed. Such map indicates which measures can be taken and when they are expected to be necessary (including measures required now to ensure that options that may be needed in the long-term can be implemented by then) (DP 2014, p.47).

A key aspect in ADM was having options *'for switching between strategies*' (DP 2013, p.77, 95). In each Preferential Strategy, the map of 'adaptation paths' indicates the conditions under which it is reasonable to change of measure or path, and it identifies short-term measures required to be able to change strategies later, if necessary (DP 2013, p.77, 95). Each Preferential Strategy, in its 'adaptation path(s)', includes measures for the short-, and options for the mid- and long-term (possible measures that may be used after 2050) (DP 2014, p. 49,148).

The DP has developed *'multiple strategies that can be alternated between'* (i.e. several paths), and valued the *flexibility* of solution strategies (DP 2013, p.102). In each Preferential Strategy (in its map of *adaptation paths*), depending on climatic and socioeconomic developments, measures may be taken sooner or later (DP 2014, p.47), and it may be necessary to switch of measure. Overall, the *adaptation paths* of the DP contain diverse measures sequenced over time which can be implemented according to the changes that occur (Marchand and Ludwig 2014, p.8).

Importantly, the APs approach allows for possible shifts (switching) between different measures or *paths* (i.e. switching from a measure or path to another), if necessary, in view of climate change or socioeconomic developments, and seeks to ensure that options are kept open for the long-term (Bloemen et al. 2018, p.12; Haegen and Wieriks 2015, p.56, 50, 54). The APs' map shows a range of options from which a decision-maker can choose, in this way, it supports decision-making for sustainable FRM under changing conditions (Haegen and Wieriks 2015, p.50-51).

In the DP, the design of pathways required the identification of various possible measures (as *strategic alternatives*) and sequencing them (Werners et al. 2016). ADM involves the development of diverse trajectories that the system may follow as time unfolds and as changes occur, by using the APs method. With the APs, planners could assemble sequences of measures and plan the timely activation of such measures (Zandvoort et al. 2018, p.189).

Overall, the development of adaptation pathways implies exploring diverse measures (or combinations of measures) and designing various pathways (to cover a wide range of plausible future scenarios), and requires the capacity to alternate between measures as conditions change. The map of adaptation pathways allows exploring alternative measures and possible shifts between them. This map shows the measures that can be successively implemented, and the conditions under which a transition from a measure to another should be made (transition points). The date of a transition point helps to estimate when a decision should be made on the measures (Brugge and Bruggeman, p.2).

The design the adaptation pathways required the use of the ATP method. This method requires analysing at which level of a climate-related variable (or other relevant parameter) a given measure is no longer suitable or acceptable and must be substituted by an alternative measure (e.g. specifying a physical threshold at which a transition of measure is required). Then, to identify the moment in time of an ATP, it is necessary to place the threshold levels under different (climatic and socioeconomic) scenarios (Klijn et al. 2015). By crossing ATPs with scenarios, it is possible to obtain information on the timing for new measures. The analysis of ATPs is essential to develop pathways (Zevenbergen et al. 2018).

In line with the 1st principle of ADM, the DP's strategies should coherently link the short- and long-term, which implied *'looking far ahead into the future, with all the concomitant uncertainties'* and addressing the question of '*how long the current policy will suffice*' and '*when the tipping-point (at which a policy is no longer tenable) will be reached*' (DP 2010, p.68). ADM required a careful analysis of ex-ante policy and a future outlook to examine if a policy transition is needed, followed by the identification of possible measures and design of alternative strategies (pathways), and their assessment. Moreover, regarding FRM, in particular, ADM demanded the design of pathways that included diverse measures, namely technical, policy-related and spatial planning measures (Klijn et al. 2015).

According to the *ADM Implementation Guide*, to develop *robust flexible strategies*, it is necessary to identify tipping-points and design adaptation pathways (which implies ordering possible measures in time). To make strategies *flexible*, it is important to know '*when to take action or change course*', i.e. when an ATP might be reached (Restemeyer et al. 2017, p. 931). As explained in the Guide, '*thinking about the first decision, and potential follow-up decisions in the long-run, is important to be prepared on time for the long-term challenges regarding flood safety and freshwater supply. Being able to adjust flexibly to changing social and climate conditions is necessary to prevent the so-called lock-in and lock-out situations'* (Rhee 2012, *in* Restemeyer et al. 2017, p. 933).

The 'APs approach' delivers several elements of flexibility:

- The APs serve to visualize alternative measures that may be needed in the short-, mid- and long-term, including measures that might be required to keep options open in the long-term, and, in this way, decisionmakers can reduce the risk of under- and over-investing (Rhee 2012 *in* Zevenbergen et al. 2018). By using APs, the DP could frame various possible measures in a timeframe and seek an optimal balance between '*not too much too early*' nor '*too little too late'* (Alphen 2015). The APs approach is particularly useful in long-term planning, and to link the implementation of FRM measures to other investments (Rhee 2012, *in* Zevenbergen et al. 2018).
- The APs approach provides insight into the possible measures available in the future, namely options that are kept open for the long-term, but also into potential *lock-ins*, *lock-outs* and *path-dependencies* and opportunities that may arise from other investments (Zevenbergen et al. 2018, p.4; Deltares, p.2-4; Klijn et al. 2015, p.849; 2016).[83] In this way, it safeguards the flexibility to adapt to a wide range of future developments (Zevenbergen et al. 2018, p.4), and contributes to enhance the Plan's and the system's flexibility (and capacity to adapt to a multitude of possible future conditions and changes) (Deltares, p.4). The APs method allows an in-depth analysis of the flexibility required in measures and pathways (Marchand and Ludwig 2014; Rhee 2012, *in* Klijn et al. 2016). It allows for *exploring path-dependencies, lock-in and lock-out situations, and the flexibility of actions in general*' (Rhee 2012, *in* Klijn et al. 2016).

[83] ADM seeks to avoid of *lock-ins* / *-outs* and seize opportunities (Zandvoort et al. 2018; Werners et al. 2016, Restemeyer et al. 2017). Under an uncertain future, it is important to path-dependencies that represent lock-ins, and one way of doing this is to envision alternative pathways. For Marchand and Ludwig, *path-dependency* is 'the extent to which a policy action is limited by actions implemented in the past or by actions planned anterior in the pathway'; Restemeyer et al. define *lock-ins / -outs* as situations where past decisions compromise the adaptive capacity in the long-run. The *ADM Implementation Guide* mentions that *lock-ins / -outs* should be prevented whenever possible, but this is somewhat undermined: most urban development in the Netherlands occurred without considering the possibility of floods, thus, the potential for spatial adaptation is limited and only possible in few areas (Rhee 2012, *in* Restemeyer et al. 2017, p.933) (Note 222).

4. How the 'ADM approach' was applied in the DP: process of steps followed

The APM approach defines the process of steps required for the development of an 'adaptive plan' and for an 'Adaptive Delta Management'. This section describes the process of the ADM approach: first it identifies its main steps, then, it explains how these were applied in the DP, namely how the APs method was used to develop an *adaptive programme*. It builds on the analysis of the DP Reports (DP 2012, 2013, 2014, 2015) and prior studies (e.g. Bloemen et al. 2018; Restemeyer et al. 2017; Gersonius et al. 2016; etc.) (see more in Note 223).

4.1. ADM process and its steps

The ADM approach involves a phased decision-making process (DP 2012, p.88) that includes the design of adaptation pathways. The process of ADM is based on the process of the DAPP approach (presented by Haasnoot et al. 2013 and by Jeuken et al. 2014). The ADM process involves a cycle with 6 main steps (inspired in the DAPP cycle) (Note 224). These steps are outlined in Figure 30 and in Table 7.

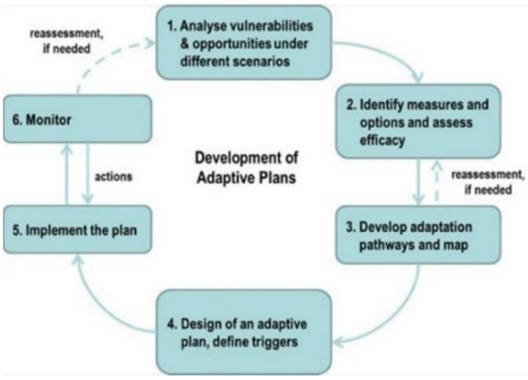


Figure 30. The 6 main steps of ADM. Source: Deltares (adapted from Haasnoot et al. 2013); Brugge and Bruggeman.

- ***Step 1. Analyse vulnerabilities and opportunities under different scenarios***. This step, also called '*problem analysis*', serves to examine the possible occurrence of problems (risks, hazards, adverse impacts), their nature, extent and timing, under diverse future scenarios (Deltares, p.2-3; Brugge and Bruggeman). It involves: a) the definition of the main objectives for now and in the future, and b) the identification of 'vulnerabilities' (external developments to which the objectives are most vulnerable or that may threaten the objectives) and 'opportunities' to achieve the objectives (Jeuken et al. 2014, p.4-5). Sub-step b requires analysing the amount of change that the system can handle (critical levels) and specifying (what are) the *Adaptation Tipping-points* (ATPs, i.e. conditions / points at which the objectives cease to be met), and assessing when the first ATP might occur using various scenarios (Jeuken et al. 2014, p.4-5) (i.e. '*how long the current management strategies continue to be effective under different climate change scenarios*') (Deltares, p.2).

  Step 1 requires: a) the definition of objectives, and b) the identification of current and future vulnerabilities (i.e. problems, needs, challenges), and opportunities, under future scenarios (Haasnoot and Jeuken). Step 1b implies the identification of constraints and uncertainties relevant for decision-making, and such uncertainties must be considered in the generation of an ensemble of plausible future scenarios (Haasnoot and Jeuken; Gersonius et al. 2016).[84] The scenarios are then compared to the defined objectives to see if problems (vulnerabilities), or opportunities, arise; and they are used to determine when the first ATP may occur and a new measure will be needed (Haasnoot and Jeuken).

[84] These uncertainties concern external factors and their possible future changes, e.g. uncertainties about future (climatic and socioeconomic) changes that may influence the future decisions taken, namely about SLR, river discharges, etc. (Gersonius et al. 2016, p.205).

- ***Step 2. Identify measures and options and assess their efficacy.*** This step involves identifying possible measures to solve the problem (i.e. management / adaptation actions) and assessing their efficacy (Deltares, p.2-3). In this step, it is necessary to: (a) identify measures / actions (based on the vulnerabilities and opportunities found in Step 1), and (b) assess performance (efficacy) of each measure in light of the predefined objectives to determine its tipping-point (Haasnoot and Jeuken). In the DAPP approach (which inspired ADM), an adaptive plan should contain measures for the short-term and options for the long-term, including measures that should be taken now to keep options open to adapt the plan (its strategies or measures) if necessary in the future (e.g. by changing/ switching of measure) (Haasnoot and Jeuken). Through an iterative assessment of measures' efficacy and tipping-point, it is possible to select the most successful measures; and, once a set of measures seems adequate, it is possible to build various possible pathways (Jeuken et al. 2014, p.4).

- ***Step 3. Develop adaptation pathways and the APs map***. This step consists of the design of adaptation pathways (APs). A pathway is a sequence of possible measures (which is assembled with measures identified in Step 2). This step requires constructing / assembling several possible pathways (sequences of measures) (Jeuken et al. 2014, p.4-5). Crucial to design the APs are the adaptation tipping-points (i.e. points/ conditions under which a measure no longer meets the defined objectives); when an ATP is reached, other / additional measures are required to achieve the objectives. The APs map shows when decisions should be made, and which measures are available (Deltares, p.2-4).

  Step 3 consists of the development of 'adaptation pathways'; this requires assembling various possible adaptation pathways (sequences of measures) by using the promising measures (identified in Step 2) as building blocks, and then, representing such pathways in an APs' map (and the costs and benefits of each pathway may be presented in a scorecard) (Haasnoot and Jeuken).[85]

  Step 4. Design an adaptive plan, and define triggers. This step consists of the formulation of an adaptive plan. This requires: (a) the selection of one or more preferred pathways as input for an adaptive plan (i.e. an 'action plan'), and (b) the specification of indicators / signposts and triggers (critical values at which it is necessary to activate actions, which act as warning signals for the implementation of actions or reassessment of the plan) (Haasnoot and Jeuken; Marchand and Ludwig 2014). Step 4 requires the definition of a monitoring system to collect information on indicators and triggers (Haasnoot and Jeuken). A trigger may indicate that it is necessary to activate *contingency actions* (to keep the pathways open as long as possible) (ibid).

  Step 4 requires: (a) the appraisal of the various pathways on their social and economic feasibility, robustness and flexibility[86], and the selection of one or more pathways as input for a 'dynamic adaptive plan'; and (b) the specification of 'triggers' (critical values beyond which it is necessary to make adjustments or change of measure, and which must be monitored) (Deltares, p.2-3; Jeuken et al. 2014, p.4-5). Thus, this step implies the definition of a monitoring system and mechanisms to adjust the plan (e.g. its strategies) if necessary (Deltares, p.2-3). To keep open the preferred pathway as long as possible, it may be necessary to specify contingency actions (Jeuken et al. 2014, p. 4-5).

- ***Step 5. Implement the plan***. This means implementing the plan's measures, namely measures necessary to keep open options that may be needed in the future (Deltares, p.2-3; Jeuken et al. 2014).

[85] ADM is based on DAPP. In DAPP, one of the main ingredients to design an adaptive plan is the development of adaptation pathways (APs). The AP method requires exploring the ATPs of measures. AP and ATP are key methods in DAPP (Haasnoot and Jeuken), as they are in ADM.

[86] An adaptive plan / policy is considered **robust** if the desired objectives can be achieved under a variety of circumstances (i.e. scenarios), whereas flexibility is related with the easiness with which a plan can be adapted to changing conditions and the capacity to adapt to a multitude of possible future conditions and changes. The flexibility of a plan is enhanced if its measures can be adapted, implemented earlier or later than planned and meanwhile the plan's goal will still be reached (Deltares, p.2-3), if it is possible to shift from one measure or pathway to another.

- ***Step 6. Monitor, reassess the plan (its strategies or measures), and adjust it, if necessary***. This step implies the monitoring and evaluation of external changes, implemented measures, and progresses in knowledge, and the reassessment of the plan, and, if necessary, its review (Haasnoot and Jeuken). It requires a monitoring and evaluation system to keep track of climatic and socioeconomic developments, and assess if and when it is necessary to review or adjust the plan (e.g. change its strategies or measures) (Deltares, p.2-3). Step 6 is essential to allow a truly adaptive planning and management. Variables that may induce to triggers must be monitored (Jeuken et al. 2014, p. 4).

The ADM process differs from the traditional adaptation planning approaches: the starting point of the analysis is the question of 'how long will the current strategies be effective under different scenarios'; which leads to the exploration of alternative measures and the design of multiple solution pathways (rather than a single solution that is designed for a 'business-as-usual' scenario or worst scenario). The basic idea underlying the APs approach is to '*generate a wide array of pathways*' (a pathway is a *series of measures*) through which the policy objectives are achieved under changing conditions (Deltares, p.4, 3). The set of pathways presented in a map provides a range of options that may be used in future decision-making. In this way, the APs help to enhance the plan's and system's flexibility and adaptability (capacity to adapt to a multiple plausible future conditions and changes) (Deltares, p.2-4).

Table 7: Steps and sub-steps of the ADM process	
1. Analyse vulnerabilities and opportunities under different scenarios	Step 1 involves: (a) the definition of objectives, i.e. a '*strategic vision of the future*', goals and criteria for success (also called '*agenda setting*'); (b) the identification of current and future problems and needs based on relevant future scenarios (also called '*problem analysis*', this requires using scenarios) (Marchand and Ludwig 2014; Zevenbergen et al. 2018; Haasnoot and Jeuken; Gersonius et al. 2016). Step 1a implies defining a *vision* (a framework of policy goals); ADM assumes that clear goals can be defined to then find measures and design '*development trajectories'* (Zandvoort et al. 2018, p.190). In Step 1b, it is necessary to specify (define) what are 'adaptation tipping-points', i.e. the 'boundary conditions' / points under which the objectives are no longer met (e.g. an unacceptable level of SLR) (Kwadjik et al. 2010), and then, confront such ATPs with a range plausible futures to estimate the moment when such ATPs might occur. It is important to use different futures with changing conditions to gain insight into the possible occurrence of ATPs, and estimate when the first ATP might happen (the point at which the current measure will no longer meet the objectives and new measures will be required). In Step 1, it also is important to: analyse the current policy measure; translate the objectives into tasks for the short- and long-term; and define metrics / parameters to describe changing conditions, e.g. the rate of SLR in cm/year (Gersonius et al.2016, p.204-206). Overall, step 1 consists of analysing when and where problems will occur under the different scenarios. A problem occurs if the policy objectives (e.g. flood safety, flood protection standards, required water levels) are no longer met. This is also denominated a 'tipping-point'. Step 1 requires analysing the nature, extent and timing of the problems in diverse scenarios (Brugge and Bruggeman, p.4-5).
2. Identify measures and options, and assess their efficacy	Step 2 consists of the identification of possible measures and options to manage risk – i.e. management / adaptation measures (to reduce the risk probability, or the systems' vulnerability, and / or increase resilience) – for short- and long-term future conditions (Marchand and Ludwig 2014, p.3). Step 2 requires searching for possible measures / options available, and assessing their efficacy and for how long a given measure will be effective (the timing of this is largely influenced by the scenario considered); and, then, exploring which other measures are available (Brugge and Bruggeman, p.4-5). Step 2 involves: (a) the exploration of all possible or relevant measures around an ATP; and (b) the evaluation of each measure's performance under different future scenarios (and changing conditions) and against pre-defined criteria and standards. In Step 2, it is necessary to identify measures that can be used to meet the objectives and tasks. This implies identifying possible measures, and assessing their efficiency and cost-effectiveness (costs, effects and benefits) over the different scenarios) The cost-effectiveness and efficiency of measures are influenced by mid- / long-term developments (e.g. land use changes, or construction in areas for FRM measures) (Gersonius et al. 2016, p.204-206, 202). Short-term decisions should avoid an unnecessary increase of future costs; and it is necessary to efficiently link measures for the short- and long-term. Short-term measures must be coherently linked to long-term objectives and tasks, they *must be logical in the long-term*; and this implies preparing measures to keep open options for the long-term (Haegen and Wieriks 2015). Moreover, measures can be grouped in sets with a specific rationale (e.g. protection via hard defences).
3. Develop adaptation pathways	Step 3 consists of developing 'adaptation pathways' (Haasnoot and Jeuken; Gersonius et al. 2016, p.204; Brugge and Bruggeman, p.4-5). A pathway is a sequence of measures that may be activated before an ATP

and the APs map	occurs (Gersonius et al. 2016, p.204). This step requires building adaptation pathways as flexible routes to achieve the goals, rather than 'blueprints' (Zevenbergen et al. 2018). In this Step, it is necessary to design various adaptation pathways in a map (based on the assessment of the efficiency of the individual measures identified in step 2). The various pathways provide flexibility to adapt to a wide range of future changes. The APs' map shows the points in time for implementing measures, and the points at which a decision should be made on the potential options (Gersonius et al. 2016). This step also implies the assessment of the proposed strategies (pathways) on their *robustness* and *flexibility*, under different scenarios. Moreover, other criteria, e.g. '*impacts*', '*uncertainty involved*' or '*desire to keep options*', may be used. The results of this assessment can then help to select a subset of promising pathways. It is important to include inputs from different actors and seize opportunities to link different investment agendas (Gersonius et al. 2016, p.204-206). This step requires an assessment of the flexibility of the pathways, and a scanning of options to keep open (Zandvoort et al. 2018, p.189). The APs' map provides insight into potential lock-ins and options that should be kept open. It is important to explore opportunities to mainstream FRM / adaptation measures with other planned investments, e.g. in urban renewal. The consideration of opportunities to mainstream adaptation may require adjusting the timing for implementing measures (Gersonius et al.2016). To design the adaptation pathways in a map, the method of Haasnoot et al. (2012, 2013) is used (Brugge and Bruggeman). Adaptation pathways are series of sequenced measures that provide a solution to problems. The pathways are generated (assembled) and then assessed, which may lead back to Step 2 in an iterative way. The pathways are assessed on their effectiveness, costs and side-benefits. In addition, in the assessment of the pathways, two important factors must be considered: a pathway's *robustness* and *flexibility*. The goal is to elaborate *robust flexible strategies*. A *robust strategy* is one that achieves the desired objectives under diverse future scenarios. An important tool for making a strategy robust is flexibility; flexibility can be delivered by having the possibility to adapt strategies as necessary over time – e.g. adjusting measures or implementing new measures – and still meet the objectives. The APs map shows *transition points* (conditions under which it is necessary to switch from one measure to another, or their moment in a scenario). It is important to assess which measures must be taken now and which can be postponed (Brugge and Bruggeman, p.4-5). Several methods can be used to assess measures and pathways, their ATPs and effects, e.g.: cost-benefit, cost-effectiveness and multi-criteria analyses; robustness analysis (focused on measures' performance under diverse scenarios); feasibility analysis (focused on barriers and facilitators) (Deltares) (Note 225).
4. Design of an adaptive plan, and define triggers	In Step 4, the results of the prior steps are used to formulate an adaptive plan that contains possible measures and specifies 'triggers' for modifying the strategies or measures. Decisions will be made based on this adaptive plan (Brugge and Bruggeman, p.4-5). The result of Step 3 is usually a map showing a subset of 'promising adaptation pathways', which includes possibilities for transferring from one pathway to another. Step 4 implies the translation of such APs' map into a 'plan of action', which requires deciding which pathways should be followed and kept open and analysing the implications of this for short-term actions. Step 4b implies the definition of a monitoring and evaluation system that specifies 'triggers' (critical points beyond which it is necessary to make adjustments to the strategy or shift to another measure) and 'preparatory actions' (required to enable long-term options, e.g. adjustments in rules / legislation, research, spatial reservations, etc. (Gersonius et al. 2016, p.204-206). It is also important to integrate measures with investments of other actors (Zandvoort et al. 2018, p.189).
5. Imple-ment plan	This step consists of the implementation of the plan. The selected short-term measures are implemented, as well as measures necessary to keep options open in the long-term (and, thus, maintain flexibility).
6. Monitor, reassess the plan accordingly, and, if necessary adjust it (its strategies/ measures)	Step 6 implies a monitoring and evaluation system that keeps track of climatic, physical, and socioeconomic trends. The monitoring of climatic and socioeconomic developments is necessary to identify when it is necessary to adjust a strategy (e.g. to shift from a measure to another) (Deltares, p.5). In this step, the monitoring and evaluation system is conducted: it tracks climatic and socioeconomic changes relevant for adapting the plan's strategies or measures, e.g. for anticipating / delaying the implementation of measures. For example, if SLR unfolds at a faster rate than expected and a tipping-point is expected to be reached earlier, it may be necessary to implement a measure earlier than projected (if SLR evolves slower, then, the measure can be delayed). The monitoring system indicates the rate and direction of risks and their implications for adjusting the plan. It is required to allow the adjustment of the plan- its measures or their timing (Brugge and Bruggeman, p.4-5). This adjustment also implies adaptive capacity in the institutions involved.

In sum, ADM involves a cyclical and iterative process of 6 main steps. Each step offers the possibility to adjust elements of the plan / strategy, and, thus, helps to ensure the adaptive capacity in the general plan, and in planning and management process. Adaptability is necessary to cope with change and uncertainty in policymaking: it is not known what scenario will unfold, but it still is necessary to make decisions (Brugge and Bruggeman, p.4). ADM offers a structured management process that considers uncertain future conditions and change into planning and decision-making (Zevenbergen et al. 2018).

4.2. Annual cycle of the DP: steps to develop the *Delta Decisions* and *Preferential Strategies*

The DP follows an annual development cycle. In this cycle, the DP has carried out the steps of the ADM process (or similar steps to those prescribed in ADM) (DP 2016, p.6) (Figure 31). In each annual cycle, research (its concretization and scheduling) is undertaken in parallel with decision-making (which is based on research results of the prior year); e.g. the research undertaken for the DP 2013 happened in parallel with the implementation of the DP 2012 (Werners et al. 2016).

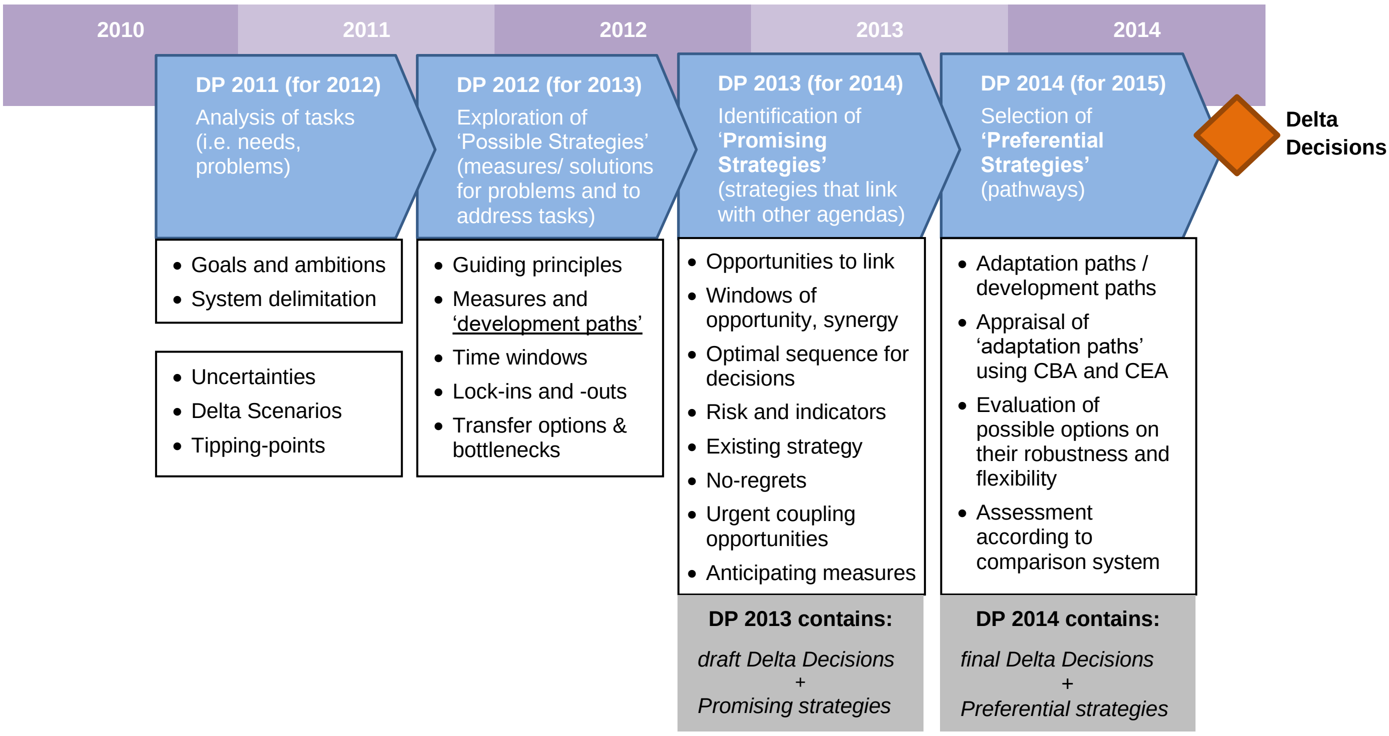


Figure 31. The process of planning of the DP contents, which also illustrates key elements of ADM as an adaptive approach. Source: own elaboration, based on Rhee 2012, p.9., Werners et al. 2016. The DP 2013 presents the 'draft Delta Decisions' and the 'Promising Strategies', while the DP 2014 presents the final 'Delta Decisions' and 'Preferential Strategies' (DP 2013, p.6). The Subprogrammes developed *Possible Strategies* in 2011-2012, *draft Delta Decisions* and *Promising Strategies* in 2012-2013, and the *final Delta Decisions* and *Preferential Strategies* in 2013-2014. See also Note 226.

In 2011-2012, each Subprogramme explored *Possible Strategies* for its region (i.e. possible measures / solutions). In 2012-2013, these *Possible Strategies* were further developed into *Promising Strategies* (i.e. measures and pathways presented in the DP 2013). In 2013-2014, the *Promising Strategies* were further detailed into *Preferential Strategies* (which are presented in the DP 2014). The 'Preferential Strategies' correspond to the final strategies proposed, which were adopted in 2015 (DP 2013, p.56, 78).

Each Strategy contains '*objectives, associated measures and the associated development path*' (DP 2013, p.56). Each Strategy contains a map with an '*adaptation path*'. The term '*adaptation path*' refers to an 'adaptation pathway'. An *adaptation path* is a logical set of measures that includes measures for the short-term (namely no-regret measures) and options for the long-term (DP 2013, p.56).

The main steps undertaken by the DP per year are described next.

Year 1 (2010-2011): Analysing the tasks (*tasking*)

The DP was initiated in 2010 with the aim of ensuring FRM and FS. During 2010-2011, the Sub-programmes inventoried / identified the *tasks* of FRM and FS for 2050 and 2100, through 'joint fact-finding' (DP 2014, p.132; 2012, p.43). To identify the tasks, the DP team examined '*what is needed, now and in the future*' to comply with the objectives (DP 2011, p.14). Joint-fact finding was used to identify the tasks for the 9 Subprogrammes, in which various *Delta Scenarios* were used (DP 2011, p.14). The DP 2011 contains the results of this analysis: it presents tasks for the short-, mid- and long-term, and outlines the process of steps to be followed each year to design the Delta Decisions and regional Strategies until 2015 (DP 2011, p.14) (Note 226). Importantly, in 2010, the DP had started to develop a set of scenarios, so-called *Delta Scenarios*, which would be used for all studies in the DP, and an evaluation system to assess and compare solutions (DP 2010, p.4).

According to Werners et al.[87], in this year of 'problem definition', the regional subprogrammes focussed on identifying adaptation needs, e.g. analysing '*what are the effects of climate change on the region'* and '*how can the long-term safety of the region be safeguarded*' (Werners et al. 2016). This implied gathering studies on climate change effects, prioritizing effects according to their likeliness, severity and impact on DP's objectives, and consulting experts for advice in research institutes, ministries, etc.

Year 2 (2011-2012): Exploring / identifying the *Possible Strategies*

In 2011-2012, the Subprogrammes explored and formulated possible solution strategies for their regions, so-called '*Possible Strategies*' (DP 2014, p.132, 12; 2013, p.56). A 'possible strategy' contains targets, related measures and a '*development path*' (or *solution-path* or *adaptation path*) (DP 2012, p.12, 43; 2011, p.14). To develop their adaptation paths, the subprogrammes analysed at what time new measures will be required, i.e. the moment of thresholds / tipping-points (DP 2012, p.89).

The *Possible Strategies* consist of the playing field of measures available (DP 2012, p.43). Their development was grounded on several requisites, e.g.: the new protection standards, the principle that problems and costs should not be passed on to future generations, and their cost-efficiency should be optimal; in addition, though the magnitude and rate of the effects of climate change and socioeconomic developments are uncertain, they will largely influence future FRM tasks, therefore, it was advisable to use an '*adaptive strategy*' able to respond to changes '*in a flexible manner'* (DP 2012, p.56, 37). With this in mind, in 2011/2012, the subprogrammes devised several '*development paths*'. A path is generated by '*putting the first steps and the long-term possibilities in a logical chronological order*', and, in this '*adaptive strategy*', the steps envisioned for the short-term should leave sufficient scope for different follow-up measures, in line with ADM (DP 2012, p.61, 69). The *adaptation paths* are a powerful way of understanding what measures can be taken, when, and how tasks and options for the long-term affect short-term decisions and measures (DP 2012, p.82).

During 2011-2012, ADM was progressively made more concrete and applied by the subprogrammes (DP 2012, p.89). The Subprogramme for Rhine Estuary-Drechtsteden started to develop its *adaptation paths*, and describe under what conditions new measures will be required, i.e. tipping-points/ thresholds for FRM (e.g. dykes that no longer meet the standard) and for FS (e.g. salinization of intake points) (DP 2012, p.89). On their turn, the subprogrammes for the IJsselmeer Region and for the Southwest Delta already presented their 'possible development paths' in the DP 2012 (DP 2012, p.59, 69) (Note 227).

In 2011/2012, the Subprogrammes focused mainly on the identification of measures, by analysing how the flood protection standards could be met under climate change (Werners et al. 2016). Besides this, during 2011-2012, the DP stimulated the subprogrammes to assess '*how much longer current policies and management practices were expected to suffice and when adjustments would be required'* (Werners

[87] Werners et al. (2016) analysed the process of policymaking of the DP, focusing on the Subprogramme for the Wadden Region.

et al. 2016). This is related with the identification of the first ATPs: a failure of the pre-existing policy / management measures. The DP acknowledged that climate change may threaten management objectives or lead to socially unacceptable changes; and that adaptation will be necessary if the amount of change is unacceptable or if the objectives can be realized more effectively with other measures. Hence, each Team identified a range of possible measures, as broad strategic alternatives which should be further studied (e.g. innovative flood defences) (Werners et al. 2016).

Moreover, in 2011 / 2012, the DP has developed its *VGS evaluation system*, a system to assess and compare the Strategies (DP 2012, p.87). In 2011-2012, there was a greater engagement of DP central staff, allowing the harmonization of subprogrammes and the refinement of guidance documents (e.g. Linde and Jeuken 2011) and criteria to compare measures (Werners et al. 2016) (Note 228). Moreover, during this year: research continued to *(re)identify adaptation needs* and climate change effects on each region (regional ecosystems and flood safety); the *Delta Scenarios* were issued in 2011, enabling further agreement on the range of future effects that should be considered. As the seriousness and timing of climate change remained uncertain, the DP decided that it would create a monitoring system to provide early signals of climate change and detect thresholds (Werners et al. 2016).

Year 3 (2012-2013): Developing the *draft Delta Decisions* and the *Promising Strategies*

In 2012 / 2013, the Subprogrammes further developed and narrowed down the range of '*Possible Strategies*' into '*Promising Strategies*' (the latter are presented in the DP 2013) (DP 2013, p.56; 2014, p.132). Moreover, in 2012-2013, the DP Team started to develop 5 *draft Delta Decisions* (issued in the DP 2013) (DP 2014, p.132). In this year, the 'Possible Strategies' (and their adaptation paths) were refined and further detailed, resulting in the Promising Strategies (DP 2013, p.56; 2012, p.80; 2011, p.14). The Promising Strategies, and their measures, were assessed on their cost-benefit (DP 2012, p.80). The Promising Strategies were elaborated via the refinement and filtration of the Possible Strategies, as the less cost-effective solutions were abandoned (DP 2012, p.80; 2014, p.132).

The Promising Strategies consist of promising sets of measures. '*Promising*' means that the objectives for FRM and FS are achieved in a cost-effective way, i.e.: with the maximum benefits as possible, at reduced costs, with minimal negative effects, and seizing linkage opportunities with other investments or objectives) (DP 2013, p.56; 94; 2012, p.80). Each Subprogramme developed its Promising Strategies (for its region) in coordination with the other subprogrammes. The '*Promising Strategies*' were based on the '*draft Delta Decisions*', but also provided input for them (DP 2013, p.56).

In line with ADM, '*development paths*' (later called '*adaptation paths*', i.e. adaptation pathways) were designed in each of the Promising Strategies. This implied analysing the. conditions under which it is advisable to move from one measure to another (i.e. ATPs), and how options could be kept open to allow a future transition (DP 2012, p.81). The development of the *adaptation paths* required: plotting concrete measures and projects on a timeline, visualizing multiple options, and exploring when it will be necessary to shift from one option to another (DP 2013, p.56). A Promising Strategy identifies the objectives (e.g. update the standard), and it contains concrete measures for the short-term and indicative measures for the long-term (including *options that need to be kept open*), and the resultant *development path* (in a schematic schedule) (DP 2012, p.81).

In specific, in 2012-2013, the Subprogrammes analysed which measures were promising to meet the objectives (e.g. attain the protection standards and ecological interests). This year consisted mainly of: 1) detailing and assessing measures and options; 2) developing strategies, i.e. designing 'paths', and 3) appraising them (Werners et al. 2016). FRM measures were aggregated (*clustered*) and sequenced, to produce several ‘paths’, i.e. strategic alternatives that may be progressively implemented according to the speed of climate change effects, especially SLR. For each Strategy, diverse FRM measures were studied in detail (often requiring stakeholder consultation or exploratory studies).[88] To assess the measures and ‘paths’, several criteria (set by the central DP staff with local actors) were used: flood risk reduction, cost, opportunities for other values and functions, feasibility, trade-offs, etc. The possible measures were assessed on these criteria, resulting in a subset of promising measures, with which the *Promising Strategy* was built.[89] Moreover, studies on possible site-specific measures (their qualitative effects on nature, economy, and actors’ perspectives), and quantitative modelling studies on measures’ performance and spatial effects, were conducted. The results of these studies were essential to the cost-benefit and multi-criteria analyses. Besides this, in 2012-2013, each subprogramme continued to conduct research (which focussed on further exploring risks, adaptation and monitoring needs), and refine its research agenda (underlining the need to investigate adaptation options) (Werners et al. 2016).

Year 4 (2013-2014): Defining the *final Delta Decisions* and the *Preferential Strategies*

In 2013 / 2014, the DP Team further elaborated the previous ‘*draft Delta Decisions*’ into the final ‘*Delta Decisions*’ (proposed in the DP 2014); and the Subprogrammes further developed and narrowed down the *Promising Strategies* into *Preferential Strategies*, which are presented in the DP 2014 (DP 2014, p.132, 8; 2013, p.94, 97) (Note 229). Most of the Delta Decisions, and all the Preferential Strategies, include an ‘adaptation path’. Each regional Subprogramme has made up a Preferential Strategy for FRM for its ow region (DP 2014, p.8, 46).

The Preferential Strategy, and its measures, were analysed under such Delta Scenarios (DP 2016, p.6). The diverse Strategies devised were subjected to a ‘robustness test’ to see which strategies were effective under the different scenarios; the ‘*preferential*’ strategies are those that perform well even in more drastic climatic scenarios (DP 2014, p.8). Moreover, the costs of the Preferential Strategies were estimated, especially of the measures envisioned until 2050 (DP 2014, p.47).

The Subprogrammes elaborated *adaptation paths* for each Preferential Strategy, which implied defining the conditions under which changing measure is necessary (DP 2013, p.95). Each Preferential Strategy contains measures for the short-term (planned with a fair level of certainty) and options for the long-term. Short-term measures are often linked to other planned investments or objectives of other policy fields or regions, to ensure cost-effectiveness and sufficient support (Note 230). During the development of the *adaptation paths*, it was important to keep open options for long-term, i.e. have possibilities to switch to other measures if future climatic or socioeconomic changes, or new knowledge that emerges, require so.[90] The Teams also identified additional short-term measures necessary to be able to change strategies later and analysed if it was necessary to embed options (or make changes) into laws or institutional practices (DP 2013, p.95).

[88] An exploratory study was conducted on ‘innovative flood defences’, such as *overtopping-resistant dykes*, *dykes combined with saltmarshes*.

[89] In what regards the assessment of measures and paths, Werners et al. identify some gaps: the lack of criteria specific of climate adaptation, namely ‘flexibility’ and ‘robustness’; measures and strategies (paths) were mainly assessed quantitatively in detriment of qualitative aspects (time and costs largely influenced the selection of measures); consensus-building was not explicitly addressed in the appraisal of measures; some measures and strategies were left out at an early stage due to political reasons (rather than formal appraisal criteria) (Werners et al. 2016).

[90] The DP considered and anticipated the long-term: most Preferential Strategies include possible options for the long-term, some may not be required after 2050 but are included anyway as an ‘option to be kept open’ (DP 2013, p.102-103) (Note 231). In 2012-2013, in the development of the Promising Strategies, some options for the long-term were eliminated (e.g. a dam with locks in the Nieuwe Waterweg, a ring of floodgates in rivers around Rotterdam) and, thus, not used in the Preferential Strategies. Other options were kept open and used in the Preferential Strategies of 2013-2014 (e.g. new design requisites for the Maeslantkering, flood storage, etc.) (DP 2013, p.95).

In line with the 1st principle of ADM, the DP sought to identify measures for the short- and mid-term that *agree with* the long-term tasks (DP 2013, p.102). Long-term tasks are linked to decisions to be taken in the short-term (DP 2017, p.22). In ADM, short-term decisions must be coherently linked to long-term tasks and goals, short-term measures *must be logical in the long-term* and do not hinder long-term options, and it may be necessary to prepare short-term measures to keep options open for the future (Haegen and Wieriks 2015). Each Preferential Strategy contains short-term measures linked to options for the mid- (2050) and long-term (2100).

The *Delta Decisions* and *Preferential Strategies* were elaborated with 2100 as horizon, which fostered the consideration of climate change into decisions and investments in flood defences, infrastructures and built environment, and the integration of agendas of distinct policy fields and actors (Alphen 2015). The Delta Decisions and Preferential Strategies were developed based on 4 *Delta Scenarios* (DP2014, p.136).

In September 2014, the *Delta Decisions* and regional *Preferential Strategies* were presented to the House of Representatives (Parliament) (DP 2017, p.7; Haegen and Wieriks 2015; Alphen 2015), and were approved by the national government and Parliament (Buuren et al. 2016). By the end of 2014, the government set down the *Delta Decisions* and *Preferential Strategies* as policy in the '*National Water Plan*' (DP 2017, p.7).[91] The Delta Decisions and Preferential Strategies form the main content of the DP advice for the year 2015 and onwards (Restemeyer et al. 2017, p.928).

In sum, the stage of 'analysis and strategy development' took 4 years (from 2010 to 2014). In this period, the DP and its Subprogrammes[92] developed 5 *Delta Decisions* and 6 *Preferential Strategies* (Haegen and Wieriks 2015; Alphen 2015; Zevenbergen et al. 2018).

The development of the Delta Decisions and Preferential Strategies was a gradual process of exploration and assessment of measures / options, design of 'adaptation paths' and their successive appraisal (DP 2014, p.132). In the 1st year (2010-2011), the regional Subprogrammes carried out the 'Problem Analysis', in the 2nd year (2011-2012), they explored and developed *Possible Strategies*; then, in the 3rd year (2012-2013), they narrowed down towards the *Promising Strategies*; and in the 4th year (2013-2014), they further defined and selected the *Preferential Strategies* (Restemeyer et al. 2017, p.928; DP 2014, p.132; Werners et al. 2016).[93] After 2014, there was shift towards the implementation of the *Strategies* and detailed design of their measures (Zevenbergen et al. 2018).

Since 2015, the DP annual reports have documented the progress made in the planning and implementation of the Delta Decisions and Preferential Strategies (of the DP 2014), and if they are on schedule (DP 2018, p.19; 2016, p.6).[94] Moreover, since 2015, the DP has monitored, every year, new developments or changes that might require the adjustment or fine-tuning of the Preferential Strategies.

[91] In addition, the provinces, Water Boards and municipalities signed the '*Administrative Agreement on the DP*', showing their commitment to the DP and to adopt the Delta Decisions and Preferential Strategies into their own plans (DP 2017, p.7).

[92] Since 2010, central government, provinces, municipalities and Water Boards worked on, with the collaboration of social organisations and businesses, the Delta Decisions and Preferential Strategies, under the leadership of the DP Commissioner (DP 2014, p.132). Each of the regional strategies was elaborated by its respective subprogramme, which worked together with provinces, municipalities and Water Boards, involving the scientific community, NGOs and private sector (Bloemen et al. 2018). The content of the Strategies was developed by the subprogramme's team; such Preferential Strategies had to be explicitly linked to ADM (Restemeyer et al. 2017, p.928) (Note 232).

[93] The teams first explored the range of *Possible Strategies*, then narrowed down to *Promising Strategies*, and then to the *Preferential Strategies* (Werners et al. 2016; DP 2014, p.132).

[94] The DP follows an annual cycle of development, in which new research is programmed and commissioned every year (Werners et al. 2016). In 2015/2016, the DP created a *Knowledge Agenda* proposing research and studies about e.g., the cost-benefit assessment of measures, indicators, threshold values, 'intervention points' within the adaptation paths, the incorporation of ADM in 'real' practice (DP 2016, p.25).

4.3. Application of ADM process in the DP: the steps followed to develop an *adaptive programme*

The DP, within its annual development cycle, has followed the steps of the ADM process (DP 2016, p.6). More specifically, in the development of its Preferential Strategies and Delta Decisions, the DP has applied and followed the ADM process (and its main steps). The DP Subprogrammes applied the ADM approach and its process to elaborate the *Delta Decisions* and the *Preferential Strategies* (though each Subprogramme had different objectives). To this end, the Subprogrammes carried the main steps of the ADM process, namely the design and appraisal of adaptation pathways (Brugge and Bruggeman, p.5-6; Marchand and Ludwig 2014, p.27) (Note 233).

In the DP, ADM involved a process with several steps to create the *Strategies* (Zandvoort et al. 2018). A *Strategy* contains goals, measures and development trajectories, presented through '*adaptation paths*' (Rhee 2012, p.18; Zandvoort et al. 2018, p.190). Each *Preferential Strategy* of the DP presents objectives, measures to achieve the objectives, and the associated '*adaptation path*' (i.e. a set of measures in a timeline, an APs' map) (Bloemen et al. 2018; Alphen 2015; DP 2013, p.56). The steps of the ADM process were followed to develop the Strategies for FRM and FS, in the yearly updated DP reports (Zandvoort et al. 2018, p.191). Since the outset, the Subprogrammes have used the ADM approach in their work, namely in the development of Strategies (DP 2011, p.50). The Delta Decisions and Preferential Strategies were created based on ADM approach, its principles and process (DP 2011, p.18).[95] ADM explained how to develop adaptation pathways to address the objectives and tasks for FRM and FS (Gersonius et al. 2016). The main steps of ADM – as taken and carried in the DP – are outlined next.

Step 1) Problem analysis

Sub-step 1a: Definition of a '*vision*', i.e. objectives, ambitions, and tasks

The Team elaborated a vision of how to deal with the risks and problems expected the future.

Sub-step 1b: Analysis of vulnerabilities and opportunities under different scenarios

In the DP, the ADM process started with the analysis of current and future situation and problems (Gersonius et al. 2016, p.205). The DP analysed which developments or changes might influence the current and future tasks on FRM and FS (DP 2012, p.88). In the DP, the analysis of *what might happen in the future* required the generation of the four *Delta Scenarios* (Klijn et al. 2016).

<u>Within sub-step 1B: working with several plausible futures: the four 'Delta Scenarios'</u>

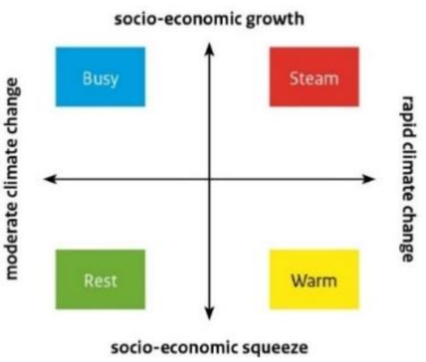
To deal with uncertainties about future conditions and changes – and *render them manageable* – the DP has used four plausible futures, called *Delta Scenarios* (DP 2014, p.135; 2013, p.6). The *Delta Scenarios* are different plausible scenarios which show how the climatic and socioeconomic conditions might change until 2050 and 2100 (they are not predictions nor target scenarios) (Brugge and Bruggeman p.3).

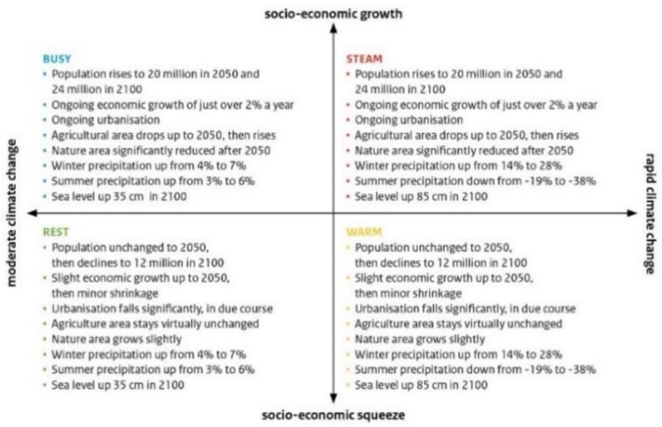
The four *Delta Scenarios* (issued in 2011/2012) were developed based on the scenarios of climate change generated by the *Royal Netherlands Meteorological Institute* (KNMI-2006), and on the scenarios of socioeconomic development from other research institutes and planning offices (e.g. the *Netherlands Environmental Assessment Agency* (PBL), the *Netherlands Bureau for Economic Policy* (CPB), and Wageningen UR/LEI), under the leadership of Deltares (DP 2011, p.11, 14, 47; 2012, p.35; 2014, p.135, 168; Restemeyer et al. 2017; Gersonius et al. 2016; Marchand and Ludwig 2014; Werners et al. 2016;

[95] In 2011, the DP staff issued several guidance documents, e.g. on the assessment of ATPs (Linde and Jeuken 2011) and ADM (Rhee 2012) (in Werners et al. 2016). The subprogrammes progressively used ADM to develop '*adaptation paths*' (DP2012, p.89; 2011, p.14) (Note 228).

Klijn et al. 2015; Brugge and Bruggeman; Deltares; Seijger et al. 2017) (Figure 32) (see also Note 234). The development of the *Delta Scenarios* took into consideration the most up-to-date information available on climate change effects and socioeconomic projections (DP 2013, p.32).

In the DP, scenario development started with the formulation of a central question: which external events, circumstances and changes / developments, are critical to FRM and FS. Drawing on this, the major drivers of change were identified and classified according to their impact and uncertainty. The most important drivers identified (in terms of impact and uncertainty) were ‘climate change’ and ‘socioeconomic development’. The two drivers were represented as the two axes of a four-quadrant matrix, which resulted in the four different scenarios. Key-variables were quantified for each scenario, and detailed descriptions of each scenario were developed (e.g. specific water-related implications for diverse time-horizons, and land use maps for each scenario) (Marchand and Ludwig 2014, p.16-17).





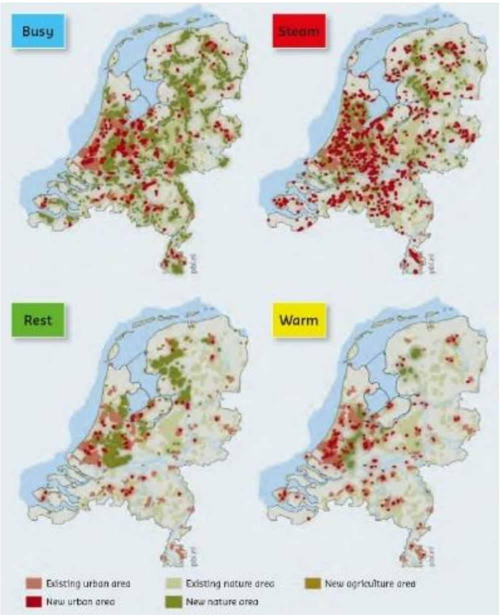


Figure 32 (top left and right). The 4 Delta Scenarios (*Busy*, *Steam*, *Rest* and *Warm*), and their corresponding figures . Source: DP 2011, p.14, 46; 2012, p.35; 2013, 100; Marchand and Ludwig 2014; Deltares; Brugge and Bruggeman. The Delta Scenarios combine rapid / moderate climate change with socioeconomic growth / decline. For example, the Steam scenario represents rapid climate change and continual growth of economy and population, which results in the worst case in terms of flood risk (Alphen 2015). In the Steam scenario, there is a rapid climate change (4ºC temperature rise in 2100), while in the Rest scenario, there is a moderate climate change (2º C temperature rise in 2100) (Gersonius et al. 2016, p.208). The Busy and Warm scenarios foresee an increase in flood risk due to SLR, higher river discharges, and / or socio-economic growth (Haasnoot et al. 2013, p.491).

Figure 32 (bottom left). The expected expansion of urban, nature and agricultural areas in each of the Delta Scenarios, in 2100. Source: Brugge and Bruggeman, p.3; Deltares.

The Delta Scenarios assume 2050 and 2100 as time horizons / reference years (not fixed endpoints) where climate change and socioeconomic developments vary (DP 2013, p.100; 2011, p.48, 70). The 4 scenarios differ in terms of moderate / rapid climate change (X axis), and in terms of socioeconomic growth / decline (Y axis) (DP 2012, p.35; 2014, p.168; Marchand and Ludwig 2014; Haegen and Wieriks 2015; Alphen 2015; Restemeyer et al. 2017; Bloemen et al. 2018). Each scenario has its corresponding climatological and socioeconomic circumstances and provides its respective figures for SLR, drought and soil subsidence (DP 2016, p.6, 2014, p.136). The climatic parameters considered in these scenarios were SLR, extreme river discharge, precipitation, evaporation (the values for such parameters were downscaled from the IPCC AR5 to the Netherlands); whereas the socioeconomic parameters were the future size and spatial distribution of population and land uses (as these influence flood risk and FS) (Alphen 2015; Haegen and Wieriks 2015; Jeuken et al. 2014).

Though each Delta Scenario has its respective climatological and socioeconomic figures, the climatological and socioeconomic circumstances may turn out differently than expected in the Delta Scenarios. Hence, the Preferential Strategies were designed to be *adaptive* and *resistant to slower and faster climate change* than the expected (DP 2014, p.136). Moreover, the Delta Scenarios may be periodically updated over time (DP 2014, p.168) (Note 235).[96]

The Delta Scenarios served to:

- Assess possible future risks and impacts (Jeuken et al. 2014, p.10, 11). Investigate future flood- and water-related problems, risks and needs by 2050 and 2100. The four Delta Scenarios represented the 'corner flags of the playing field of plausible futures' (Alphen 2015, p.312). These scenarios translate the most relevant uncertainties about plausible future changes and diverse sociocultural perspectives (Marchand and Ludwig 2014, p.15). In 2012, the Delta Scenarios were used by the Subprogrammes to explore what problems of flood safety and freshwater supply might occur in the future (Brugge and Bruggeman, p.5; Haegen and Wieriks 2015).
- The Delta Scenarios were used as the basis for analysing the future tasks, and for developing strategies (DP 2011, p.14, 20).
- Support the development of the Delta Decisions and Preferential Strategies (inform strategy development) (Bloemen et al. 2018; DP 2014, p.136). The DP developed its Strategies based on the Delta Scenarios (DP 2013, p.32).[97] The Delta Scenarios were used in the development of strategies, namely to: assess the various measures and determine when these will be needed (Brugge and Bruggeman), e.g. to determine when the current actions will be ineffective or insufficient (the date of first ATP) (Alphen2015). The Delta Scenarios supported the design of strategies: they were used to test the measures and strategies (paths) – their performance – under different future conditions (Marchand and Ludwig 2014, p.12; Alphen 2015). Scenarios were used for the assessment of individual measures and strategies, in cost-benefit and multi-criteria analyses (Jeuken et al. 2014, p.10, 13), and to assess their robustness (Seijger et al. 2017).
- Define the earliest and latest moment to adapt, considering the lead-time necessary for planning and implementing measures (Jeuken and Reeder 2011, p.7) (i.e. implementation- and decision-moments).

In 2010-2011, the DP Teams used the scenarios to assess how much longer the current measures (policy and management actions) are expected to suffice and when adjustments will be required – i.e. when the tipping-point of the existing system will be reached (DP 2010, p.3-4, 32). The main issue was analysing if and for how long the current measures will still be satisfactory under a changing climate (more than determining the exact levels of SLR) (DP 2010, p.36). The DP defines *tipping-points* as points at which the existing system ceases to meet the requirements (DP 2011, p.8). A tipping-point occurs when, due to changes in climate or socioeconomic circumstances, the existing measure, policy, or infrastructure becomes insufficient to comply with the defined criteria (due to physical, technical, or financial constraints or socially unacceptable effects) (DP 2011, p.71). The analysis of ATPs sets out when decisions and new measures need to be taken (DP 2011, p.55).

[96] The data underlying the Delta Scenarios is periodically updated (e.g. for climatic parameters, the latest data used were the 2014 KNMI climate scenarios (DP 2014, p.168). For example, the Delta Scenarios were revised in 2012 (being supplemented with new insights on climate change, namely contents of IPCC 2014 AR5, and new insights on the regional effects of climate change); the subprogrammes worked with these revised Delta Scenarios since 2012 (DP 2014, p.136; 2013, p.100). In 2016, the DP commissioned research to explore the implications of new knowledge for the Delta Scenarios, for FRM and FS tasks, and for Preferential Strategies (DP 2016, p.6) (Note 235).

[97] All subprogrammes worked with the same 4 *Delta Scenarios* (DP 2012, p.35; Werners et al. 2016).

The DP Teams analysed for how long the current policy measure will suffice and when the first tipping-point (at which such measure is no longer tenable) will be reached. To answer this, scenarios were used (it was not known the rate at which the climate will change, an ATP may be reached at any time) (DP 2010, p.68).

STEP 2) EXPLORING AND IDENTIFYING POSSIBLE MEASURES, AND ASSESSING THEIR EFFICACY AND ATPS

This step involved the exploration of possible measures for the short-, mid- and long-term, and their delineation in a schematic map. First, the Teams identified measures for the short-term, and then they assessed if other measures, or eventual amendments / adjustments, will be needed in the mid- or long-term, by looking at the conditions under which it will be wise to switch to an alternative measure (Gersonius et al. 2016, p.205). Each subprogramme focused on identifying which possible measures and options were required to comply with the FRM objectives at local level (Gersonius et al. 2016).

The design of adaptation pathways requires the identification of ATPs. In ADM, tipping-points correspond to points / conditions under which the current management actions / measures or policies become '*too expensive*, *technically impossible or societally unacceptable*'; the date of an ATP indicates an 'expiration date' at which a given measure or policy ceases to be feasible (Rhee 2012, p.18, *in* Zandvoort et al. 2018, p.190). More precisely, in ADM, tipping-points indicate conditions under which a given measure or policy action ceases to be effective or acceptable, and a new measure is required. An ATP indicates that a given measure no longer suffices and a new measure is required.

This step required assessing the effectiveness of the diverse measures under different scenarios and determining their ATPs.[98] The moment of an ATP could be measured in relation to scenarios: by placing alternative measures against diverse future scenarios, their tipping-points emerge. Despite the difficulty of determining the exact moment of ATPs, the ADM approach primarily seeks to inform about the time needed to implement measures, and what are the measures available (Zandvoort et al. 2018, p.190-191).[99]

With ADM, the DP sought to achieve the highest possible cost-effectiveness in measures: in ADM, the selection of measures must take into account the costs and effects of each measure during its whole lifetime (including the planning, management and maintenance stages) (DP 2011, p.49).

A key feature of the Preferential Strategies (and also of the Delta Decisions) is that '*it should be possible to take additional measures in the long term (after 2050) to address the challenges following from climatological and socioeconomic developments*', and *'the options for these are ready'* and *'included in the adaptation paths of the preferential strategies*' (DP 2014, p.148). An example of an option for the long-term is the replacement of the Maeslantkering storm surge barrier.[100] The DP sought to ensure that it has '*potential measures at hand'* should conditions change faster than expected, and '*sufficient elbow room*' for them (DP 2014, p.150, 9).[101] Depending on future developments, it may be necessary to

[98] In ADM, measures are not designed for a worst-case scenario (no fixed value is assumed in indicators for 2100) (DP 2014, p.138; 2011, p.48,70). It differs from the approach where an optimal solution is chosen for a *business-as-usual* or *worst* scenario (Brugge and Bruggeman).

[99] The focus is on what measures can be taken if the current system reaches its limits. To determine the date of an ATP, multiple variables can be compared under each scenario, and a time-window (in which the expiration date may occur) can be estimated: *the first and last moments at which a measure (...) does not suffice anymore and, thus, additional measures need to be taken* (Rhee 2012, *in* Zandvoort et al. 2018, p.190).

[100] Some of the options for the long-term envisioned in DP 2014, are: (a) the replacement the Maeslant storm surge barrier with a new closable-open barrier, or (b) the construction of locks in the Nieuwe Waterweg (when this barrier needs to be replaced, or earlier) (DP 2018, p.22; 2016, p.11). Other options proved to be ineffective and were abandoned (e.g. a dam with sealocks in the Nieuwe Waterweg) (Note 236).

[101] *Keeping options opens* helps to clarify future needs, identify locations necessary for future measures and rule out developments that could render measures unviable (DP 2014, p.49), but a decision on the long-term option is left open (Note 236). The DP developed solutions for problems that may occur in the long-term future, but in some situations, it is hard or not advisable to set now measures for the next 50 / 100 years, and solutions should be allowed to arise alongside emerging knowledge and changing conditions (DP 2012, p.88).

reconsider the options for the long-term, using e.g. more transformative measures. To be able to take other measures after 2050, these must be already considered in spatial policy, which implied the designation of '*spatial and policy-based reservations*' for long-term options (and tools to minimise their drawbacks) (DP 2014, p.148-149).[102]

The Teams sought to maintain the possibility of taking new measures in the long-term, presenting them in the '*adaptation path'* of each Preferential Strategy. Each *path* contains options for the long-term that are intentionally kept open due to uncertainties about future climatic and socioeconomic conditions. These options, and the possibility of keeping them open, will be subjected to scheduled reassessments over time, and as new knowledge emerges, or conditions change (Petersen and Bloemen 2015).

BOX 5: Using different types of measures, the Multi-layered Flood Risk Management (ML FRM)

The DP uses different types of FRM measures, e.g.: classic 'dyke improvements', 'river widening', 'building with nature' solutions, multifunctional dykes / defences (e.g. dykes integrated in seaside boulevards), '*Delta Dykes*' (very robust dykes that reduce the probability of breaching), spatial planning-related measures to climate-proof spatial development (e.g. flood-proofing accommodation measures, water-robust spatial design), sediment solutions enhancing nature values (DP 2013, p.8; 2014; Seijger et al. 2017; Werners et al. 2016). The choice of measures depended on the effectiveness costs and benefits of measures, and on local conditions (measures were customized per area) (DP 2013, p.8) (Note 237).

Since 2011, the DP has employed the concept of '*multi-layered flood risk management*' (ML FRM) (DP 2012, p.37), which relies on three 'layers' of FRM measures: (1) flood prevention (it relies mostly on flood protection measures); (2) spatial planning-related adaptation measures; and (3) disaster management measures. These types of measures can be used separately or in 'smart combinations' to achieve the required safety level. The 1st layer focusses mainly on flood prevention, the 2nd and 3rd layers focus mostly on limiting flood impacts (Werners et al. 2016). Although the use of 'smart combinations' of the 3 layers is encouraged, it seems be useful only in cases where traditional dykes or 'river widening' measures are not feasible (DP 2013, p.41). The 1st layer remains the *cornerstone* of the Dutch approach to FRM (DP 2012, p.37). The ML FRM can contribute to achieve the safety level *if standard solutions involving dykes and/or room for the river (i.e. prevention) are not or barely socially or financially viable* (DP 2013, p.8).

After 2012, the DP clarified how the 2nd and 3rd layer, and '*smart combinations*' of the three layers, can be used to achieve the flood safety objectives, and the subprogrammes studied possibilities of using measures of the 2nd and 3rd layer (to reduce impacts, damage and casualties) as a supplement to prevention measures (1st layer) (DP 2012, p.37). The Subprogramme for the Rhine Estuary-Drechtsteden applied the ML FRM in pilot zones, e.g. Dordrecht.

Some Preferential Strategies, in their 'adaptation path' contain measures of the 2nd layer (e.g. measures to flood-proof urban areas in Rotterdam), but their inclusion does not mean that is part of formal policies (Buuren et al. 2016).

In the DP, FRM strategies should be made of a combination of diverse measures that make the whole strategy more effective (e.g. *dyke improvement* in conjunction with *river widening*). Moreover, the DP envisioned (short-term) measures to enable / prepare options for the long-term, e.g. 'reserving space now' (e.g. for dyke realignments, bypasses, or water retention). Besides this, large-scale interventions should not occur until they are inevitable (DP 2014, p.136).[103]

STEP 3) DEVELOPING THE STRATEGIES WITH THEIR MAP OF '*ADAPTATION PATHS*' (PATHWAYS)

In this step, each Regional Subprogramme developed a strategy for FRM for its region. Each of the regional *Strategies* contains a map of adaptation pathways, called *'adaptation paths'*. The *Preferential Strategies* correspond to the preferred strategies for each region (Buuren et al. 2016).

To develop the *adaptation paths*, the Subprogrammes' Teams used the APs and ATPs methods. Each Team devised various adaptation measures and possible pathways (i.e. trajectories to achieve the objectives). This required assessing the effectiveness, costs, and benefits of the various measures under

[102] Some of the measures that will be needed in the mid- and long-term require *land*, thus, the DP established links with central government's property strategy (DP 2014, p.149). In ADM, it is important to allocate land for measures that may be needed in future or reserve it for temporary land uses (DP 2010, p.70). Any spatial components of the options for the long-term must be taken into account in spatial policies now (e.g. spatial reservations, as defined in the '*General Spatial Planning Regulations Decree*') (DP 2018, p.23).

[103] By using the methods of ATPs and APs, some authors found that the Dutch FRM system based on flood protection through dykes and coastal sand nourishments can be sustained for some centuries, however, there may be other reasons for a transition to other measures (e.g. measures with better performance, lower costs, more benefits, improvements to well-known measures, etc.) (Klijn et al. 2015).

different scenarios, and analysing when new measures will be needed to achieve the objectives (Zandvoort et al.2018). Thus, the design of the 'adaptation paths' implied the identification of tipping-points (Buuren et al. 2016). It was also necessary to *keep options open* (have possibilities to alter the course) (Zandvoort et al.2018, p.191).

The *Preferential Strategies* needed to be: *robust* (i.e. the objectives should be achieved with the Preferential Strategy under all *Delta Scenarios*) and *flexible* (i.e. the implementation of a strategy / measure can be sped up or slowed down easily and it is possible to change to a different strategy / measure, if necessary) (DP 2013, p.94). Flexibility is provided *'through the types of measures selected, by leaving options for adjustment or switching to other measures open for the future. In this way, measures can be adjusted to new insights and circumstances*' (DP 2014, p.169).

In line with ADM, various *adaptation paths* were designed in each of the Strategies elaborated (DP 2012, p.81). The map of '*adaptation paths*' provides a schematic overview of the measures needed in a certain region (DP 2011, p.48). Each Preferential Strategy presents a map of 'adaptation path(s)'. The map shows, from the current situation and moving ahead into the future, the various measures available for the short-term and possible options for the mid- and long-term (including possible adjustments / adaptations that may be necessary in the strategies), and it indicates the conditions under which it is advisable to shift from a strategy (or measure) to another (DP 2011, p.48; Gersonius et al.2016, p.205).

The *adaptation paths* designed were assessed under different scenarios (in which changing conditions were reflected). The strategies had to be flexible in terms of: timing (possibility of postponing or advancing measures in time), possibility of choosing another measure or strategy, and avoidance of lock-ins. The paths were also assessed on their adequacy to context (physical, socioeconomic and institutional conditions) (Zandvoort et al. 2018, p.191).

The Preferential Strategies were developed on the basis of the four *Delta Scenarios*, but they are, by nature, *adaptive*: they can be adapted *to slower and faster climate change* than those expected in the *Delta Scenarios*. The '*adaptive nature of the strategies'* makes it possible to act according to evolving conditions and changes, for example, *'by accelerating or slowing down the implementation of measures*' – e.g. the number and amount of sand replenishments per year along the coast can be adjusted to the measured SLR. Based on new knowledge and monitoring, the strategies and / or measures within them may be advanced or postponed, and adjusted in terms of scope and design (DP 2014, p.136).[104]
The Subprogramme for the Rhine Estuary-Drechtsteden developed its 'adaptation path' for FRM, which indicates diverse measures and at what times these will be required (DP 2012, p.90) (Note 238).

In sum, to create 'strategies', the ADM process builds on the construction of pathways, and this implies the scanning of options to keep open, and the assessment of the flexibility of measures and pathways. These aspects were patent in the development of the Strategies for FRM and FS of the DP (Zandvoort et al. 2018, p.189, 191). Based on the map of *adaptation paths*, the Subprogrammes' Teams looked for possibilities to link the implementation of the Strategies with other investment agendas of other fields (integration of FRM measures with other investments) (DP 2011, p.48; Gersonius et al.2016, p.205).[105]

[104] Yet, in some areas, the working rate cannot be exclusively based on monitoring, e.g.: in areas where climate change signs are hard to detect due to the great natural variability in indicators (e.g. river discharge), or areas where waiting for monitoring results could lead to a late implementation of measures that take a long time to be prepared (e.g. dyke improvement). For this reason, the Preferential Strategy for areas around rivers assumed fixed values for the peak river discharges of the Rhine River and Meuse River (DP 2014, p.136).

[105] In line with the 4th principle of ADM, the DP sought to link measures with other investments, spatial developments or objectives (DP 2013, p.102; 2014, p.12; 47; DP 2017, p.22). It searched for opportunities to mainstream measures into planned and ongoing investments (Zevenbergen et al. 2018), e.g. a dyke integrated into a car park, covered by a dune (Haegen and Wieriks 2015).

Sub-step 3b: Assessing the Strategies and their '*adaptation paths'*

As mentioned, the subprogrammes followed a screening process from *Possible Strategies* to *Promising Strategies* and then to the *Preferential Strategies* (preferred pathways). In this process, the strategies were assessed on their: cost-benefit, effectiveness in meeting the objectives (targets), and secondary effects (on nature, shipping, etc.), through cost-benefit analyses and expert judgment (Restemeyer et al. 2017, p.933). In ADM, it is important to assess the effectiveness of measures under different scenarios, and select the best possible strategy based on this and on societal agreements on the desirability of their measures (Zandvoort et al. 2018, p.191).

To assess the measures, and, in this way, substantiate the Delta Decisions and Preferential Strategies, the Subprogrammes used several economic assessment tools, e.g.: cost-effectiveness analysis, cost-benefit analysis, and social cost-benefit analysis[106] (DP 2013, p.105; 2014, p.137). With these tools, the DP conducted a sound analysis of the Preferential Strategies (and Delta Decisions). The costs of each Preferential Strategy were estimated, especially of measures until 2050 (DP 2014, p.47). All Preferential Strategies were assessed under the *Delta Scenarios* (DP 2016, p.6) (Note 239). Moreover, in 2013-2014, the Delta Decisions and Preferential Strategies were assessed in an *Environmental Impact Assessment*. The results were also used to decide on the Preferential Strategies (based on their environmental, natural, and cultural-historical effects) (DP 2013, p.100).

BOX 6. Assessment tools used: *Delta Tools*

Since 2010, the DP developed a set of *Delta Tools* to ensure that all subprogrammes apply the same methodology, principles, and state-of-art knowledge. The *Delta Tools* contain methods and instruments that the subprogrammes use to substantiate their decisions and strategies, namely: the 'Delta Model' and the 'VGS Evaluation System' (DP 2011, p.11; 2013, p.100) (Note 239). The *Delta Model* is a group of one- and two-dimensional hydrological models to analyse how measures from the Strategies contribute to the objective of reducing water-related risks (DP 2014, p.135; Alphen 2015). It uses 'effect modules' for land uses (e.g. agriculture, nature, shipping). Some effects of the Promising Strategies were analysed with it (DP 2013, p.101).

The *VGS evaluation system* serves to assess the Strategies on five criteria: (1) effectiveness on FRM targets, (2) effectiveness on FS targets, (3) secondary effects and opportunities, (4) practicability, (5) financing. The Subprogrammes used it to assess and compare the effects of the Promising Strategies (DP 2013, p.101, 90, 84; 2012, p.87; 2014, p.135).

Main criteria	Criteria
1. Flood risk management target range	Probability of flooding, casualties, risk of casualties, damage inside the dykes
2. Freshwater target range	Availability and conditions for urban areas, infrastructure, agriculture, shipping, nature, drinking water extraction, energy sector, industry, inland fisheries and leisure activities
3. Secondary effects and opportunities	Effects of and opportunities for the national and international competitive position, the regional and local business community, risks in areas outside the dykes, quality of life in cities and villages, spatial quality, agriculture, fisheries, industry, shipping, ports, leisure activities and tourism, nature, energy and base materials
4. Practicability	Risks for technical, procedural and social practicability, opportunities for linking with developments in other policy areas, adaptability of the strategy (including the possibility to phase)
5. Financing	Investment costs, management and maintenance costs, risks of private and public financing

The five criteria with which the VGS Evaluation System evaluates the Strategies. Source: DP 2012, p.87.

Furthermore, in ADM, it is important to assess the robustness and flexibility of the proposed strategies (pathways and their individual measures) against several scenarios (Gersonius et al. 2016, p.4). The DP Teams assessed the flexibility of the measures in a simplified way, for instance, by examining if it is easy to realize measures step-by-step or adjust them to accommodate to changes as these occur (DP 2012, p.88). The flexibility of a strategy could be assessed using the 'VGS evaluation system'; the VGS considers: the flexibility of the strategy itself and of its measures, and the possibility to link agendas,

[106] The 'social cost-benefit analysis' (MKBA) takes into account the long-term costs and benefits of measures, using a discount rate that sets out a relationship between the current and the future value of the costs and benefits of a measure (DP 2013, p.105; 2014, p.137-138).

and their added value in terms of cost reduction, practicability, and effects. In the DP, the added value of flexibility was quantified in a simple way: it was incorporated in economic analyses. Flexibility, alongside other criteria, could play a role in the ultimate choice (DP 2012, p.90). The appraisal of the pathways raised issues about how to valuate flexibility (the methods to do it) and what are its costs and benefits (Brugge and Bruggeman, p.7).[107]

Each Subprogramme should assess if its Strategy was robust, flexible, feasible, efficient (cost-effective), holistic (integrated), among other aspects, using the evaluation system (DP 2013, p.95). The Preferential Strategies were subjected to a *robustness assessment* under worst-case events beyond the scope of the *Delta Scenarios* (e.g. a SLR greater than 85cm in 2100), which showed that the *Delta Decision on the Rhine-Meuse Delta*, the *Decision on Sand*, and all *Preferential Strategies*, were satisfactory even in worst-case events (DP 2014, p.135, 8).

STEP 4) DESIGN OF THE *ADAPTIVE PLAN*

Sub-step 4a: Selecting the preferred pathways as input for an adaptive plan (an *action plan*)

The main outcome of ADM is a set of pathways or a single pathway with which planners can schedule measures in the face of uncertain future change. ADM '*leads to a composite strategy, or a set of alternative strategies with intermediate possibilities for revisions*' (Rhee 2012, p.14, *in* Zandvoort et al. 2018, p.191). Within a strategy, there may be: i) measures that are still part of the current strategy, ii) measures that are part of an improved strategy, iii) measures that are beneficial through the coupling with other agendas and whose timing is optimized, and iv) measures to keep options open for a future choice (allowing different strategic directions) (Zandvoort et al. 2018, p.191).

The Preferential Strategies constituted guides for programming the measures to be implemented (DP 2013, p.56). The measures planned in each of the Preferential Strategies for the next decades are programmed and indicated – as '*projects*' or '*implementation programmes*' – in the *Delta Plan on FRM*, in the *Delta Plan on FS*, and in the *Delta Plan on Spatial Adaptation* (DP 2014, p.46, 19, 56). Since 2014, the annual DP report describes all *programmed measures* in such Delta Plans (DP 2014, p.8, 86).[108] The Delta Plans are like '*action plans*' that guide the implementation of the measures planned and their incorporation in regional or local spatial planning (Marchand and Ludwig 2014, p.27).

In this step, the Teams identified decisions and measures to be taken in the short-term (including measures necessary to ensure that enough options are available in the future and to allow an adaptive approach) (DP 2012, p.88). The DP has sought that the first steps / measures taken were measures that are worthwhile in any scenario – i.e. 'no-regret measures' (DP 2012, p.88).

Sub-step 4b: Developing the monitoring and evaluation system

ADM requires an adequate monitoring of changes and developments (namely climatic and socioeconomic developments), of new knowledge and insights that may emerge, and of implemented measures (i.e. of '*what is being done and with what effects*'), and, based on the monitoring results, a regular evaluation of the strategies followed (implemented and planned) (DP 2014, p.149; 2016, p.6).

---

[107] The DP used ADM to design flexible strategies: flexibility is deemed crucial to be able to respond to uncertain futures (represented in the Delta Scenarios) (DP 2012, p.90, 107). By maximising robustness and flexibility, it is possible to avoid later costs. The DP commissioned a study on how flexibility could be weighted in investment decisions under uncertain futures (DP 2014, p.138) (Note 240). As the Route-map approach of the TE2100, ADM seeks to ensure that any short-term decision is taken within a framing that does not lead to maladaptation if the future unfolds differently from what is considered 'the most probable future' now (Gersonius et al. 2016, p.4).

[108] Every year the DP must issue its proposed *programme of measures*: with detail for the first 6 years, with an indicative outline for the next 12 years and a broad general view until 2050. This led to the creation of the *Delta Plans* on FRM and FS (DP 2014, p.8, 86) (Note 241).

Hence, the ADM cycle presupposes the existence of a 'monitoring and evaluation system' and a 'systematic learning', which are necessary to allow the adaptation / adjustment of strategies, if this is prompted by changes or new insights (DP 2016, p. 6,11). Such monitoring and revaluation system should observe how climatic, physical, and socioeconomic conditions are changing, and ensure that '*response to these changes is an adaptive one'* (DP 2014, p.9) (Note 242).

Monitoring and evaluation are necessary to '*know in good time when the strategy has to change and when other measures that have already been prepared should be put into effect*' (DP 2014, p.13).

BOX 7. ADM demands a '*continuous alertness during the implementation phase*', which required the DP to:

- Periodically check if new insights and developments are sufficiently reflected in the programming and implementation of strategies and measures.
- Regularly reassess the strategies agreed upon (their 'adaptation paths') and carry out a 'robustness assessment', in order to ensure that the strategies (and their measures) '*provide a satisfactory answer to the climate changes observed and forecast'*; are timely implemented or adjusted (if necessary), and to address new conditions that may go beyond the scope of the Delta Scenarios.
- Analyse if there is *'sufficient room for decision-making in the long-term*' (e.g. if additional resources are needed, if innovations can help to achieve objectives quicker) (DP 2014, p.149).

ADM requires an '*adaptive implementation*' of the measures planned in the Preferential Strategies which, in turn, implies '*targeted monitoring and periodically adjusting*' (DP 2014, p.145). 'Targeted monitoring' means keeping track of developments, uncertainties, assumptions, decisions and measures (implemented and planned), and systematically use results. '*Periodically adjusting'* means that monitoring results and new insights (e.g. into climate change, water system's behaviour, interventions' effects) may lead to '*periodical adjustments to policy, implementation programmes and the design of measures'*. In this way, a '*learning system*' develops, which ensures an ongoing exchange between implementation, monitoring and policy development (DP 2014, p.145).

After 2014, the DP Team started to develop its monitoring and evaluation system: the '*Monitoring, Analysing, Acting* (MAA) system' (DP 2016, p.6, 59; 2014, p.149). It is deemed the *engine of ADM*. The MAA system would serve to:

- monitor changes and developments, measures' effects, new insights and knowledge that may emerge, and, in accordance, properly acting on this information; and, regularly revaluate the strategies and measures (implemented and planned) (DP 2016, p.6, 9). The system should keep track of (external and internal) developments, to allow a timely adjustment of strategies (e.g. a change of course or measure), which is indispensable to ensure an adaptive approach (DP 2016, p.59; 2017, p.13).
- collect information necessary to examine if and how the Preferential Strategies need to be adjusted, and to operate an adaptive approach. The MAA generates insights into the progress made and into changes or developments that may constitute a reason for adjustment (DP 2016, p.6, 9, 11).
- monitor 'linkage opportunities' available (DP 2014, p.149).
- foster a co-learning process in which results, lessons and successes were shared, and report the progresses made (in the DP Report) justifying the resources spent. The MAA's results should underpin the DP report (DP 2016, p.59, 11; 2017, p.13).

With the MAA, the DP aims to: evaluate (review), every year, whether any new developments demand the adjustment or fine-tuning of the Preferential Strategies and Delta Plans; and monitor (keep track of) any new conditions, developments or changes that may impact the goals and the measures defined, and if necessary, adjust them (DP 2016, p.6-7).

The MAA gives and receives inputs from the Delta Decisions and Preferential Strategies. The results of the MAA system must be used to update the DP (and its Commissioner) on observed and forecasted effects and must be considered in any revision of the programmed measures (*projects* and *implementation programmes*) (DP 2014, p.149).[109] The MAA focusses on three specific questions:

1) *is the implementation on schedule* (*are we doing what we agreed*) (*output*); i.e. is the DP on schedule.
2) *are we achieving our goals* (*outcome*); i.e. whether the FRM and FS targets are being achieved.
3) *are the preconditions still in order* (*input for follow-up*) (DP 2016, p.59, 11) (Note 243).

The '*output*' concerns the measures agreed in the Preferential Strategies and Delta Plans; the '*outcome'* concerns the goals defined in the Delta Decisions and Preferential Strategies; and the '*input for follow-up*' concerns conditions such as funding, expertise, effectiveness, collaboration, etc. (DP 2016, p.59).

To answer these questions, the MAA relies on two lines: the blue line and the green line (Figure 33).

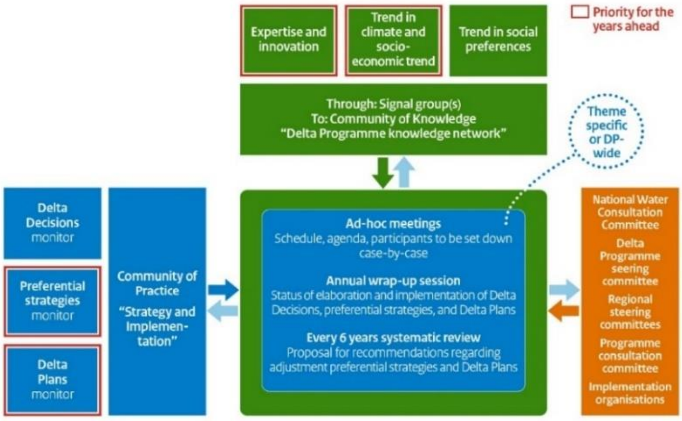


Figure 33. The blue line (*output*, *outcome*), and the green line (external developments), their coordination and advisory process. Source: DP 2016, p.59-60.

The 'blue line' examines if the elaboration and implementation of the Delta Decisions, Preferential Strategies, and Delta Plans, are proceeding as planned and on schedule; and it addresses the '*output'*, '*outcome'* and '*input for follow-up'* questions mentioned above. Within the blue line, there is a '*Community of Practice'* that reviews the progress of the Preferential Strategies and Delta Plans several times per year (and it meets several times per year).[110] Moreover, it evaluates if the objectives (for FRM, FS, and spatial adaptation) are being met, and explores 'linkage opportunities' (DP 2016, p.59-60).

The 'green line' identifies changes or developments that may affect the elaboration or implementation of the Preferential Strategies and Delta Plans and require their adjustment or refinement. It indicates '*if the DP is still on track*'. This line systematically monitors three developments: (a) *knowledge and innovation* (e.g. new insights on the cost-effectiveness of measures); (b) *climate and socioeconomic developments* (e.g. new climate scenarios); and (c) *societal preferences* (on the measures) (DP 2016, p.60). Within the green line, there is '*Signal Group*' that monitors these three developments (and it meets once or twice a year); then the results of the analyses are discussed in the '*Community of Knowledge*' and in the '*DP Knowledge Network'* (DP 2016, p.60).[111] The 'Signal Group' examines which external developments (e.g. pace of climate change) can constitute a reason for revising the Preferential

[109] The MAA involves several organizations: planning agencies; the Dutch Environmental Assessment Agency, knowledge institutes (KNMI, Deltares, Alterra). Businesses, social organisations and citizens can also be involved (DP 2014, p.150). The Commissioner is responsible for monitoring the progress of the *programmed measures* and the consistency of the adaptive approach (DP 2014, p.148).

[110] The 'Community of Practice' has representatives of the fields of FRM, FS and spatial adaptation, and of the regions; it meets several times a year to share results and experience about the implementation of the Preferential Strategies and Delta Plans (DP 2017, p.13). Every year, the DP annual reports document the progress made, in the chapter of the Delta Decisions, Preferential strategies, and Delta Plans (DP 2016, p.59).

[111] The *Signal Group* is a group of external experts. The *Knowledge Network* includes representatives of the main themes and regions and knowledge institutes (DP 2016, p.60).

Strategies and Delta Plans (focussing on whether and when the Preferential Strategies and Delta Plans might need adjustments) (DP 2017, p.13).

The *Community of Practice* (blue) and the *Signal Group* (green) meet once a year to connect the results of the two lines (and discuss the elaboration and implementation of the Delta Decisions, Preferential Strategies and Delta Plans), and define recommendations that must be provided (and to whom). This meeting results in recommendations about the 'progress' (*are we still on schedule*) and 'direction' (*are we still on track*) (DP 2016, p.61). The DP every year reports on the progress in the elaboration and implementation of the Delta Decisions, Preferential Strategies and Delta Plans (DP 2016, p.6).

Moreover, every six years, the DP will carry a systematic review to check '*whether it managed to keep up the pace and adjust its course on time*' and analyse if the monitoring results indicate that it is necessary to maintain or adjust the course or the pace (i.e. the measures or their timing) (DP 2016, p.6). Based on new knowledge and monitoring, the strategies and / or their measures may be anticipated or postponed, or adjusted in terms of scope and design (DP 2014, p.136).[112]

Although the DP operates in *a dynamic environment*, with ongoing developments, a '*continuous adaptation of all the strategies to those developments is neither feasible nor necessary'*, and this implies finding an appropriate '*rhythmicity for the adaptation of strategies and plans'* (DP 2016, p.61) (Note 244). Thus, it is important to assess the potential effects of new developments for the Preferential Strategies, their significance and certainty. If effects are *significant* and *certain* (and occur in the near-term), the recommendation may be that the Strategy needs to be adapted in the short-term. If the effects are *significant* but *uncertain* (in terms of scope or time), the recommendation will be that further research needs to be conducted. In other situations, the recommendation will be to take a decision regarding a possible adjustment in the next review that will occur once every six years (DP 2016, p.61).

The MAA system was developed since 2015, and it started to operate in 2017 (DP 2016, p.3, 63).

BOX 8: the MAA system in 2017

Since 2017, the MAA system has addressed four main questions (DP 2017, p.13, 8; 2018, p.19):

1) '*on schedule'* (*is the implementation on schedule*, are the measures being implemented within the timeframe and budget agreed. This relates to the progress of implementation, i.e. 'output';
2) *on track*' (are we on the right track; are we on track or do external developments constitute a reason for reconsideration of goals or measures), which is related to the attainment of goals, i.e. the '*outcomes*' (this implies analysing: if the DP is 'on track' or whether there is any reason for changing the pace or course of measures or the goals; if the proposed measures are sufficient in terms of attaining the goals or if it is necessary to change the course);
3) '*integrated approach*' (*are we addressing the taskings in an integrated manner*);
4) '*participation*' (*are governments, businesses, NGO's, and residents involved on a wide scale, where such is called for*).

Progress is reviewed with these 4 questions in mind, in the Delta Decisions and Preferential Strategies. The *Community of Practice* focuses on the questions 1, 3 and 4, while the Signal Group focuses on question 2 (DP 2017, p.13).

Indicators to be monitored

In 2017/2018, the Signal Group defined 8 *indicators* to be monitored in order to detect signals that may prompt an adjustment of the Preferential Strategies, and / or developments that could jeopardise the attainment of goals, e.g. SRL, extreme river discharges, land use, etc. (DP 2018, p.111; 20). Moreover, it defined more specific *variables* to measure such indicators, which can measure: a) '*driving forces*' of tasks (i.e. *drivers variables* that provide early signals for the tasks), or b) '*impacts of changes*' on the system (i.e. i*mpact variables* that indicate consequences of a particular change and constitute a strong incentive to take action) (DP 2018, p.111). The *indicators* and *variables* are shown in Table 8.

[112] The MAA serves to evaluate if it is necessary to adjust the course or pace, or reconsider targets or measures (e.g. if developments demand a switch of strategy or measures, or a modification in their timing) (DP 2017, p.8, 17). The DP recognizes the potential need of periodic updates of the 'adaptation paths'. A review of all Preferential Strategies will occur every 6 years; in addition, an analysis to see if the safety standards must be revised will occur every 12 years; both will allow a periodic update of the adaptation paths that were designed (Bloemen et al. 2018).

An indicator may require: more targeted research; monitoring and scheduled evaluations; analysis of consequences; and if necessary, the adaptation of measures or policy amendment. Signals must be identified in a *sufficiently timely* manner (given *'the time required for plan preparation, design, and construction'*) and in a *reliable manner* (which detects *'a significant trend or warning signal from an observation series that often features a great deal of noise from annual fluctuations*') (DP 2018, p.111).

Indicator	Variable	Why
Sea level rise	Expected rise in sea level along Dutch coast by 2050, 2100 and 2200, including a bandwidth	Assumed in the Delta Scenarios; determining for FRM
	Volume / year of beach replenishments	*Impact indicator* for SLR with possible impact on the Preferential Strategies
	Closure frequency of storm surge barriers (Maeslant, Hollandsche IJssel, Oosterschelde)	*Impact indicator* for SLR with potential impact on the Preferential Strategy for Rhine Estuary-Drechtste.
	Storm surge frequency at NW > 8 Bft	*Impact indicator* for SLR, with impact on Preferential Strategy for Ijsselmeer
Extreme river discharges	Expected extremely high (1/100) and low river discharges by 2050 and 2100 in Rhine and Meuse. Average discharge in summer, etc.	Assumed in Delta Scenarios; determining for FRM, FS, and the Preferential Strategy for Rivers
Land use (use of space) and population	Forecast of land use, economic value, population by 2050 per region (to periodically evaluate the protection levels of dyke rings)	Assumed in Delta Scenarios; determining of the flood protection level, water demand, and *Delta Plan on Spatial Adaptation*.
	Population (e.g. living within a dyke ring)	
Climatological drought	Precipitation shortage (calculated based on several sub-aspects)	Assumed in Delta Scenarios, with potential impact on Preferential Strategies for FS
Salinisation	Inlet intake stops (frequency and duration) Maximum salt concentration at inlets	*Impact indicator*, with potential impact on Preferential Strategies
Waterlogging	**Increasing frequency of peak downpours.** Measured and expected peak precipitation in urban areas / hour, or rural areas / 2 days	---
Heat stress	Measured + expected (2050, 2085) heat waves; number of tropical days (>30°C); etc.	Heatwaves affect health (mortality)
New knowledge	New knowledge, e.g. about damage and casualty functions, cost functions	Assumed in the design of measures; with impact on Preferential Strategies

Table 8. Indicators and variables defined in 2018. Source: DP 2018, p.111, 112-113.

<u>A 6-year review, and the eventual adaptation, of the Preferential Strategies</u>

The DP (2018) mentions that '*in the event of new insights showing that the current course will not enable achievement of the FRM, FS, and spatial adaptation goals by 2050, the Preferential Strategies may need to be adjusted*', and that '*the Preferential Strategies are open to annual adjustment*' (DP 2018, p.22). In addition to this, the Delta Decisions and Preferential Strategies will be subjected to a review every six years. The results of the 1st review should be published in DP 2020, and they should explain to which extent the goals set out in DP 2014 are being achieved in time. This will be measured with the criteria that were defined to gauge goal attainment. If the 6-year review prompts so, the DP Commissioner may propose adjustments to the Delta Decisions or Preferential Strategies. In the 6-year review, it will also be assessed the need of keeping the envisioned long-term options open or adding new options (DP 2018, p.22).

The Signal Group and the DP should meet at least twice a year (DP 2018, p.111-112):

- In <u>January of year X</u>, the Signal Group and the DP discuss which developments constitute a reason for adapting the Preferential Strategies. The Signal Group presents wide, generic developments (e.g. accelerated SLR), while the Regions present the theme- and region-specific developments (e.g. changes in water demand). The conclusions are submitted to the DP Consultation Committee that meets in March and chooses which developments deserve elaboration. These developments are then reported in the DP Report of year X (developed for the year X + 1). Moreover, knowledge institutes and managers analyse such developments and determine where adaptations are required in which themes or regions. This phase occurs from March to the end of August.

- Then, in September of year X, the *Signal Group* and the DP discuss the topics (developments already elaborated) that require the adaptation of the current strategies, and if such adaptation must be made in that year or if it can wait until the next 6-year review. Their conclusions are submitted to the Consultation Committee, and, if necessary, to the Steering Group, to see which elements of which strategies need to be adapted. These adaptations are implemented by the DP offices. The debate and decision about adaptations occur between October of year X and February of year X + 1 (included), and the adaptations are reported in the Report elaborated in the year X + 1 (for year X + 2).

This annual process generates a progress report: the DP annual report. Therefore, a 'signal / indicator' may activate a multi-year process, which may require a 'policy evaluation' and lead to a decision to adapt policy (Decisions or Strategies) (DP 2018, p.112).

Step 5) Implementation

The DP presented the Delta Decisions and Preferential Strategies in the 2014 Report (DP 2013, p.112, 125). In late 2014, the central government embedded and anchored the national policy resultant from resultant from Delta Decisions and Preferential Strategies in an interim amendment / revision of the '*National Water Plan 2010-2015*'; and then, in late 2015, into the '*National Water Plan 2016-2021*' (DP 2016, p.64; 2014, p.8)[113].

After 2014, the DP entered in a new phase focused on: the detailed elaboration of the Delta Decisions and implementation of the Preferential Strategies, the close observation of how the climatic, physical and societal conditions are changing, and on ensuring the continuation of the adaptive approach (DP 2014 p.9, 144; 150; 2013, p.114; Alphen 2015; Bloemen et al. 2018; Zevenbergen et al. 2018).[114]

The DP Commissioner supervises the implementation of the measures by the Water Boards, Provinces, Municipalities, disaster management organizations, and Rijkswaterstaat (the National Authority for Water Management and Public Works) (Alphen 2015), and has submitted the annual DP report reporting the progress of the proposed measures on FRM and FS (DP 2013, p.112).

By 2016, most Provinces had already incorporated the Delta Decisions and Preferential Strategies into their policy (namely in their *framework visions* or *environmental visions*, as occurred in the '*Spatial Planning and Mobility Vision*' of Zuid-Holland Province which includes Rotterdam); while the Water Boards anchored policies resultant from the Delta Decisions and Preferential Strategies in their new *Water Management Plans* (DP 2016, p.65) (Note 245).

ADM requires the DP to *keep a close eye on how society and the climate are changing* and *respond adaptively* (DP 2014, p.150). Dealing with new insights and changes should be part of the implementation of the Delta Decisions and Preferential Strategies. This not only implied '*preparing a sufficiently broad scope for decision-making for the long-term*' (including '*plans for use in good time*'), but also the creation of '*a properly embedded monitoring and evaluation programme*' and '*a steering model that is in line with the adaptive approach*' (DP 2014, p.148). Attention was needed on the

---

[113] The DP Commissioner submitted the Delta Decisions to the Cabinet in 2014 so that they could be embedded into the 2015 National Water Plan (DP 2010, p.4; 2011, p.14; 2012, p.35).

[114] ADM was largely developed in the DP with the active involvement of knowledge institutes and specialized consultancies. Until 2014, the DP focussed on using ADM in the development the Delta Decisions and Preferential Strategies, while after 2014 the focus shifted to the elaboration and implementation of the Decisions and Strategies in line with ADM (DP 2014, p.148). In 2016, the Cabinet underlined the need of *jointly continuing the elaboration of the Delta Decisions and Preferential Strategies*, and of joint efforts of the DP parties, within their own responsibility, to move ahead in the elaboration and implementation phases (DP 2016, p.7).

governance arrangements required to enable adaptation. This implied agreements on 'who does what', the monitoring of 'the conditions under which policy should be adapted', and ways to ensure that 'options are actually kept open when required' (Brugge and Bruggeman, p.7).

Moreover, ADM requires an '*adaptive implementation*' of the measures planned in the Preferential Strategies, which in turn, demands an ongoing search for more efficient strategies (or measures), a combined programming of projects in the fields of FRM, FS and spatial adaptation; the consideration of expected future conditions in the design of measures (*future-oriented dimensioning*); '*targeted monitoring and periodically adjusting*' (DP 2014, p.145). In the programming and implementation of measures, the DP has sought to link the measures of FRM, FS and space, and seize opportunities, e.g. by combining normal dyke improvements with spatial adaptation measures (DP 2014, p.9).

Alongside regular maintenance of flood defences, the main FRM tasks for the next decades (up to 2050) involve: applying the new flood protection standards; improving the primary flood defence systems that fail the Statutory Assessments (through the *Flood Protection Programme HWBP*) (DP 2013, p.124). The '*Flood Protection Programme HWBP 2015-2020'* plays a key role in what concerns 'dyke improvements'. In what concerns spatial measures, the parties should select an adequate form of organisation on a project-by-project basis (DP 2014, p.9). A dynamic implementation of the DP also depends on a continual investment in FRM: sufficient financial resources are an important condition (DP 2014, p.120; 2013, p.120) (Note 246).

In sum, with the publication of the DP 2014, the phase of 'strategy development' formally ended, and the phase of elaboration and implementation of the strategies began; some responsibilities were transferred to ministries and project-execution organizations; and regional and local governments were charged to coordinate the activities in their region. ADM and 'thinking in APs' were important in the phase of 'strategy development', but they should also be preserved in the phase of implementation: '*the necessity to maintain the adaptive character of the DP in the implementation phase was stressed by several organizations including research institutes'* (Bloemen et al. 2018, p.13). Gradually, the emphasis shifted from the development of *adaptive strategies* towards their implementation in practice. The effectiveness of ADM still needs to be proven in this implementation phase, which will require monitoring of external drivers, regularly evaluate the effectiveness of measures applied and proposed, and assess if it is necessary an anticipation or delay of measures, or a transition to another strategy (Zevenbergen et al. 2018). Adaptivity should be conserved in the next phase (Bloemen et al. 2018).

STEP 6) CARRYING THE MONITORING, EVALUATION AND REVIEW SYSTEM

Since 2015, the DP has reported every year on the detailed elaboration and implementation of Delta Decisions, Preferential Strategies and Delta Plans, if their progress is on schedule, and has assessed (every year) whether any new developments demand their adjustment or fine-tuning (the annual Report contains the results of the prior year and a look ahead). It has also monitored new developments / changes that may affect the goals and strategies defined, and, if necessary, it adjusts them (DP 2016, p.6-7).

The MAA system has helped to get a clear picture of the annual status of the DP, to analyse the progress made, the state of affairs, and the need for strategy adjustments (DP 2017, p.13; 2016, p.6; 2018, p.19). Moreover, it underpins the adaptive approach of the DP.

In 2016/2017, the DP monitored external developments (e.g. climate change effects) that may affect the pace or direction of the Preferential Strategies, and evaluated whether the DP is 'on track' or whether there is any reason to adjust the course or pace, or reconsider targets or measures (e.g. whether external developments demand a switch of strategy / measures, or a modification in their timing). The DP also specified the design of the Preferential Strategies: it defined interim goals / benchmarks for 2020-2050 to assess if the Strategies need to be adjusted in the face of external developments (DP 2017, p.8, 17). The DP (2017) presents an overview of the progress made (by the DP and its subprogrammes) in implementing the Preferential Strategies and Delta Plans, based on the MAA: information is organized according to the four questions mentioned in page XX (*on schedule*, *on track*, *integrated approach*, and *participation*) (DP 2017, p.13, 15).[115] In 2016-2017, the DP was, in general, 'well on track': most of the measures agreed were being implemented as planned. In 2017, the implementation of *Delta Plans* was '*on schedule'* (the measures envisioned in them have been mostly accomplished within the timeframe and budget agreed). Between 2015 and 2017, the actors involved stayed '*on track*' and kept up the pace in the implementation of the measures defined in the Delta Plans. Moreover, in 2016-2017, the Signal Group monitored external developments (climatic and socioeconomic changes) that may affect the pace or direction of the Preferential Strategies, and examined whether external developments demanded an adjustment of the course (DP 2017, p.8, 17).

The DP (2018) reports the progress made in 2017-2018. In 2017-2018, most of the measures scheduled in the DP 2014 were well '*on schedule*'. Moreover, in 2018, the future financial security of the Delta Fund was deemed '*up to par*' (DP 2018, p.15) (Note 247). The Signal Group continued to monitor developments relevant for deciding the future course (DP 2018, p.14, 20). In 2018, the objectives seemed to be attainable with the proposed measures, but a clearer picture will be obtained in the coming years, via the assessment of the primary flood defence systems (DP 2018, p.20).

Importantly, the DP 2018 mentions that there have been signals that the sea level is rising faster than assumed in the Delta Scenarios, which led the DP to commission Deltares to analyse the potential effects of an accelerated SLR, and its consequences for the DP, to allow the DP '*to respond in a timely and adaptive manner*'. This study showed that a potential acceleration in SLR will not be noticeable until 2050 (DP 2018, p.14).[116] The results obtained by Signal Group in 2017-2018 helped the DP to obtain new insights, which will be incorporated in the proposals for the first 6-year review of the Delta Decisions and Preferential Strategies in 2020. The policy decisions resultant from this review will be embedded by government authorities in their plans (DP 2018, p.22).

As mentioned, the 6-year review (in 2020) will assess the need of keeping the envisioned long-term options open or adding new options. Based on the 2018 results, these options seem to be worthwhile after 2050. Thus, any spatial components of these options must be taken into consideration in spatial policies (e.g. spatial reservations for rivers have remained in force) (DP 2018, p.22-23).

ADM, and its ongoing nature, are reflected in the annual update of the DP (every year a new DP report is issued, including a reprogramming of measures, and submitted to the Parliament) (DP 2014, p.95; Bloemen et al. 2018). In this process, the monitoring and research, and the design and implementation phase, can be conducted at the same time and influence each other (DP 2014, p.149).[117]

---

[115] The DP 2016 also documented the progress made in, per region, in 2015-2016, namely of the *Delta Plan on FRM* (DP 2016, p.3, 5).

[116] Still in 2017, insights provided by KNMI estimated that the expected SLR and increasing precipitation (frequency and intensity) may occur more rapidly than assumed in the Delta Scenarios. Hence, in 2018, the DP commissioned a study to examine the potential impact of more rapidly SLR and increase in severe downpours (in anticipation of the new KNMI scenarios expected in 2021) (DP 2017, p.8). The first analysis of the Signal Group, based on measurements and new research, indicated a potentially faster and more extensive SLR than foreseen in the Delta Scenarios; for this reason, Deltares has explored the potential consequences of this for the DP (in anticipation of the 2019 IPCC Report and its translation into downscaled forecasts for the Netherlands by KNMI) (DP 2018, p.20-21). Other sign observed was the increase in torrential rain; and the risk of waterlogging was also analysed (DP 2018, p.20-21) (Note 248).

[117] Ongoing knowledge development and monitoring is necessary to deal with uncertainty. The DP sought to ensure that new knowledge is included into strategies, during their revisions. This occurs in the new *Flood Protection Programme* (HWBP): the programme is updated every year as part of the DP, allowing it to incorporate new knowledge, technical and financial innovations (DP 2014, p.95; 2013, p.109) (Note 249). The subprogrammes have also sought to include innovations. As new knowledge emerges, this is included in the DP Reports and in the guidelines for the design of flood defences; e.g. the Ministry of Infrastructure and the Environment will include new know-how about FRM systems into the '*Statutory Assessment Tools*', every 12 years, at least (DP 2016, p.11). The DP intends to analyse new insights about climate change brought by the Paris COP21 and the 2019 IPCC Report, and their implications for the *Delta Scenarios* (DP 2016, p.6).

4.4. ADM STEPS IN THE *PREFERENTIAL STRATEGY OF THE RHINE ESTUARY-DRECHTSTEDEN*

The Subprogramme for the Rhine Estuary-Drechtsteden (RE-D) applied the ADM approach, and its steps, to develop its Preferential Strategy for FRM (Brugge and Bruggeman, p.6) (Note 250).

- **Step 1**

In 2010-2011, the RE-D Subprogramme analysed the future tasks. The tasks for the short-term (up to 2028) were based on the findings of the 2nd and 3rd Statutory Assessment of primary flood defences, and on the new flood protection standards defined (with their respective design water levels).[118] In this region, the main pre-existent FRM measures were *'dyke improvements*' and '*repairs of storm surge barriers*'. New measures will be required in the mid-term (until 2050) due to expected changes, e.g. SLR, increasing river discharge, soil subsidence).[119] The Team used the scenarios *Steam* and *Rest* to analyse the tasks stemming from these changes. Moreover, the Subprogramme on FRM examined if the existing levels of protection (and standards) were still sufficient. This analysis showed that several parts of the RE-D had to increase their protection level. The DP 2014 proposed new protection standards as part of the *Delta Decision on FRM* (Gersonius et al. 2016, p.207-208).

Thus, the future tasks result from external developments expected in the mid-term (e.g. SLR, shifts in river discharges and soil subsidence) and internal changes (the new flood protection standards defined in the *Delta Decision on FRM*). In the case of Dordrecht Island (located within the RE-D region), significant tasks were expected to be needed until 2050 to improve dykes, and in some areas, this would be complicated (when the space required for dyke improvements is not available in urban areas). This required the definition of a comprehensive vision for FRM for this region.

A key question that arose was whether the existing strategy / measure, i.e. 'dyke improvements', was adequate to meet the objectives and tasks and the new protection standards in a cost-effective way, or whether a shift to another measure was required (Gersonius et al. 2016, p.208). The complexity of improving dykes, or the desire to reduce investments in dykes, among other factors, led to the need to explore alternative measures and develop other strategies (than traditional 'dyke strengthening'). In Dordrecht, the high costs and spatial impacts of some dyke improvements led to the development of an alternative strategy based on the three layers of the 'ML FRM'.

- **Step 2**

In 2011-2012, some steps of the ADM process had already been accomplished. The Subprogramme had already defined (qualitatively) the tipping-points of the existing policy and system, and determined their timing / date in the various *Delta Scenarios*; and it also developed '*interrelated packages of measures*', i.e. strategies, which were then subjected to a '*stress test'* in order to identify potential vulnerabilities and ways to tackle them in the short-term (Brugge and Bruggeman, p.6). These steps were undertaken in two workshops with field experts and planners. Moreover, during 2011-2012, the RE-D Subprogramme further explored how ADM (concept and approach) should be applied.

The RE-D Subprogramme searched for tipping-points, i.e. moments in which a measure / strategy does not work anymore, and it is necessary to shift to another. However, such moments were difficult to find or do not exist, thus, the exercise was more about '*spreading measures in time*' than '*exploring*

118 As mentioned, in the Netherlands, dykes must meet the flood protection standards that are legally binding (set out in national law since 1961, as the maximum acceptable overtopping probability that the dykes must withstand, i.e. exceedance frequency of the design water level). In Dordrecht, this standard was 1/2000 per year. In unembanked areas, there are no legal protection standards; residents and users are responsible for consequence-reducing measures (e.g. flood-proofing measures). The Statutory Assessment indicated that 28% of the dykes in Dordrecht were below the standards, requiring improvement (Gersonius et al. 2016, p.207).

119 These future changes increase the hydraulic load conditions or reduce the resistance and, thus, will generate additional tasks for up to 2050, particularly in the transitional areas of the RE-D.

alternative measures to shift to'; and, in worse scenarios, measures would be implemented earlier than in 'lighter' scenarios (Restemeyer et al. 2017, p.932).

In the case of Dordrecht, the Team identified several possible measures available, and then assessed their effectiveness. To evaluate to what extent the proposed measures will meet the objectives in the short, mid- and long-term, the ATPs' method was used. The performance of the measures was assessed under the most extreme Delta Scenarios (the *Rest* and *Steam*) (Gersonius et al. 2016 p.212).

- **Step 3**

Then, using the measures identified, the Team developed its 'adaptation paths' (pathways). The RE-D Subprogramme developed *adaptation paths* for FRM for the region. This implied designing sequences of interrelated measures over time, and testing them under the Delta Scenarios, to see assess if future problems or ATPs arise, and identify solutions to tackle them (Brugge and Bruggeman, p.6).

In the case of Dordrecht, during the phase of 'strategy development', the measures identified were not only assessed on their efficiency and cost-effectiveness, but also on their legitimacy and social feasibility. Measures that may be regretted later were avoided as much as possible, and alternatives to 'dyke strengthening' were explored, e.g. green adaptation measures (Gersonius et al. 2016 p.212).

The APs' map shows which measures need to be taken and when (a time window) and provides insight on how the tasks for the long-term may influence short-term decisions (Gersonius et al. 2016 p. 211). The scheme of 'adaptation paths' shows the measures available for the short-term (2030) and mid-term (2050), and possible options to keep open for the long-term (up to 2100). This includes (anticipatory or preparatory) measures required to keep open options for the long-term (e.g. measures necessary to shift from the current measure to another in the future), e.g. research studies on a particular option (ibid).

The pathways deliver 'flexibility' in several ways: the strategies can be accelerated, slowed down, or adjusted, by using other options that are previously kept open (i.e. by shifting from one measure to another which is available). The approach allows the adjustment of short-term decisions, within the context long-term tasks for FRM (Gersonius et al. 2016 p.212-213).

Though the Subprogramme worked with the four Delta Scenarios (translated to the regional context), but the effectiveness of the strategies was only assessed in the *Steam* and *Rest*. The question of 'which scenario should be used' did not matter too much, because whatever scenario happens, the existing flood defence system (with its dykes and storm surge barriers) could cope with it, and it would require some improvements but not radical modifications (Restemeyer et al. 2017, p.931).

In the Dordrecht case, the ADM approach, and, in particular, of the APs method, served to develop a '*robust flexible strategy*' for FRM. The development of APs ensures flexibility, since the pathways can be accelerated, slowed down, or adjusted (through shifts from a measure to other), and options to keep open are shown (Note 251). ADM was also crucial for tailoring the Strategy to the local context, its spatial and economic characteristics (the exploration of FRM measures took into account local spatial and economic features, and the diverse perspectives of stakeholders, in order to fit the strategy to the context). The Team collected perspectives of various stakeholders and examined how measures could be linked with investments and urban projects in the area (Gersonius et al. 2016 p.12, 213, 209).

5. Delta Programme's contents

The DP issues its updated report every year, including the DP's proposals and the Cabinet's response. Until 2014, each annual report essentially presented the main decisions and strategies for FRM, FS and spatial, for the country and its diverse regions, as they were developed in each year for the next year (Note 252). This research focuses on the DP 2014 report, which contains the final 'Delta Decisions', the regional 'Preferential Strategies' for FRM and FS, and two Delta Plans on FRM and FS (Figure 34).

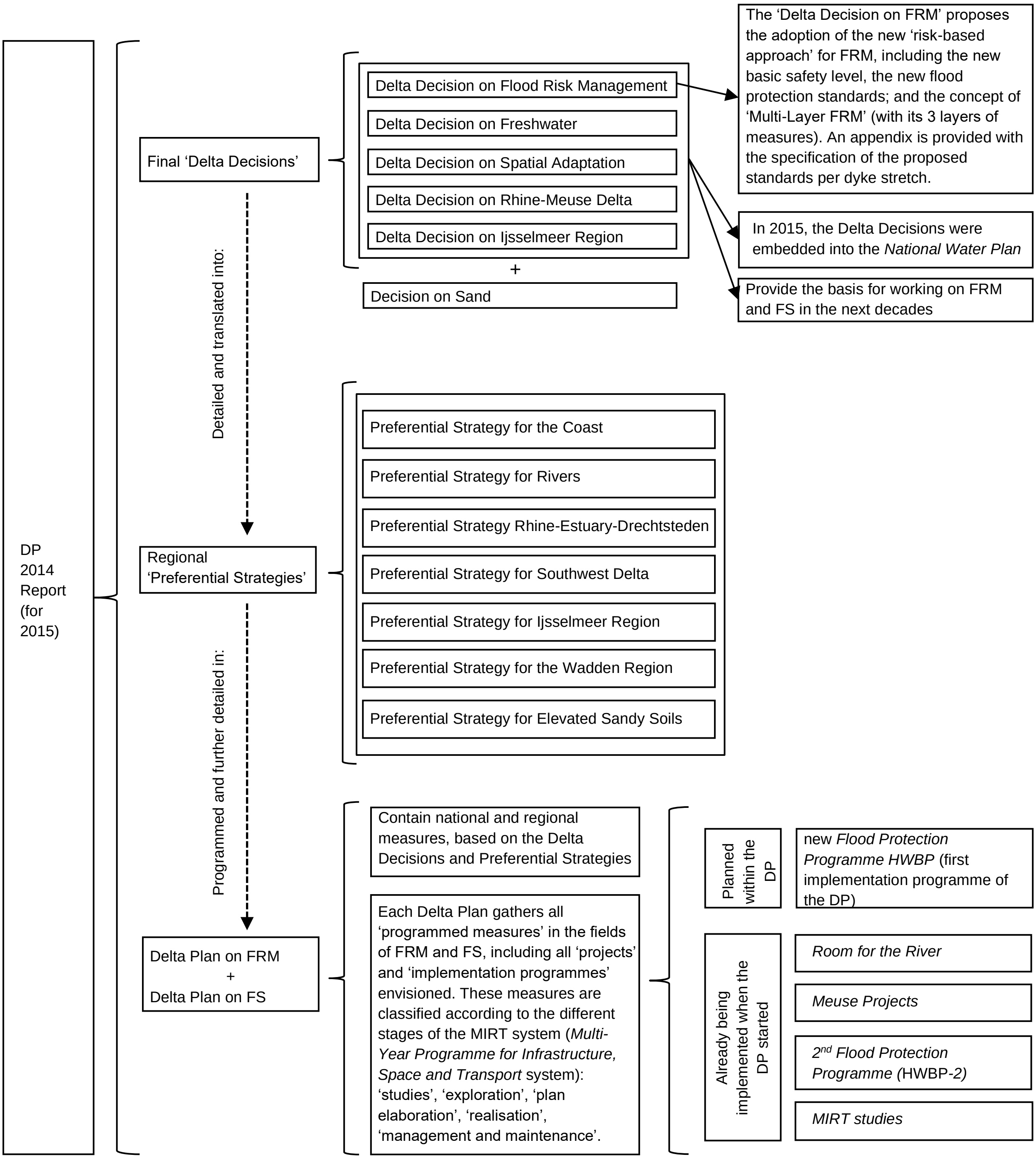


Figure 34. Contents of the DP 2014 Report. Source: own elaboration, based on DP 2014, p.5; 2013, p.6. Note 252. Each annual DP report presents all 'programmed measures' in the field of FRM and FS – including all 'projects' and 'implementation programmes', classified according their stage in the MIRT system (*Multi-Year Programme for Infrastructure, Space and Transport system*): 'studies', 'explorations', 'plan elaborations', 'realisation', 'management and maintenance'; thus, including measures underway when the DP was initiated and those already devised in the scope of the DP) (DP 2013, p.12).

In September 2014, the DP issued the final *Delta Decisions* and the *Preferential Strategies* (DP 2014, p.6, 7, 13). The Delta Decisions consist of '*structuring decisions regarding the work on the delta in the decades ahead*' (DP 2017, p.7), which provide a normative guide, while the Preferential Strategies contain the measures for each area (DP 2014, p.6). As the objectives and measures differ across the diverse regions of the country, the Delta Decisions were specified and translated into detailed measures in the Preferential Strategy for each region (DP 2014, p.46; Seijger et al. 2017). The Delta Decisions provided the normative framework / guide for the Preferential Strategies, and, on their turn, the regional Preferential Strategies provided concrete specifications ensuing from the Delta Decisions for each region (DP 2014, p.47,46; 2013, p.94).[120] Each Preferential Strategy contains measures to achieve the objectives and policy aims (resulting from the Delta Decisions) (DP 2016, p.6).

Importantly, the Delta Decisions and Preferential Strategies were developed based on the ADM approach, namely on the four basic principles of ADM (DP 2014, p.47, 12; 2017, p.7; 2011, p.18). The 2014 Delta Decisions and Preferential Strategies constitute the basis for the work on FRM and FS that will be done in the country in the next decades (DP 2013, p.6) (Note 253).

The Delta Decisions and Preferential Strategies were developed between 2010 and 2014. Since 2015, the Delta Decisions and Preferential Strategies were progressively incorporated into existing policy instruments and legislation (e.g. *National Water Plan* and the *Flood Protection Programme*).
The Delta Decisions and the Preferential Strategies were accepted in late 2014, and the required budget until 2028 was allocated (Bloemen et al. 2018, p.10). In 2014, the Cabinet submitted the Delta Decisions and Preferential Strategies to the House of Representatives; and in late 2014, the central government anchored the national policy resultant from the Delta Decisions and Preferential Strategies as policy in the *2015 National Water Plan* (in an interim amendment of the *National Water Plan 2010-2015*) (DP 2017, p.7; 2016, p.64; 2014, p.8; 2013, p.100, 6). Then, in late 2015, the *National Water Plan 2016-2021* was endorsed, and it contained the Delta Decisions and Preferential Strategies (DP 2016, p.64).

This work focussed on: the Delta Decision on FRM, the Delta Decision on the Rhine-Meuse Delta, the Decision on Sand, the Preferential Strategy for the Rhine Estuary-Drechtsteden, and the Preferential Strategy for the Coast. In each Preferential Strategy, and in most Delta Decisions, there is a map with an 'adaptation path', which identifies measures that can be taken in the short-term and possible measures (options) for the long-term on which a decision will be taken in due time.

5.1. Delta Decisions

The Delta Decisions concern: Flood Risk Management (FRM); Freshwater Supply (FS); Spatial Adaptation (water-robust and climate-proof redevelopment of built-up areas); the Ijsselmeer Region (focussed on FS and FRM); and the Rhine-Meuse Delta (on FRM). In addition, there is the *Strategic Decision on the Sandy Coastal System*, which contains the main decisions regarding sand replenishment on the coast (DP 2014, p.7, 13; 2013, p.36).[121] The Delta Decisions contain the main decisions on FRM and FS: they structure the approach to the objectives and set the tasks and the direction for the measures, in the short-, mid- and long-term (DP 2012, p.35; 2013, p.16, 32, 36, 94) (Note 254).

[120] The Delta Decisions and the Preferential Strategies were conceived in a symbiotic way: work on the Delta Decisions led to concrete solutions that were incorporated into the Preferential Strategies, and the Preferential Strategies indicated policy-based conditions that were included in the Delta Decisions (DP 2014, p.46). The development of the Preferential Strategies required the collaboration of all government levels, social organisations and business companies in each Subprogramme. Each area organised its own process (DP 2014, p.19). The Delta Decisions were prepared by public authorities, with the collaboration of social organizations and businesses (Bloemen et al. 2018), and developed based on technical assumptions (controls, requirements), calculations, politico-administrative considerations (DP 2012, p.35).

[121] The first three Delta Decisions are national-wide Decisions, the last two are region-specific Decisions for regions between rivers and sea, where the measures defined affect or impose conditions on surrounding regions (Alphen 2015; Haegen and Wieriks 2015). See more on the Delta Decisions on Spatial Adaptation in Note 255, on FRM in Note 256, on Rhine-Meuse Delta in Note 265; and on Sand in Note 266.

5.1.1. DELTA DECISION ON FLOOD RISK MANAGEMENT

The Delta Decision on FRM proposed the adoption of a new '*risk-based approach*' to FRM, the establishment of a '*basic safety level*', and the definition of new *flood protection standards* for the flood defence systems (DP 2014, p.7, 13; 2013, p.32-36). In specific, this Decision proposed (Note 256):

- The introduction of a 'risk-based approach' to FRM. This approach takes into account both the 'likelihood (probability) of a flood' and the 'potential consequences (impacts) of a flood', in the calculation of flood risk (DP 2013, p.7, 36, 40; 2014, p.16-17, 6-7, 12-12; Peterson and Bloemen 2014; Alphen 2015; Buuren et al. 2016; Ritzema and Steensma 2018).
- The stipulation of a 'basic safety level' (a level of safety from flooding) to everyone in the Netherlands. This basic safety level refers to the risk of individual loss of life due to flooding for every citizen to everyone living or working behind dykes, dunes or dams. The risk of an individual dying due to flooding must be less 1:100 000 per year (i.e. 10^{-5} / yr) by 2050. Every citizen must count on this same 'basic safety level' by 2050; and, in areas with a large number of potential victims, or with significant economic value and / or vital and vulnerable infrastructure of national relevance, a higher safety level may be provided if this is preferable or more cost-effective (DP 2013, p.7, 40; 2014, p.6, 16-17, 154; 2017, p.24; 2018, p.33; Peterson and Bloemen 2014; Ritzema and Steensma 2018, p.4; Haegen 2014; Gersonius et al. 2016; Klijn et al. 2016; Alphen 2015). This means that the risk (probability) of an individual of dying due to a flood must not exceed 1 in 100 000 per annum (0,001%) for any location; and, in some areas a higher safety level may be adopted. By 2050, everyone living or working behind dykes or dunes must count on a level of safety of at least 10^{-5}.
- The definition of new (updated) 'flood protection standards' for the primary flood defences (expressed as a 'probability of flooding'), which should substitute the existent legally embedded standards (which were expressed as an 'overtopping probability') (DP 2013, p.7, 40; Klijn et al. 2016; Peterson and Bloemen 2014; Haegen 2014; Buuren et al. 2016; Ritzema and Steensma 2018).
- The uptake of the concept of 'Multi-Layer FRM' with its three 'layers' of measures and through their 'smart combination' (Ritzema and Steensma 2018; Klijn et al. 2016; DP2013, p.40; DP2013, p.40).

5.1.1.1. The 'risk-based approach' to FRM

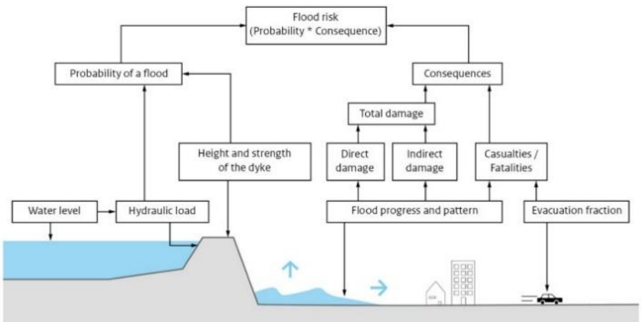


Figure 35. The '*risk-based approach*'. Source: DP 2013, p.36. The approach takes into account two factors contributing flood risk: the likelihood (probability) of a flood and the consequences (impacts) of a flood. These two factors were determinant for defining the new standards for dykes (DP 2013, p.36, 7). This allows a more integrated FRM, including measures to reduce the probability of flooding (determined by the hydraulic load, defence strength or height), and measures to reduce consequences (damage and casualties), determined by evacuation and flood characteristics (Alphen 2015).

The new the new *risk-based approach* is substantially different from the past traditional Dutch approach to FRM: in the past, efforts focused mostly on improving the protection against floods according to the existing statutory standards – which referred to a probability of overtopping (i.e. of exceeding a water level), while the new '*risk-based approach*' considers both the 'probability of a flood' and the 'consequences of a flood' in the calculation of flood risk (DP 2014, p.6, 16; 2013, p.7, 43) (Figure 35). With the *risk-based approach*, FRM is expected to become more cost-efficient (by making targeted investments where risk is higher) (DP 2014, p.16, 6). With its implementation, the economic damage caused by floods in the country, and the number of fatalities, are expected to decrease over time (DP

2013, p.7): economic risk is expected to decrease by a factor of 20, and the group risk (probability of 1000 flood victims) by a factor of 45 (DP 2014, p.6) (Note 257).[122]

5.1.1.2. *Basic safety level*

As mentioned, one of the goals this Delta Decision is that, by 2050, the probability of fatality (annual risk of dying) due to flooding for every individual (living or working in an area protected by dykes, dunes or dams) must be *1 in 100 000 per year* (0,001%), and, in areas prone to large number of victims, major economic damage, or failure of vital infrastructure, a higher safety level may be stipulated (DP 2017, p.24; 2018, p.33; 2014, p.6, 17, 154; 2013, p.7; Gersonius et al. 2016, p.8; Ritzema and Steensma 2018, p.4; Peterson and Bloemen 2014; Haegen 2014; Alphen 2015; Klijn et al. 2016). This means that in 2050, everyone in the Netherlands must count on a safety level of at least 10^{-5}/yr; and a higher level of safety may be adopted in certain areas (DP 2013, p.7; Peterson and Bloemen 2014).[123]

The DP's new approach to FRM is based on three principles:

- Ensuring a 'tolerable individual risk' for everyone living behind dykes, dunes or dams (i.e. a probability of dying due to a flood) of, at least, 1/100 000 a year (10^{-5} / year).
- Avoiding social disruption in case of flooding (a great number of casualties and economic damage).
- Preventing the failure / breakdown of vital and vulnerable infrastructure and functions of national or local importance, during and after a flood (DP 2013, p.38, 40; 2014, p.154; Haegen & Wieriks 2015).

The basic level of safety was defined based on these 3 principles (DP 2013, p.40, 38) (Note 257). In 2013, analyses showed that in some areas the level of safety was lower than the desired 'basic level of safety' (e.g. parts of the Rhine Estuary-Drechtsteden, Almere, areas around major rivers) (ibid, p.38).

5.1.1.3. Multi-layer FRM

To manage flood risk, the concept of Multi-Layer FRM can be applied. It uses 3 *layers* of measures:

- Layer 1: measures to reduce the probability of a flood, also called 'prevention measures', which mostly consist of *protection measures*.
- Layer 2: spatial planning-related and spatial adaptation measures to reduce the consequences of a flood, and, in some cases, to contribute directly to FRM (to achieve the basic safety level).
- Layer 3: disaster management measures to reduce the consequences of, and respond to, floods (DP 2013, p.38; 2014, p.14; Gersonius et al. 2016; Ritzema and Steensma 2018; Veelen and Meyer 2016; Haegen & Wieriks 2015; Restemeyer et al. 2017; Alphen 2015; Buuren et al. 2016; Klijn et al. 2016).

Flood risk can be managed (and, mainly, reduced) through these three different types ('layers') of measures, which can also be used in an integrated way, i.e. through a 'smart combination' of measures (within the same or different layers) (DP 2014, p.14; Alphen 2015; Ritzema and Steensma 2018).[124]

---

[122] In 2007, the *European Floods Directive* prescribed European countries to develop '*risk-based*' flood policies that included measures to reduce the probability of floods (i.e. preventive protection measures), and measures to reduce the consequences of flooding through spatial planning, building codes and disaster management (Alphen 2015). The DP's *risk-based approach* is based on latest insights into flood risk, climatic and socioeconomic changes, and on recent techniques for calculating the course and impacts of floods (DP 2014, p.6, 17).

[123] This level was determined based on a social cost-benefit analysis of the *Central Planning Agency*, which showed that higher safety level (10^{-6} / yr^{-}) would not be cost-effective (Ritzema & Steensma 2018, p.4). The probability of dying (drowned) due to a flood should be no more than 10^{-5}/yr (*tolerable individual risk* -LIR). It was decided to provide the same basic safety level to everybody in a protected area (Klijn et al. 2016). For Alphen (2015), this 10^{-5}/yr was mainly a political decision, a level of 10^{-6}/yr would require 5 billion EUR extra investment.

[124] The concept of 'Multi-layered flood Safety' (*meerlaagsveiligheid*) was first introduced in the *2009 National Water Plan*, so that Dutch FRM, which has historically relied on protection measures, started to include spatial planning measures and emergency response measures (Buuren et al. 2016; Gersonius et al. 2016; Klijn et al. 2015). The ML FRM has gained ground since then (Buuren et al. 2016). The Dutch usually call Layer 1 'prevention'. This differs from the term of the EU Floods Directive, where prevention means risk prevention through spatial planning. In Dutch mindset, 'preventing floods' is the main issue, rather than preventing risk (Klijn et al. 2015, p.852).

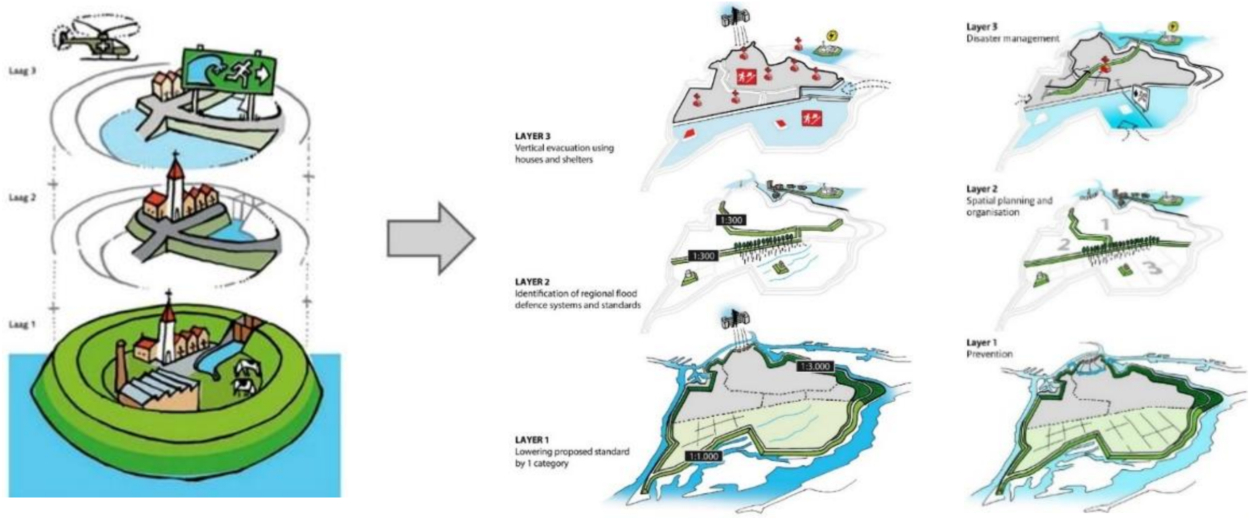


Figure 36 - left. The Multi-layer FRM concept with its three layers (Haegen and Wieriks 2015).

- Layer 1 aims to ensure the prevention of floods and protection against floods. It usually involves protection measures / defences, e.g.: dyke improvements (reinforcement, widening, raising), dyke solutions (e.g. breach-resistant dykes called 'delta dykes), or seawalls, barriers, beach nourishment, measures to improve existing defences, *'room for the river'* measures, etc.
- Layer 2 aims to reduce the consequences of floods and / or the vulnerability to flooding. It involves spatial planning-related and spatial adaptation measures, e.g.: *accommodation measures* for built environment (e.g. flood-proofing built assets and urban redeveloped areas), water-proofing techniques, compartimentalization of dyke rings; land use organization, land reservation, construction restrictions, adaptation measures for critical services, etc.
- Layer 3 involves measures to reduce the potential impacts in case of flooding and avoid social disruption (damage and fatalities), e.g.: disaster preparedness and management, evacuation measures, flood shelters, contingency plans, flood warning systems, recovery plans, risk communication (DP 2013; Ritzema & Steensma 2018; Alphen 2015; Veelen and Meyer 2016; Gersonius et al. 2016; Haegen & Wieriks 2015) (Note 258).

Figure 36 - right. The Strategy proposed by the pilot project for Dordrecht Island (DP 2016, p.35; Gersonius et al. 2016; Ritzema and Steensma 2018), which includes measures of: Layer 1 (reinforcing part of the dyke ring to meet the required 'protection standard'), Layer 2 (compartmentalising defences, creating a safe haven for evacuation inside the dyke ring), Layer 3 ('smart shelters'; protection of infrastructure, crisis communication) (DP 2014, p.20; 2013, p.83).

The DP put the Multi-Layer FRM (ML FRM) (Figure 36) at the core of its Delta Decision on FRM, Delta Decision on Spatial Adaptation, and Preferential Strategies (DP 2012, p.37, 14; Buuren et al. 2016) (Note 258). During the elaboration of the Promising Strategies (in 2012-2013), the Subprogrammes mapped out possible measures, and combinations, to achieve the desired '*basic safety level*' (Note 259). To gain more experience in applying the ML FRM, and explore its effectiveness in achieving the goals, the DP carried out pilot projects in several places, e.g. in Dordrecht (DP 2013, p.41).

The 'basic safety level' can be achieved through '*smart combinations*' of measures from the 3 layers, however, Layer 1 (prevention measures) stands as the main priority. In principle, the *desired safety level*, and the new protection standards, will be achieved via prevention measures (e.g. dyke improvements, barriers, sand replenishments on the coast, and 'room for the river'), and, in the locations where achieving the desired safety level with such measures is too costly or has too many detrimental impacts, a *smart combination* of measures from the three layers can be used to meet the *desired safety level* (DP 2014, p.16, 19; 2013, p.41). The motto underlying the Delta Decision on FRM is *'prevention first, smart combination as an exception*', thus, Layer 1 remains paramount: the *desired safety level* is expected to be achieved mainly through measures to reduce the probability of floods (DP 2014, p.19) (Note 260).[125]

In a ML FRM, alongside traditional measures (e.g. large protection structures), it is necessary to apply measures to reduce the impacts and the vulnerability of the physical and social environment to floods and enhance their preparedness, which demonstrates that Dutch FRM is moving '*from a rather sectorial*

125 *Smart combinations* require a tailored agreement (case-by-case) on the responsibilities and funding, and Minister's approval. The resources available for a 'smart combination' must be more or less equal to the savings made in the budget of the *Flood Protection Programme*. Studies have been conducted to explore 'smart combinations' for Dordrecht, the IJssel-Vecht delta, and Marken (DP 2014, p.16, 19-20).

policy field to a more holistic risk management', focussed on reducing the probability, but also the consequences of floods (Restemeyer et al. 2017, p.924). The uptake of the ML FRM represented a shift in the Dutch FRM approach, from a flood risk policy mostly focused on flood prevention to a more integrated FRM, however,, in the ML FRM as applied in DP, Layer 1 is still seen as the keystone (Haegen and Wieriks 2015), which, in part, reflects a continuation of the policy of the last 50 years (Klijn et al. 2015, p.852).[126] Most of the measures of Layer 2 and 3 aim to reduce potential impacts of floods, thus, they do not replace the protection role of defences; and, in most cases, Layer 1 will be the most effective solution, and other criteria must be considered to design a successful strategy, e.g. acceptability, impacts on ecology, etc.) (Ritzema and Steensma 2018, p.7, 4-5).

5.1.1.4. New flood protection standards

The Delta Decision on FRM contains a proposal of new 'flood protection standards' for the flood defence systems (DP 2014, p.16; 2013, p.7, 43). The new *risk-based approach* required the definition of new standard specifications for flood defence systems, and new tools to test and design defences.
The DP 2014 defines a new standard specification for each dyke section (DP 2014, p.6). In 2013, the DP indicated possible upper and lower limits for the standard per dyke section; in 2014, it presented the proposed '*flood protection standards*' for flood defence systems (DP 2013, p.40, 38, 7, 73-75).

The definition of the new standards was based on the new *risk-based approach* and the *basic safety level* (DP 2013, p.7, 38-39; Gersonius et al. 2016, p.8; Ritzema and Steensma 2018, p.4; Buuren et al. 2016). In 2011-2012, the DP Team examined whether it was necessary to update the flood protection standards, by addressing two main issues: (1) whether and to what extent the existing statutory *protection standards* still sufficed everywhere; (2) if new standards based on the probability of flooding would do more justice to the latest insights into FRM than the existing standards (which were based on overtopping probability) (DP 2012, p.36; Gersonius et al. 2016; Klijn et al. 2016). Following this, the Cabinet decided to update the standards and identified areas where the level of safety had to be improved. The areas around major rivers, parts of the Rhine Estuary-Drechtsteden, and Almere, should increase their protection standard; in other areas the existing standards were sufficient for the long-term, e.g. the coast (DP 2012, p.36).

The Delta Decision on FRM (of the DP 2014) contains the '*new standard specifications*' proposed for the primary flood defences. In specific, this Delta Decision defines '*new standard specifications for the primary flood defence systems'*, expressed as a flood probability per year and per dyke stretch, according to 6 classes (1:300, 1:1000, 1:3000, 1:10 000, 1:30 000, 1:100 000) (DP 2014, p.16, 17, 154) (Figure 37). The new standard specifications will substitute the prior standards (which were expressed as the *overtopping probability per dyke ring*) (DP 2014, p.16, 17, 154) (Figure 38). All primary flood defence systems must meet the new standards until 2050, at latest (an objective defined in the *National Water Plan*) (DP 2014, p.7, 16, 20, 120, 124, 128; 2013, p.43). The 2014 'standard specifications' were later used as the basis to define the specific standards that are embedded in law (Water Act) (DP 2014, p.16, 17, 154). The government embedded the new standards in legislation in 2017, and, even before that, they served as the basis for designing FRM measures (since the *National Water Plan 2015*) (DP 2014, p.16).

[126] The ML FRM concept emerged in the context of an increasing recognition that full protection against floods is impossible even in the Netherlands (residual risk cannot be dismissed), and it was necessary to deliver FRM via land-use planning measures (to reduce effects of land uses on risk) and measures to mitigate flood impacts. Prevention measures (Layer 1) are no longer sufficient, namely if the expected climate change effects (e.g. flood frequency) worsen. Yet, the adherence to ML FRM is not uniform in the FRM community. In 2011-2013, the DP identified pilot locations for ML FRM; developed a toolkit for ML FRM; provided tailor-made designs of ML FRM. However, in 2011-2013, there was strong opposition to the ML FRM from civil-engineering proponents of dykes. In 2014, pilot projects were initiated to explore *smart combinations* of dyke solutions with measures of Layer 2 and 3 and lower the protection standards (Buuren et al. 2016).

Rhine Estuary-Drechtsteden

Stretch	Standard specification
14-1	100,000
14-2	10,000
14-3	10,000
15-1	30,000
15-2	10,000
16-1	100,000
16-2	30,000
16-3	30,000
16-4	30,000
17-1	3,000
17-2	3,000
17-3	100,000
18-1	10,000
19-1	100,000
20-2	10,000
20-3	30,000
20-4	1,000
21-1	3,000
21-2	300*
22-1	3,000*
22-2	10,000*

Figure 37 (left). The new flood protection standards, expressed as a *flood probability per year*, proposed for different sections of flood defences. Source: Alphen 2015; Klijn et al. 2015. **Figure 37, right:** the proposed 'standard specifications' in a class of flood probability per section of defences (DP 2014, p.158). Three areas required special attention (their standards must be increased): the Rhine Estuary-Drechsteden, areas around major rivers, and Almere (in Amsterdam); and, in areas where the pre-existing level of protection was satisfactory, it is necessary to maintain and manage the existing defences (DP 2013, p.7).

Old flood protection standards (in effect until 2014)

- Expressed as a '*probability of overtopping*', i.e. the probability that a certain water level or wave height is exceeded (the maximum overtopping probability allowed) (DP 2014, p.17, 23, 154; DP 2013, p.7, 38). However, it is now known that this is not the unique phenomena that can cause of a flood) (DP 2014, p.17, 23).
- Defined for each 'dyke ring' (the entire defence enclosing an area, and its elevated soils / embanked area) (DP 2014, p.17, 23; 2013, p.38; Gersonius et al. 2016, p.7).
- Set out in national law as the 'exceedance frequency of a design water level that dykes must withstand' (Gersonius et al. 2016, p.7; Alphen 2015; Klijn et al. 2016).
- Defined in the 1960's, according to the population and investments at that time (Bloemen et al. 2018 p.10).
- Requirements for defences were based on normative water levels and the probability of overtopping. It was assumed that the consequences of a flood were the same for the entire area behind a dyke. However, it is now known that the consequences of a flood depend on where the dyke ring is breached (DP 2013, p.38; 2014, p.17).
- With the old standards, a flood defence was assessed by analyzing the question: *is it able to withstand a certain hydraulic load without significant damage.* These standards focused on protecting against a certain design flood level (exceedance probability) (Klijn et al. 2016).

New flood protection standards (adopted in late 2014)

- Expressed as a '*probability of a flood occurring'*, i.e. the probability that a flood defence system, or part of it, fails, resulting in a flood) (DP 2014, p.17, 23, 154; 2013, p.38).
- Defined for each 'dyke stretch', i.e. for the various sections of each dyke ring (DP 2014, p.22, 17, 23; 2013, p.38). The consequences a flood can differ per dyke section, thus, the standards should also vary (DP 2013, p.38). A classification into 'dyke stretches' was adopted (and 'dyke rings' were abandoned) (DP 2014, p.17).
- Defined based on the new '*risk-based approach*' and the '*desired safety level*' (which was translated into a standard for each dyke stretch) (DP 2014, p.17, 23).Their definition took into account climate change effects (SLR, increasing river discharge), population and economic development, land use changes (Alphen 2015).
- All primary flood defence systems must meet the new standards by 2050, at the latest (DP 2014, p.16, 7, 124; 2013, p.43). There will be nearly 35 years to implement measures to comply with them (Alphen 2015; Klijn et al. 2016; Buuren et al. 2016).
- With the new standards, a flood defence will be assessed by analyzing the question: *is its probability of failure lower than the standard?* This implied a sounder definition of 'failure' and more complex calculations. The new standards focus on protecting according a certain performance requirement (a probability of failure) (Klijn et al. 2016).

Figure 38. The old flood protection standards (prior to 2014) and the new flood protection standards proposed in the DP 2014. Source: own elaboration based on several authors.

The definition of the new standards was based on a cost-benefit analysis, in which several criteria were considered (e.g. economic efficiency, social equity, sustainability) (Klijn et al. 2016, 2015; Haegen 2014; Haegen and Wieriks 2015; Peterson and Bloemen 2014; Alphen 2015) (Note 261). In the definition of these standards, the DP Team considered climate change effects (SLR and increasing river discharges), socioeconomic and land use developments (Alphen 2015). The new standards were defined based on a single (relatively pessimistic) scenario – the 'high-end' scenario (of the four '*Delta Scenarios*' considered); in some stretches, the standards proposed were even stricter (in case of possible great disruption) (Klijn et al. 2016; Bloemen et al. 2018 p.10). The potential flood consequences played a role in the definition of the new standards: where there may be significant consequences (damage and casualties), the standards were stricter (a smaller probability of flooding should be set out), in cases of less significant consequences, a less strict standard was acceptable; regardless of this, the *basic safety level* always applies (the new standards must comply with it) (DP 2013, p.39).

Due to the new standards, the government had to adjust the tools for assessing and designing defences; the next national assessment of the primary flood defence systems (expected to occur between 2017 and 2023) must be done with the new standards and tools (DP 2014, p.16) (Note 262). This implied the definition new requirements for the strength and height of dykes (Buuren et al. 2016). In 2016, updated technical requirements, and a toolkit for the assessment and design of defences, were issued, in line with the new standards (Klijn et al. 2016). The new standards were translated into *hydraulic requirements* and enforced in the *Water Act* (Peterson and Bloemen 2014). Moreover, every 12 years, it must be conducted an assessment of whether the standards need to be adjusted, and the effectiveness of the new *risk-based approach* must be reported to the Parliament (DP 2014, p.16).

The new *standard specifications* were approved by the Parliament in late 2014, and gradually embedded in legislation (DP 2013, p.43; Alphen 2015; Ritzema and Steensma 2018, p.4; Peterson and Bloemen 2014). Since January 2017, the new *flood protection standards* (and associated tools) are embedded in law and in force (legally binding) (DP 2017, p.8; 2018, p.13; Bloemen et al. 2018 p.10; DP 2013, p.43, 39; Buuren et al. 2016). The 4th Assessment cycle (which started in 2017 and should be completed in 2023) has been carried out based on the new standards (DP 2013, p.43, 39; Buuren et al. 2016).

In areas outside dykes (un-embanked areas), there are no legal standards. According to the *National Water Plan*, in these areas, residents are responsible for taking consequence-reducing measures, e.g. flood-proofing measures (Gersonius et al. 2016, p.7). The FRM policy for areas outside dykes did not change, but the DP and involved explored possibilities to improve their safety according to the *risk-based approach* (DP 2013, p.44). In areas outside dykes located on the coast, the basic coastline must be maintained. Various regions have made efforts, e.g. the Zuid-Holland Province set an individual risk of 10^{-5} as a goal for areas outside dykes and provided information on possible measures in Layers 2 and 3. The most densely populated area outside dykes is the Rhine Estuary-Drechtsteden.

Approval of the *Delta Decision on FRM*

In late 2014, the Cabinet adopted the Delta Decision on FRM; and it was incorporated in an amendment of the *National Water Plan 2010-2015*, and, then, in 2016, in the *National Water Plan 2016-2021*. In 2017, the new 'protection standards' were included in the *Water Act*, and, since then, the 4th Assessment) has been carried out based on them (DP 2016, p.14, 16; 2014, p.22) (Note 263).

This Delta Decision marked a major update of the Dutch policy on FRM, especially with its new 'risk-based approach', the *basic safety level*, and new flood protection standards (DP 2014, p.150,126; 2013, p.124; Klijn et al. 2016). This approach aims to '*improve flood risk management (...) and make the Netherlands more robust and less vulnerable'* to flood risk and other climate-related risks, and ensure '*a safe and robust delta that is resilient enough to withstand the extremes of nature*' (DP 2014, p.12, 8).

5.1.2. Delta Decision on the Rhine-Meuse Delta

The 'Delta Decision on the Rhine-Meuse Delta' describes the future FRM in this region. In the Rhine-Meuse delta, FRM has been based on diverse types of measures, namely *dykes*, *storm surge barriers*, *'room for the river*' and the '*sandy coastal foundation zone*'; such measures seem also promising in the long-term. With these measures and innovative 'customised' spatial solutions, the DP expects that will be possible to achieve the FRM objectives in good time (DP 2014, p.37). This Decision proposes that:

- The adopted discharge distribution across the Rhine distributaries will be maintained in national policy at least until 2050. Yet, in 2017, the Government must decide, in consultation with Provinces and Water Boards, and based on research, whether to change this distribution after 2050. In the long-term (up to 2100), the maximum normative discharge allowed for the Rhine River is 18000 m³/s, and for the Meuse River is 4600 m³/s. These values are the starting points for planning FRM (Note 264).
- In the long-term, it will be necessary to protect the Rhine-Meuse delta with a new open-closable storm surge barrier in the Nieuwe Waterweg, and the Government must embed this decision in its policy. It is expected that the Maeslantkering storm surge barrier will need to be replaced by 2070. In 2014, the best solution seemed to be to build a new storm surge barrier in the Nieuwe Waterweg. This decision is also a starting point for developing FRM measures in the meantime, and it must be considered in all spatial and economic developments around the Nieuwe Waterweg and in built-up areas outside dykes. This a basic decision that also determines the water levels allowed in this area
- Research must be conducted into possibilities to improve the effectiveness of Maeslantkering barrier.
- Water storage in the Grevelingen lake is no longer considered as an option around Hollandsch Diep, Haringvliet and the Merwedes. 'Dyke improvement' should be used instead (DP 2014, p.37-38, 40).

Figure 39 shows the 'adaptation path' developed for this *Delta Decision*. The map illustrates measures for the short-term, and possible options for the longer-term (DP 2014, p.39) (see more in Note 265).

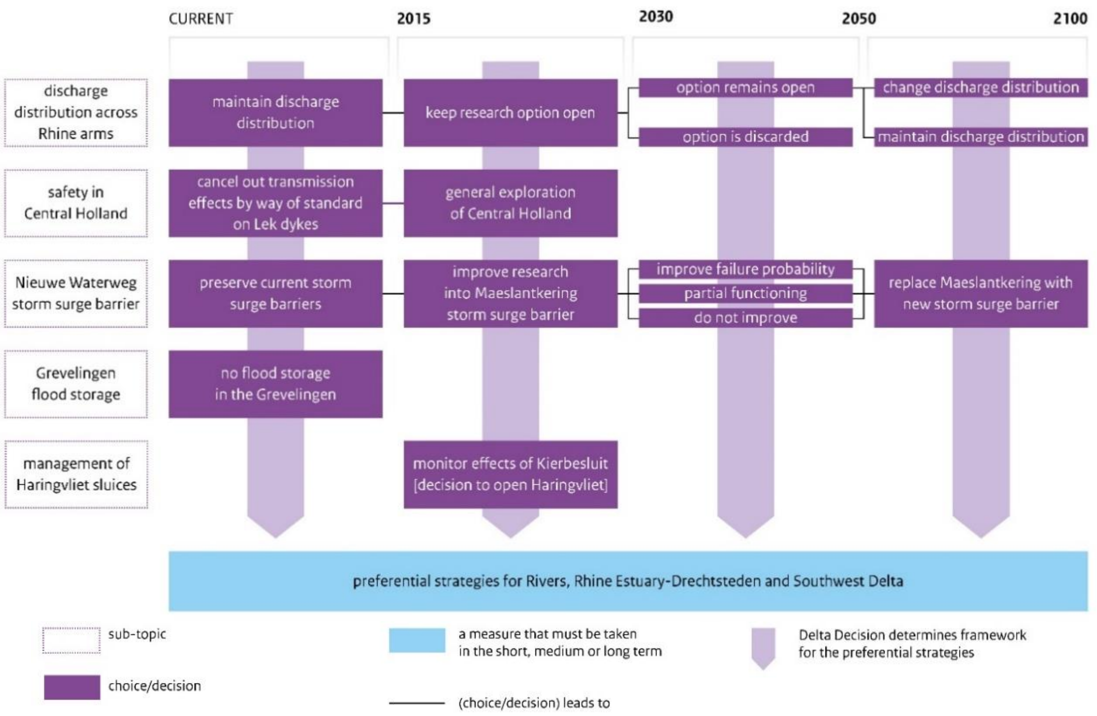


Figure 39. Adaptation path of the Delta Decision on the Rhine-Meuse Delta (DP 2014, p.39). The Rhine-Meuse delta is a transitional area between the sea and rivers, which contains several polders that can be submerged very rapidly and deeply in case of a flood. It is densely populated and hosts large-scale economic activities of national importance – namely the Rotterdam port and associated activities. Therefore, it is one of the most vulnerable areas in the Dutch delta (DP 2014, p.37).

This is an example of the use of the APs approach in the DP; the map refers to the lower parts of the rivers Rhine and Meuse near Rotterdam. It shows decisions that must be taken in the short-term, as well as options for the mid- and long-term.

Possible measures for the long-term

During 2013-2014, the DP investigated what measures could be used to better protect the Rhine-Meuse Delta in the long-term (DP 2014, p.38). The Maeslantkering will need to be replaced by 2070. Based on the 2014-existent knowledge, the best solution to do this will be to replace it with a new storm surge barrier in the Nieuwe Waterweg that will be opened under normal circumstances and closable during storms. Other possible measures for the long-term were explored, e.g. a *dam with a sea-lock in the Nieuwe Waterweg*, or a *ring of floodgates in the river branches around the Rhine Estuary*. However, the analysis showed that these measures were ineffective, too costly or have negative effects for shipping and nature. Nevertheless, as the future is uncertain, these and other options should remain available in case of unexpected changes. This is in line with ADM principles: being prepared for an uncertain future. Moreover, in 2013-2014, the central government and the regions analysed whether flood water storage in the Grevelingen lake was a cost-effective option in the long-term, in the areas of Haringvliet, Hollandsch Diep and Merwedes. Results showed is that there is no need to keep this option open. Nevertheless, in future, it may be worth (re)considering it again (DP 2014, p.38-39).

Possible measures for the short- and mid-term

In the last decades, solid FRM measures have been built in this region, and the DP expects that, with such measures and with 'customised' spatial solutions, the FRM objectives can be met. These measures are deemed more cost-effective than major technical interventions. However, measures involving *system changes* or *large-scale interventions* might be worth in the future, thus, they were taken into account as options to be left open. This is in line with ADM principles: allowing '*changing strategy in good time as necessary*' (DP 2014, p.38).

In the area of Central Holland, studies showed that 'improving the northern Lek dyke' is a cost-effective solution (DP 2014, p.38). Depending on the outcomes of a 'general exploration' for Central Holland, it may be necessary to change the primary status of C-dykes in Central Holland, e.g. dykes along Hollandsche Ijssel, Amsterdam-Rijnkanaal and Noordzeekanaal canals might lose their primary status in the future (DP 2014, p.40, 38). Any changes in the status of dykes will require alterations in legislation at a national level (amendment to the Water Act) and possibly in provincial regulation (DP 2014, p.40).

Moreover, research must be conducted into ways of improving the effectiveness of the existing flood defence systems, e.g. by reducing their failure probability or through *partial functioning* in case of failure (DP 2014, p.38). In 2015, a study should be initiated into the options for improving the effectiveness of the Maeslantkering storm surge barrier (DP 2014, p.40).

The Haringvliet sluices will be left open in 2018, except the Kierbesluit sluice (for which a separate decision will be taken in the future). It is necessary to monitor the effects of the Kierbesluit, which will provide information for a future decision in the mid- / long-term (DP 2014, p.39).

Implementation and progress on this Delta Decision

The Cabinet agreed with this Delta Decision (DP 2014, p.40). After September 2014, the Government laid down this Delta Decision (and its choices) in an interim revision of the *National Water Plan*, namely the decision of 'maintaining the current discharge distribution at least until 2050', and the decision of creating 'a new open closable storm surge barrier in the Nieuwe Waterweg' in the long-term. From 2014 onwards, the Provinces and Water Boards should base their plans on these basic choices.[127]

[127] It was decided that: in the long-term, a new (closable open) storm surge barrier in the Nieuwe Waterweg is the main measure envisioned, and it should be the starting point for developing measures in this area in the meantime. The Government must investigate whether a different discharge distribution across the Rhine distributaries after 2050 is worthwhile. It must conduct a study into ways of reducing the failure probability of the Maeslantkering barrier, and into the feasibility of partial functioning of this system. In 2017, the Government should decide whether to adopt other discharge distribution across the Rhine distributaries, based on research conducted in 2014-2017 (DP 2014, p.40).

5.1.3. Decision on Sand (Sandy Coastal System)

The 'Strategic Decision on Sand' concerns the sandy coastal system and the 'coastal foundation zone'.[128] In the Netherlands, sand replenishments are usually used to keep the amount of sand at the required level on the coast, to keep the coastline in its place, and to prevent the erosion of beaches and dunes. It is estimated that without 'sand replenishments', one metre of coast would be lost every year (the sand volume of outer deltas decreased and channels have approximated to the coast). Due to SLR, current 'sand replenishments' may not be sufficient to preserve the coastline in the future (DP 2014, p.41). Since 2000, *'an average of 12 million m^3 of sand has been replenished*' on the sandy coastal system; which has ensured that the coastline (on average) has stayed where it was (with a 'basic coastline' as a reference) and that the 'coastal foundation zone' can adapt partially to rising sea levels (DP 2013, p.54).

The main choices of the 2013 *Strategic Decision on the sandy coastal system* were (Figure 40):

- To develop an 'Adaptation Agenda for Sand' based on two principles: 1) *prevention as the main priority*, and 2) *maintaining the territory and keeping the 'coastal foundation zone' in balance in relation to relative SLR*. These principles require using the main measure already used, i.e. sand replenishments, and innovating it.
- To increase sand replenishments in relation to the relative SLR and in relation to the sand demand of open sea basins and erosion of outer deltas, and increase channel margin replenishments.
- To ensure the adaptation of dunes to relative SLR, through management, maintenance, and increase of sand replenishments in dunes (dunes are an integral part of the sandy coastal system).
- To enable the adaptation of former inlets that were closed-off with hard defences (and block sediment transport), as *open basins* that can adapt to SRL, by increasing sand replenishments (DP 2013, p.55) (see more in Note 266).

In 2013, the DP developed the 'Adaptation Agenda for Sand'. The objective of this Agenda is to safeguard the coast against floods in the short- and long-term (DP 2013, p.54-55).

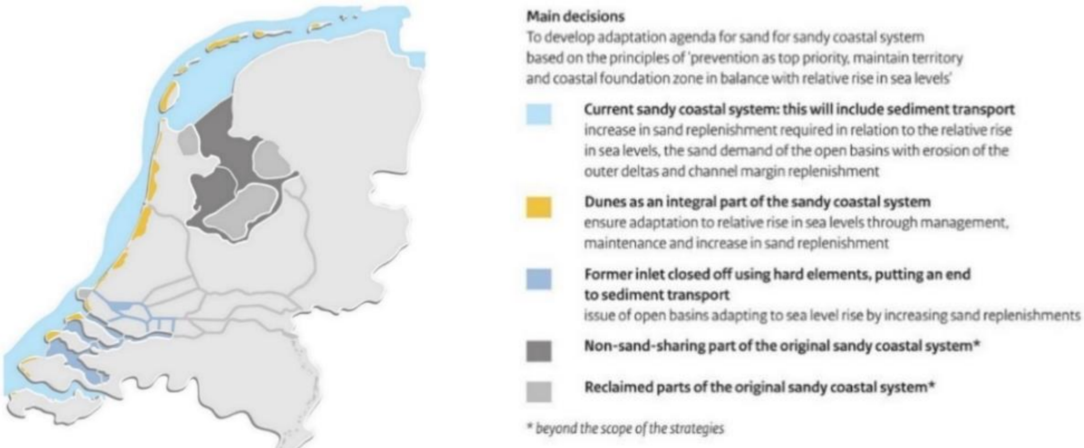


Figure 40. *Strategic Decision on the sandy coastal system* (DP 2013, p.55).

The 2014 'Strategic Decision on Sand' aims to keep the sandy system permanently in balance with SRL, by gradually adapting the 'sand replenishments' made in the *coastal foundation zone* to rising sea levels (DP 2014, p.41). This Decision proposes the following:

- The principle of '*soft where possible, hard where necessary*' remains the basic premise for ensuring coastal safety, which implies sand replenishments in the 'coastal foundation zone' (Note 266).

[128] The sandy coastal system provides a natural protection to the country. It is composed by the sandy parts of the Southwest Delta, central coast, the Wadden Region, and estuaries that connect to the North Sea – i.e. Westerschelde, Oosterschelde, Wadden Sea, and Ems (DP 2013, p.54). The '*coastal foundation zone*' is the zone between the NAP -20m isobath in the sea and the inside edge of dunes (DP 2014, p.41).

- To maintain the sand balance of the sandy coastal system, and to keep the 'coastal foundation zone' in balance with SLR, sand replenishments must be used, and increased, as necessary. Replenishments must contribute to preserve the coastline (main objective), but also, as far as possible, to ensure that the coast is economically strong and attractive and to local and regional objectives (in accordance with the *National Framework for Coastal Development - Nationaal Kader Kust*).
- Extra monitoring, research, and pilot projects must be conducted to better understand and anticipate future developments that might affect the sandy system, and to use replenishments more cost-efficiently and enable a '*learning as we go*' approach (DP 2014, p.41).

By maintaining the sand balance of the sandy system, the basic condition for preserving land area continues to be met and long-term coastal FRM is ensured. To achieve this, it is necessary to continue the current replenishment programme and intensify it, as necessary. Moreover, in order to keep the 'coastal foundation zone' in balance with rising sea levels, research has been conducted into how much sand will be ultimately needed to ensure this, and where and when replenishments are needed. Importantly, sand replenishments can be used in ways that contribute to FRM purposes but also to local and regional objectives (an economically robust and attractive coast) (DP 2014, p.41) (Note 267). Besides this, the DP has developed expertise on the functioning of the sandy system as a whole and in individual regions, and about future developments, but further monitoring, research and pilot projects must be carried out to ensure a *'learning as we go'* approach. The knowledge generated must substantiate future decisions on sand replenishments, and it will be essential to use replenishments more effectively (DP 2014, p.41). For instance, further research is needed into ways to allow the sand replenished to flow via natural processes to areas where it is needed.

Overall, the 2014 'Strategic Decision on Sand' focuses on '*keeping the sand budget along the coast up to par*' through 'sand replenishments' (DP 2017, p. 80; 2018, p.102). It involves maintaining the sand balance (within the desired average) by means of sand replenishment (DP 2016, p.52). Figure 41 shows the adaptation path of the 'Strategic Decision on Sand' – outlining decisions for the short-term and possible options for the mid-term (DP 2014, p.42).

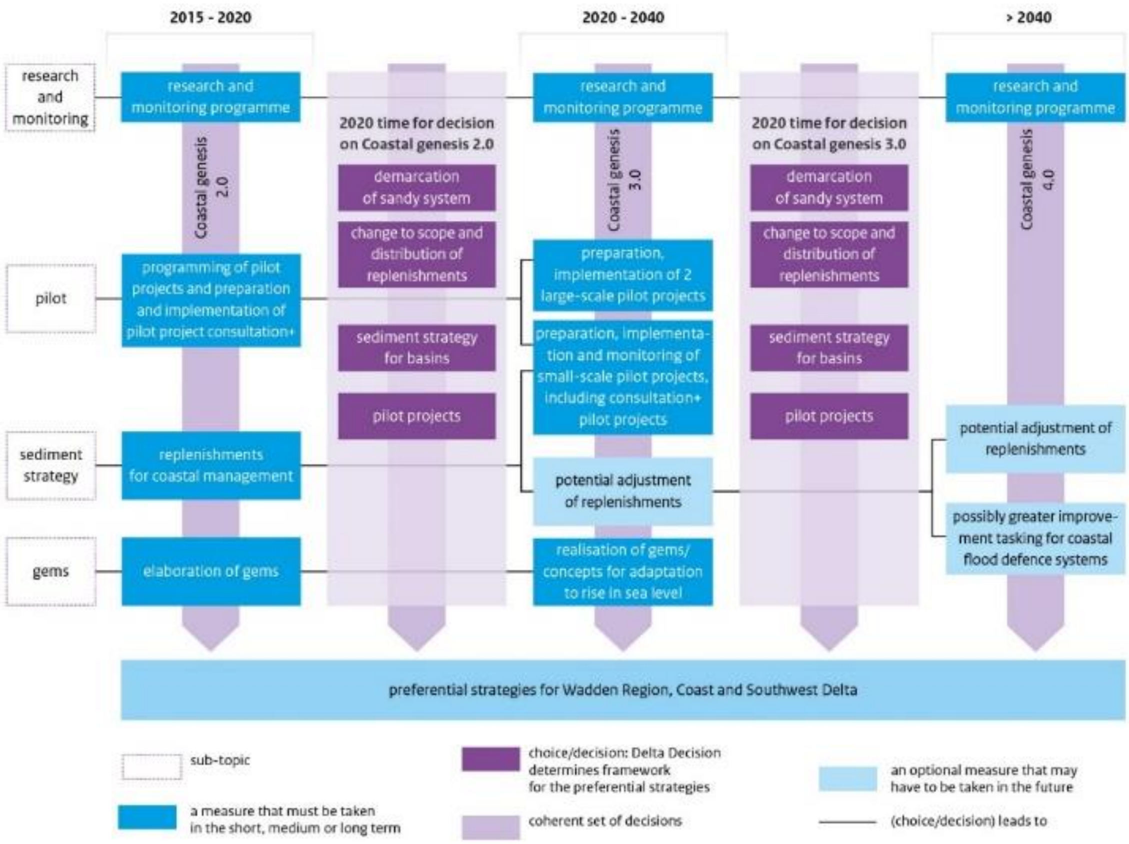


Figure 41. Adaptation path of the Decision on Sand. Source: DP 2014, p.42.

Interpreting the 'adaptation path'

Regarding the 'research and monitoring': Research and closer monitoring must be conducted, to analyse in-depth the behaviour of the sandy system and the exchange of sand between the North Sea and the Wadden Sea (DP 2014, p.42).

Regarding the 'pilot projects and studies': Small- / large-scale pilot projects must be carried out, e.g. to determine how the tidal inlet systems and channels (which are encroaching on the coast) can be balanced. A study must be conducted into the effects of the sand-sharing elements of the natural system, to understand how much sand is necessary to keep the sandy system in balance with SLR, and when and where the sand must deposited (DP 2014, p.42).

The 'Coastal Genesis II' must be initiated in 2015-2016 (DP 2014, p.42). It is a long-term research programme focused on sand transport along the Dutch coast (morphology and future sand replenishment), which develops knowledge about coastal safety, ecology, area preservation and spatial planning, in a 'learning by doing' way (DP 2016, p.52). This programme includes small-scale pilot projects with sand replenishments. Its joint programming and intergovernmental coordination are expected to contribute to improve sand replenishments (by linking them to other spatial developments). The results of the 'Coastal Genesis 2.0' must be used, by Ministry of Infrastructure and the Environment, to determine if and to what extent the replenishment volumes need to be adjusted and which pilot projects will be launched after 2020 (in the 'Coastal Genesis 3.0' for 2020-2040) (DP 2014, p.42-43). In 2015-2016, the Coastal Genesis II was designed and implemented (DP 2016, p.52).[129]

Regarding the 'sediment strategy': The existing 'sand replenishment' programme (which has involved around 12 million m^3 of sand per year) must be continued after 2014 (up to 2020). The Government incorporated the *continuation of the replenishments* – i.e. the decision to continue the sand replenishments – in the replenishment programmes.[130] Sand replenishments will be realized in the 'coastal foundation zone', and, drawing on research, monitoring and pilot projects, it will be identified the best way of maintaining the sand balance. The existing 'sand replenishment programme' will be continued, and, where necessary, stepped up. In 2020, a decision will be made on *which*, *where* and *when* measures should be taken to maintain the balance of the sandy system in a cost-efficient way, and *whether*, *how* and *where* large-scale pilot projects should be realized to deliver that balance in a controlled way. Whenever possible, natural processes should be used (DP 2014, p.43) (Note 267).

Regarding the 'gems': In seventeen locations along the coast – so-called 'gems' – the FRM measures must be linked to spatial development goals (DP 2014, p.75).

Implementation and progress on this Delta Decision

The Cabinet agreed with this Decision, namely with '*keeping the coastal foundation zone permanently in balance with the rise in sea levels*' and embedded it in the revised 'National Water Plan 2010-2015' (DP 2014, p.43). In 2018, the implementation of the 'Decision on Sand' was proceeding as planned (DP 2018, p.102).

---

[129] The Rijkswaterstaat established an 'Action Plan' to further develop knowledge about the coastal foundation zone and the exchange of sand with tidal inlet/outlet systems, as a basis to inform future coastal FRM and nature preservation. Other involved parties (District Water Boards, Provinces, university, business community, and Rijkswaterstaat) intended to secure joint funding of other studies (DP 2016, p.52).

[130] In the DP 2010, the coastal reinforcement policy was already based on '*the retention of sand and its unhindered transport*', '*the use of as many sand measures as possible*', and '*the use of solid constructions only when absolutely necessary*'. This was in line with the 'adaptive approach' already intended by the DP in 2010 (DP 2010, p.54). The existence of good sand extraction sites nearby the coast is crucial to maintain sand replenishments affordable. Sand extraction was prioritized in the zone between the twelve-mile limit and continuous isobath at NAP (Amsterdam Ordnance Datum) -20 metres. Furthermore, it was decided to extract a layer of sand of 10 metres where possible (instead of the previous 2 metres), to meet the increasing sand demand in the coming century (due to SRL and policy choices). It is also essential to ensure an effective management of the sand supply, accounting for other uses (than FRM) and nature (DP 2014, p.43).

5.2. Preferential Strategies

During 2013-2014, each regional subprogramme developed a Preferential Strategy for FRM for its region, based on the proposed Delta Decisions (DP 2014, p.8, 46, 132).

A 'Strategy' consists of objectives, associated measures, and the associated adaptation path displaced in a map of APs (DP 2013, p.56; Zandvoort et al. 2018, p.190). Thus, each Strategy (developed by its respective Subprogramme) contains a map with (one or more) '*adaptation paths*' (DP 2013, p.56). The term 'adaptation paths' refers to the 'adaptation pathways' of the APs' approach. An *adaptation path* is a logical set of measures, which includes measures for the short-term (e.g. 'no-regrets measures') and options for the long-term (DP 2013, p.56). The strategies, as *adaptation paths*, connect short-term decisions and measures to long-term tasks (DP 2013, p.56) (in accordance with Principle 1 of ADM). This work focussed on the Preferential Strategy for FRM for the Rhine Estuary-Drechtsteden (RE-D) and the Preferential Strategy for the Coast.

The Preferential Strategies were developed based on the ADM approach and its principles (DP 2014, p.47). Such principles are patent in the Preferential Strategies in several ways, for example:

- P2 (*incorporating flexibility into possible solution strategies*). The flexibility of a Strategy is ensured by '*taking the most (cost-)effective measures step-by-step'*, as well as 'leaving options open for the future (to deal with changes and new knowledge) (DP 2014, p.47).
- P3 (*working with multiple strategies that can be alternated between, i.e. adaptation pathways*). This is reflected in the use of *'adaptation paths'* as *part of the 'Preferential Strategy'*. A map of 'adaptation paths' was designed in each Preferential Strategy. The 'adaptation path' indicates *what* and *when* measures are expected to be necessary, including measures required now to ensure that the options that may be necessary in the long-term can be implemented by that time (DP 2014, p.47). Depending on the actual changes and developments in the climatic and socioeconomic conditions, measures may be taken sooner or later (DP 2014, p.47), and it may be necessary to switch of measure.
- P4 (*linking FRM and FS measures with other investment agendas*). The Teams sought to link FRM measures envisioned, as far as possible, to other objectives and ambitions in the area (e.g. regarding space or nature), as this can contribute to more innovative, efficient and sustainable solutions, in a *'comprehensive / integrated approach'* (DP 2014, p.47). The 'paths' helped to detect linkages between the measures devised and other investments, agendas and policy objectives (DP 2013, p.56).

Moreover, a Preferential Strategy should also be (DP 2013, p.94-95):

- *Robust.* I.e. with such Strategy, the objectives can be achieved in all *Delta Scenarios*.
- *Flexible.* I.e. the implementation of the Strategy can be slowed down or sped up easily, and it is possible to change to a different measure or pathway, if necessary. 'Flexibility' is related with the capacity to respond to changes, new developments and knowledge.
- *Feasible.* I.e. the Strategy is viable, considering legal, technical and procedural barriers and risks associated to it, opportunities to link it with other developments; and options to revise it, if necessary.
- *Efficient.* I.e. the Strategy (with its measures) ensures that the objectives of FRM are achieved in an efficient way, considering the financial costs and social benefits of its measures, and the lifecycle of the various measures (construction, management and maintenance). A Strategy aims to achieve the objectives *'in a cost-effective manner and with maximum benefits*' (DP 2013, p.94-95) (Note 268).

Each Subprogramme should assess if its Strategy had these features, among others (DP 2013, p.95).

Each Preferential Strategy defines specific measures customized per area (DP 2014, p.46, 8). A measure can be, for example: *dyke improvements*, *sand replenishments*, *a combination of dyke improvements and river widening*', multifunctional dykes, *reinforcement of defences*, etc. (DP 2014, p.8; 46).

A Preferential Strategy contains measures to address FRM objectives, for the short- and long-term. Within the measures for the long-term, there may be: (1) measures that are *already certain to be required in the long-term* (e.g. dyke improvements in places where no alternatives are available); and (2) measures that are not yet certain to be needed in the long-term and which will depend on climatic and socioeconomic developments (DP 2014, p.49). The final decision on the measures for the long-term will be taken later and will depend on the climatic and socioeconomic developments in the next decades. This is in line with one of the mottos of ADM: making what is needed now (measures necessary now are implemented) and identifying which measures can be implemented if the conditions change. Therefore, a Preferential Strategy usually contains 'options' that are open for a future decision about their implementation (the envisioning of long-term options in policy plans is other of the key features of ADM). This also helped to identify which locations might be needed for implementing such measures in the future, and to prevent developments that could render such measures unviable. The Dutch government can use several tools for this purpose, e.g. by defining 'area reservations' in a *General Rule on Spatial Planning* called 'Barro' (DP 2014, p.49, 62) (Note 268).

5.2.1. Preferential Strategy for FRM the Rhine Estuary-Drechtsteden (RE-D)

The Strategy for FRM for the Rhine Estuary-Drechtsteden was developed by the Subprogramme of this region. During 2012-2013, the Subprogramme Team explored 'Promising Strategies' (DP 2013, p.79). Then, in 2013-2014, the Team further developed the *Promising Strategies* into *Preferential Strategies*; it further defined and detailed the 'adaptation paths' and the timing for measures (DP 2013, p.82, 83).

In 2013, the RE-D Subprogramme adopted the '*basic safety level*', which implied increasing the 'flood protection standards' in nearly the entire region. In a large part of this region, it will be necessary to provide a higher 'safety level' than the one that existed in 2013, and, therefore, new (higher) '*flood protection standards*' were also defined for most dykes (DP 2013, p.79-80).[131] In 2013, the Subprogramme proposed upper and lower limits for the new standards; and, in 2014, it presented its recommended 'standard specifications' in this Preferential Strategy. This Strategy also defines the desired safety levels for areas outside dykes (DP 2013, p.80).

The 2013-existing flood defence system, which includes a storm surge barrier in the Nieuwe Waterweg, is expected to remain viable until around 2070[132]; and, then, in the long-term, the objectives can be met by optimizing the existing strategy, with measures in locations at greater risk (DP 2013, p.79).

In 2014, the Subprogramme defined new 'standard specifications' for the defence systems in this region. The *basic safety level* and the new *flood protection standards* will entail major tasks (DP 2014, p.65).[133]

This 'Preferential Strategy' presents the following features (DP 2014, p.65-67) (Figure 42):

131 Studies demonstrated that a 'higher protection standard' was required in almost all dykes to be able to meet the basic safety level of 10^{-5} (assuming that this objective was achieved with dykes alone). In some areas, achieving the 'basic safety level' was determinant for setting the standard, while in others, an '*economically optimal standard*' (calculated in the social cost-benefit analysis) set the standard (DP 2013, p.80).

132 The Maeslant barrier was designed to cope with a SLR of up to 50 cm. A major intervention in this system is expected to be not necessary before 2070. In 2011, the Maeslant complied with the then-current standards. Yet, in 2011, the DP Commissioner recommended a review to further increase in safety provided by this defence, and the government adopted this recommendation (DP 2011, p.36).

133 Several factors led the RE-D Subprogramme to designate new flood protection standards for this region. The RE-D is densely populated and hosts a large industrial area along the lower parts of rivers, with the economic core at Rotterdam port. The population and economic values in this region have grown intensively over the last 50 years. These factors, together with climate change effects (SRL and higher river discharges), and soil subsidence, contributed to increase flood risk. Most areas lie at an elevation where they would be submerged rapidly in case of flood. Given the great natural variability in river discharges, and the long lead time for dyke improvement projects, the DP assumed *fixed values* for peak river discharges for the Rhine River at Lobith: 17000 m^3/s in 2050, 18000 m^3/s in 2100 (DP 2014, p.65).

1. ‘*Prevention as the basis for FRM*’. Flood prevention measures will continue to be the basis for achieving the required *level of protection*.
2. ‘*Always an optimal combination of preventive measures*’. A combination of 3 types of prevention measures – i.e. ‘storm surge barriers’, ‘dykes’, and ‘river widening’ – will always provide the basic solution to achieve the required *level of protection*. It is expected that the Maeslantkering barrier and the Hollandsche IJsselkering barrier will need to be replaced in the second half of the 21st century. By then, it will be necessary to revaluate the balance needed between the requirements defined for storm surge barriers and the standards for dykes. The premise is that the rivers Hollandsche IJssel and Nieuwe Waterweg remain open rivers and allow shipping and tidal nature. Hence, if such barriers need to be replaced by new ones in the future, these will have to be *open-closable barriers*. In Merwedes area, the best combination involves *river widening* and *dyke improvements*.
3. ‘*Safety plus spatial development*’. ‘Dyke improvement’ is a measure that should always be linked to other spatial developments in urban or rural landscape. The Team formulated three possible solutions for working on ‘flood safety’ and ‘space’ at the same time:
   a) *Strong urban dykes*. This involves a greater integration of urban dykes into built-up areas, which offers opportunities to use the both sides of a dyke for urban development. This solution applies to the Rotterdam metropolitan region, Drechtsteden and Gorinchem.
   b) *Robust marine-clay islands*. The islands of Voorne-Putten, Hoeksche Waard, and Dordrecht, have robust marine-clay islands which slow down and hold back floods (act as natural defence systems). These systems must remain, and new spatial development must not increase risk.
   c) *Future-proof river dykes*. Any decisions regarding spatial planning in the area of Lek (Krimpenerwaard and Alblasserwaard-Vijfheerenlanden) and Hollandsche Ijssel must account for long-term FRM tasks, and ensure that ‘dyke improvements’ do not entail high social impacts or costs, or face public opposition. This requires ‘*a long-term policy for spatial organisation and building*’, and a flexible use of financial resources (to link FRM and spatial development). This is crucial to ensure spatial quality in these areas and the affordability of the FRM measures.
4. *Limit risks in areas outside dykes with customised regional measures*. In 2014, a ‘*strategic adaptation agenda*’ was being elaborated for these areas, including measures to reduce damage and measures for risk communication. Municipal Councils and Security Regions were developing ‘disaster plans’; and regional governments and site managers were developing plans for areas where the risks are high (e.g. Noordereiland in Rotterdam, historical port of Dordrecht, and Botlek).
5. *Multi-layer FRM*. The 3 layers, in conjunction, can make a FRM system more robust. A study was conducted to ensure FRM in Dordrecht Island by means of a ‘smart combination’ of prevention measures (Layer 1), spatial planning measures (Layer 2), and evacuation measures (Layer 3). The protection of vital infrastructures and functions must also be improved through customised solutions. Regarding Layer 3, further attention is needed on evacuation, because in case of a flood from sea, it will be difficult to leave the Rhine Estuary-Drechtsteden area in good time (there would be no time, roads are low-lying and have insufficient capacity). A better option is using refuges in high locations and improving the coping capacity of the population. Security Regions must encourage this, and provide risk communication and enough information on disaster management.
6. In the RE-D area, there are *forelands* in front of most dykes, which have a positive effect on the flood safety of the hinterland. New assessment tools will be created to analyse the current topography and the role of forelands and other elements that influence waves and water levels. Defence managers must consider forelands in the assessment of dykes (DP 2014, p.65-67).

In sum, this Preferential Strategy essentially involves: ‘prevention’ through *dykes*, *storm surge barriers* and *river widening*; the improvement of flood safety of the areas outside dykes; the improvement of the flood safety of vital and vulnerable infrastructures and disaster management; and the combination of FRM measures with spatial developments, wherever possible (DP 2017, p.63; 2018, p.89).

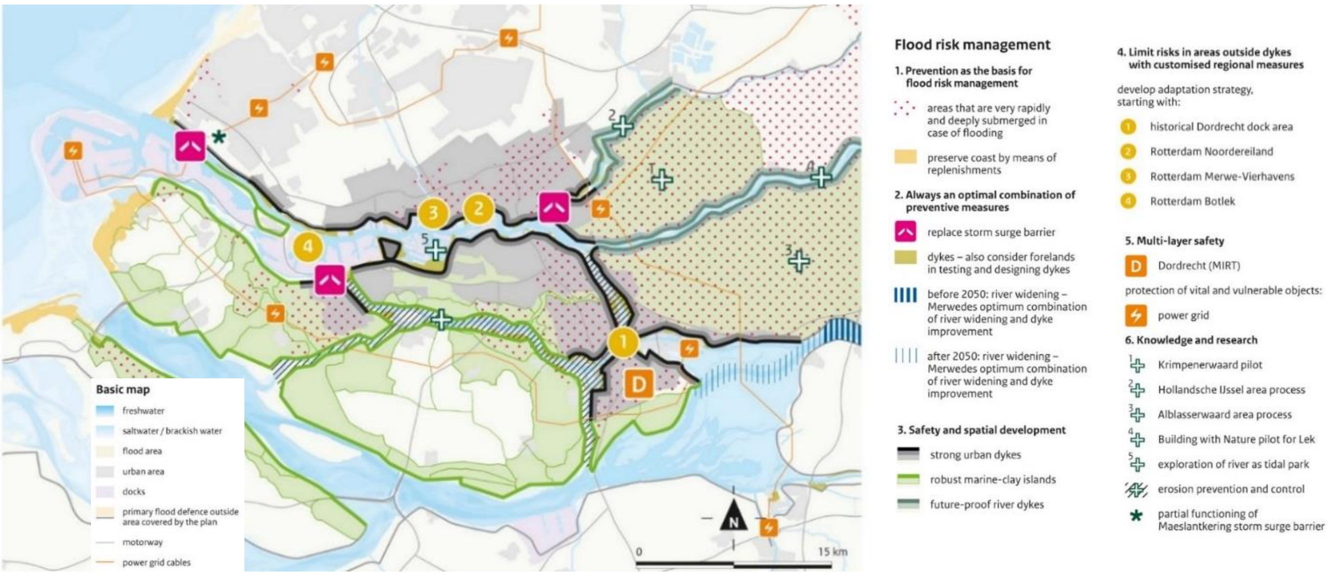


Figure 42. Preferential Strategy for FRM for the Rhine Estuary-Drechsteden. Source: DP 2014, p.64.

This Preferential Strategy proposes an *adaptation path* that contains the following measures (Figure 43):

- Develop an ‘*Adaptation Strategy for areas outside dykes*’ (also called ‘*Strategic Adaptation agenda’*, which aims at reducing flood risk in these areas), in the short-, mid- and long-term.
- Improve the Maeslantering storm surge barrier until 2050; and, then, in the 2nd half of this century, replace this barrier[134] and replace the Hartelkering barrier.
- Improve the Hollandsche Ijsselkering storm surge barrier until 2050; and, around 2050, replace it.
- Dyke improvement measures (also called ‘*dyke strengthening*’) in the short-, mid- and long-term.
- River widening measures (also called *‘room for the river*’) in the short-, mid- and long-term. And,
- ML FRM measures (combinations of three layers of measures) in the short-, mid- and long-term.
- *Adjusting river discharge distribution* may be used as an alternative to *dyke improvement*, after 2050.

In late 2014, the Cabinet approved this Preferential Strategy and decided to incorporate the measures, government actions and studies necessary to implement it in the revised *National Water Plan 2010-2015*. The Government, the Province (Zuid-Holland) and Water Boards should include this Strategy into their own plans. The Strategy should gradually materialize through ‘area processes’ that find the right balance between *dykes*, *storm surge barriers* and *river widening* (DP 2014, p.69, 67) (Note 269).

[134] By 2040, a new study into the replacement of the Maeslant storm surge barrier will be launched, the ‘Locks Plan’ will be studied as an alternative (DP 2016, p.33). The ‘Locks Plan’ envisions a new sea lock to replace the Maeslant storm surge barrier in the long-term. The Locks Plan is an option to be studied in a study that will start by 2040 (on the options to replace the Maeslant barrier) (DP 2017, p.63).

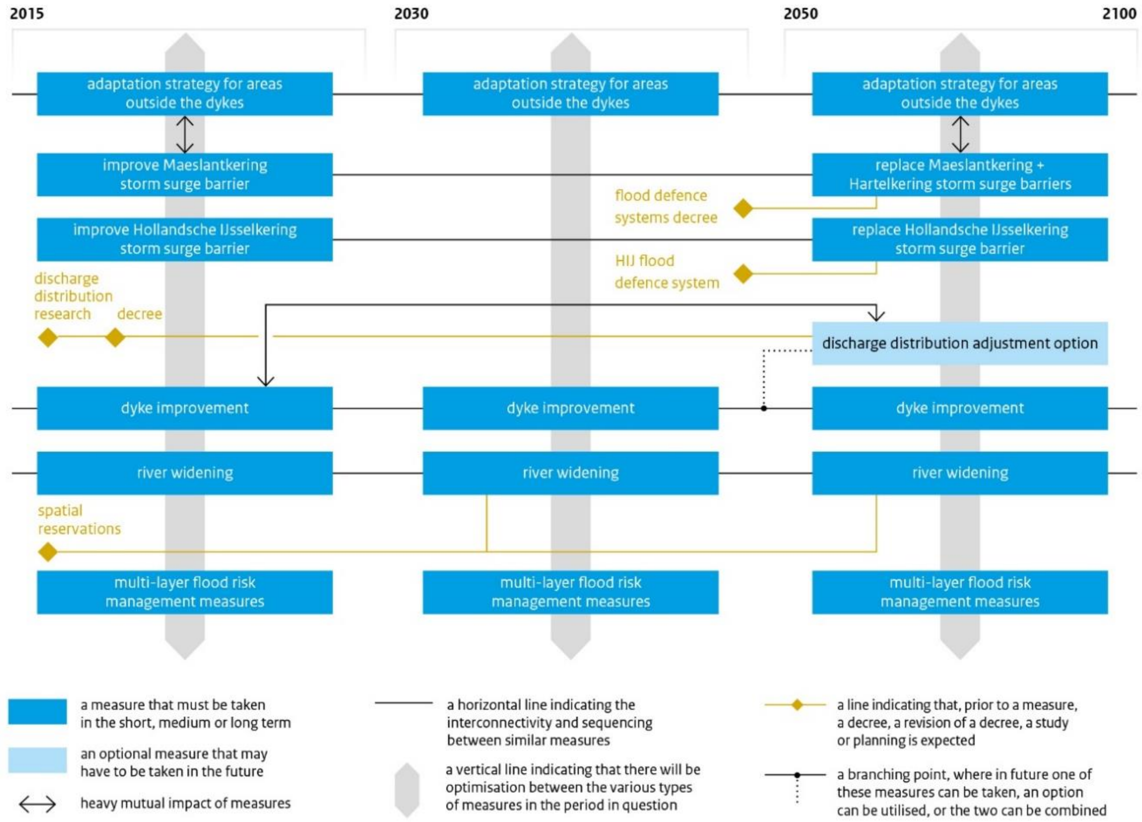


Figure 43. Adaptation path for the Preferential Strategy for FRM of the Rhine Estuary-Drechtsteden. Source: DP 2014, p.66; also discussed in Bloemen et al. 2018, p.11 and Restemeyer et al 2017, p.930. The map illustrates the measures that that must be taken (blue boxes), for three time periods: 2015–2030, 2030–2050, and 2050–2100. The light blue boxes show possible options (alternative measures) for the future. In this case, the only alternative option considered is 'modifying the discharge distribution along the Rhine River branches. The yellow diamonds represent 'preparatory actions' (e.g. the creation / revision of the decree, a study, the definition of 'spatial reservations' required for river widening; or research on the costs and technical feasibility of a possible measure). The arrows show a strong influence between measures' effectiveness (e.g. if research into the possible modification of the discharge distribution results in a decree for its implementation, then the design of 'dyke improvement projects' will need to take into account the effects of such measure) (Bloemen et al. 2018, p.11). The branching point shows a point where it will be necessary to select one option (opt for a measure or, even, use both measures) (Bloemen et al. 2018, p.11). The branching point is like a bifurcation point where either one option or a combination of options can be chosen; the yellow diamond indicates that need for a decision before the measure can be implemented. Importantly, in the map, each horizontal trajectory presents measures that will be implemented in a sequenced way; while the grey vertical stripes show measures that will be implemented in the same time period (Restemeyer et al. 2017). The vertical grey stripes demonstrate that there is optimization between the various types of measures in the same particular time period (Bloemen et al. 2018, p.11).

Interpreting the 'adaptation path(s)' of this Preferential Strategy

In theory and conceptually, adaptation pathways are '*various trajectories*' available that show *'possibilities for switching from one trajectory to another when conditions indicate it is wise to do so*'. Hence, only one of these trajectories is chosen and its measures are applied, according to the existing and expected conditions (Bloemen et al. 2018, p.14). Nevertheless, the 'adaptation path' presented in each of the regional Preferential Strategies usually contains several parallel trajectories that, actually, act as complementary measures. Though the horizontal lines appear to be different pathways, most often, they correspond to different measures that will be followed simultaneously and that are interrelated (e.g. complementing each other). Within a Preferential Strategy, there can be different measures envisioned for different zones, e.g.: dyke reinforcement projects, improvements of storm surge barrier, and pilot projects on ML FRM. In these cases, the different measures may be defined for the same period, but for different zones or fields. Yet, there are interrelationships between these 'parallel' measures / trajectories. The use of parallel measures / trajectories is deemed advantageous: a plan / strategy with parallel trajectories enhances the system's resilience, since it has more alternatives / fallback options, if one measure does not perform as expected. However, these parallel trajectories usually concern different actors in different zones or fields, thus, the interrelatedness of their outcomes tends to be disregarded, and their successful (effective) implementation becomes more uncertain (Bloemen et al. 2018).

In the Preferential Strategy of the RE-D, the only option (alternative measure) indicated is '*adjusting the discharge distribution*'. This option, which would require an analysis of how much the dykes need to be strengthened, is deemed *adaptive*, as it is possible to do more or less of it depending on the climatic and socioeconomic changes (Restemeyer et al. 2017, p.932).[135] However, it is not clear how to evaluate whether more or less of this measure should be done. For Restemeyer et al., the general strategy until 2100 (Figure 43) looks quite *determined*: it provides little room for adjustments over time; it focusses mostly on '*prevention'* through '*gradual adjustment*' of the existing defence system ('*maintaining and improving the existing system*') (Restemeyer et al. 2017, p.932, 934).

This Subprogramme followed a screening process from 'Possible' to 'Promising' strategies, and then to a 'Preferential' strategy. In this process, some large-scale measures discussed in the phase of 'Possible Strategies' – e.g. a *ring of weirs* or a *closed dam on the seaside* – were excluded, which caused controversy (this was contested by several engineers and the Agricultural and Horticultural Organization, while some nature organizations were in favour of allowing more natural estuarine dynamics in the seaside). Thus, the Subprogramme opted for '*maintaining and improving the existing flood defence system*', as a middle-course solution. The Team considered this Preferential Strategy is *robust* because it can cope with the most extreme scenario used (the *Steam*), and *flexible* because it does not imply large-scale interventions but gradual adjustments to the existing system. However, for Restemeyer et al., this Strategy may not necessarily lead to an improved adaptability, because:

- The measures of *gradual adjustment* of the existing system (namely dyke improvements, e.g. heightening / strengthening, or the optimization and then eventual replacement of storm surge barriers) are mainly aimed at reducing the probability of flooding. The measure 'river widening' is only available in one part of the region (east of Dordrecht).[136]
- Measures to reduce flood consequences (e.g. flood-proofing building measures and evacuation measures) were only considered for a few un-embanked areas (e.g. Dordrecht), though most of the region lies below sea level and would be flooded quickly.
- Further attention could have been paid to the adoption of a diversified set of measures, including both measures to reduce the probability of flooding and measures to reduce flood consequences.
- This Strategy considers risk communication and preparedness measures, but it does not mention how flood risk and evacuation possibilities should be communicated to citizens. This is pertinent, as 57% of Dutch citizens feel badly informed about flood risk but trust the Government to prevent flooding.
- This Strategy calls for the integration of FRM and spatial planning (more than other subprogrammes), but it focusses mostly on improving the integration of dykes into the physical landscape (e.g. multifunctional dykes that incorporate car parks) and less on making the landscape resilient to floods and reducing impacts. The integration of FRM with spatial planning is weak (ibid, p.934).

All in all, this Subprogramme developed a strategy that is '*predominantly preventive'*, as it is strongly based on improvements to existing defences (namely dykes and barriers) (Restemeyer et al.2017, p.934).

[135] Restemeyer et al. examined to what extent the strategies for FRM elaborated in the RE-D Subprogramme were flexible, and found that, in practice, the Subprogramme faced several difficulties in working with scenarios, ATPs and APs (Restemeyer et al. 2017).

[136] Dordrecht is an exception; it follows a more integrated approach. Most of the Island is protected by a dyke ring, but many parts of it were difficult to improve due to the proximity of historic buildings. Before the DP, Dordrecht had searched for alternatives, taking forward the 'ML FRM' and its 3 layers (Restemeyer et al. 2017, p 934). Dordrecht City is interested in ML FRM, because in case of failure of the primary defence system, flood impacts can be reduced via *adjusted spatial planning* and *evacuation plans* (Gersonius et al. 2015; Bloemen et al. 2018).

5.2.2. Preferential Strategy for the Coast

In 2011-2012, the 'Subprogramme for the Coast' explored 'possible measures' for FRM for this region (and for different types of coastal zones, e.g. wide dunes, narrow dunes, dykes, channels, ports, seaside resorts); in 2012-2013, it elaborated its 'Promising Strategies' (including physical, administrative and financial measures) (DP 2013, p.87); in 2013-2014, it developed the Preferential Strategy (Note 270). The Preferential Strategy for FRM for the Coast mentions that, at the coast, the major tasks for FRM arise from two factors: 1) the necessary management and maintenance of the 'basic coastline', 'coastal foundation zone' and defence systems; and 2) SLR and expected changes in wave patterns and heights. The DP estimates that major FRM measures along the coast will not be required until 2050, provided that sufficient effort is dedicated to the management and maintenance of the basic coastline, coastal foundation zone and defence systems. Yet, in the meantime, depending on the SRL rate, measures will have to be implemented in various places to maintain the desired *basic safety level* (DP 2014, p.75).

The 'Preferential Strategy for FRM for the Coast' aims at (DP 2014, p.75; 2017, p. 80; 2018, p.102):

- Ensuring '*a safe, attractive and economically robust coast*' (*safe, appealing, economically viable*).
- '*Connecting FRM tasking and spatial ambitions*'. This requires integration between FRM measures and goals and spatial developments. Seventeen locations demand further attention along the coast – so-called 'gems'. In these gems, the FRM measures must be linked to spatial development goals.

The adaptation path of this Preferential Strategy is shown in Figure 44. In 2014, the Cabinet approved this Strategy and incorporated it in the revised *National Water Plan 2010-2015*. This Strategy provided the framework to address the FRM tasks along the coast at regional and local level (DP 2014, p.75-76).

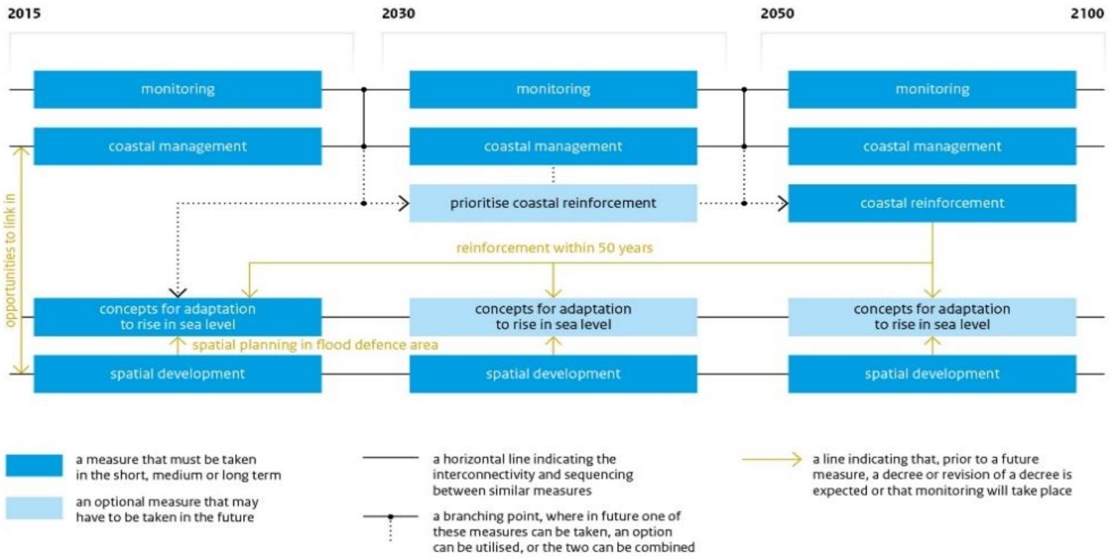


Figure 44. Adaptation path of the "Preferential Strategy for FRM for the Coast. Source: DP 2014, p.76.

Interpreting the 'adaptation path' of this Preferential Strategy

Monitoring: Since 2014, several monitoring programmes were launched (DP 2016, p.53). In late 2016, the works of programme 'Weak Links on the Coast' started to be monitored, namely development of artificial inlets in the sea strip in Meijendel (Zuid-Holland); the effects of dune compensation on the Maasvlakte port extension and the impact of the Sand Engine, at Delfland coast (effects on FRM and nature values). Until 2017, the Sand Engine expanded the coastal zone (DP 2017, p.81) (Note 271). Moreover, to substantiate sand replenishments on the coast, the 'Coastal Genesis 2 research programme' has been conducted; by 2020, its results must inform decisions on whether and how replenishments need to be adjusted. In addition, the coast will be subjected to a Statutory Assessment based on the flood protection standards every 12 years. Together, the results of the statutory 12-year assessment, Coastal

Genesis 2, and insights of the Signal Group, will enable an adequate response to potentially accelerated SLR or other unexpected developments. In 2017, the monitoring process showed that the coast is well supplied with sand, and it is estimated that it will continue meet the required standards (DP 2017, p.81).

Coastal management: In the past, Dutch coastal FRM has relied on sand replenishments, dunes and dykes; these measures will continue to be essential for coastal FRM; hence, this Strategy includes these types of measures, but also measures that provide opportunities for spatial development (DP 2013, p.87). In the coast, the main measure envisioned consists of 'sand replenishments', which ensure the management and maintenance of the coastline and sandy coastal system (DP 2014, p.75). The DP estimated that, in 2016-2019, the maintenance of the 'ordnance coastline', and the measures to keep the coastal foundation zone in pace with SRL, required less sand than the expected (an annual average of 12 million m^3 in the long-term was expected, but 10 million m^3 were used) (DP 2018, p.102) (Note 272).

Concepts for adaptation to rise in sea level: In order to explore how the several types of FRM measures can be effectively linked to spatial developmental ambitions, the parties must use a '*decision tree*'. In this 'decision tree', the 1st step is to determine where and when there are active relationships between FRM objectives and spatial ambitions. In cases where there is no relationship, each party must carry out management and maintenance with due attention to the tasks or ambitions of other parties (i.e. FRM actors pay due regard to spatial ambitions, and spatial actors pay due regard to FRM tasks). In cases where there is a relationship that endures for 50 years, the parties must jointly determine 'concepts for adaptation to SRL'. This implies a joint decision on the type of future measures, e.g. 'multifunctional dykes' or 'dyke improvements' (whether they should occur offshore, onshore, through consolidation, etc.). By using these 'adaptation concepts', integration is ensured between the long-term FRM tasks and spatial development ambitions. Each 'gem' will undergo an 'area process' in which area-based forms of cooperation will be specified. If possible, the parties should make agreements and lay them down into their policy tools (e.g. *framework visions*, *zoning plans*, or coastal management programme) (DP 2014, p.75) (Note 273). To ensure integration, further research is needed on 'multifunctional defences'.

Spatial development: In 2015, the Minister of Infrastructure and Environment and other partners jointly examined measures to keep the coast safe, attractive, and economically robust. The Minister's intention was to widen the scope for construction in the coast, which caused fierce discussion. Despite that, the principle of '*flexible where possible, rigid where needed*' (set in the Strategic Decision on Sand) and the 'integrated approach' remained the basis of this Preferential Strategy (DP 2016, p.52). In 2015-2016, this Minister and other actors (municipalities, water boards, nature organisations, and leisure sector) started to elaborate a 'Coastal Pact' (an agreement) to regulate new construction and recreational facilities on the coast, based on a new 'zoning plan' that would be anchored by government authorities into their policies and regulations (DP 2016, p.53; 2017, p.80; 2018, p.102) (Note 274). Moreover, the Zeeland Province, municipalities, nature, environmental organisations, tourism groups, and other actors, started to plan the 'Zeeland Coastal Vision', with three goals: preservation and improvement of dykes and beaches, improving nature and landscape values, and discussing the future of the recreational sector. This vision should underpin a provincial 'environmental vision' that would be issued in 2018. Moreover, in 2015, the study 'Den Helder testing ground' explored options for ML FRM (DP 2016, p.53).

Overall, in the period 2015-2018, the implementation of this Preferential Strategy was proceeding as planned, and coastal protection has been deemed to be 'up to par' (DP 2018, p.102, 104; 2017, p. 80).[137]

[137] In 2017, it was not necessary to reconsider this Preferential Strategy, as it was 'on track'. Provided that maintenance with sand replenishments is continued, the coastal system will remain *up to par* for the next decades in terms of FRM goals (DP 2017, p. 81). However, under any new signals of potential acceleration in SLR, this may change; thus, at national level, further research will be conducted into SLR, climate scenarios, and their impact on coastal FRM, with consultations on the national Coastline Maintenance Programme (DP 2018 p.104).

6. WHAT ARE THE KEY-ELEMENTS OF THE ADM APPROACH APPLIED IN THE DP

In the light of the paradigm of Adaptive Planning, under deep uncertainty about future changes, a '*dynamic adaptive plan*' is needed, such plan must have *robust and adaptive policies* (strategies). Robust policies / strategies '*perform well under a wide range of plausible futures*', while adaptive policies / strategies '*can be adapted once the future unfolds differently than foreseen*' (Jeuken et al. 2014, p.2).

The DP devised and used Adaptive Delta Management (ADM) as its Adaptive Planning approach, and with the aim of designing strategies that were *robust* and *flexible*, and thus, *adaptive*. This section identifies the key elements of the ADM approach and the main ingredients that were essential to develop *adaptive strategies* in the DP and that make the DP an *adaptive programme* per se.[138]

Table 9 sums up the main elements of ADM that were essential to develop *adaptive strategies*. Then, this section describes how these elements were applied in practice in the DP, namely in the RE-D Subprogramme. This section builds on the prior analysis of the DP and on studies of other authors.

Table 9. Key-elements of the ADM approach developed and applied in the DP
Key-element 1: To consider and prepare for a wide range of *plausible future scenarios*, i.e. different climatic, physical and socioeconomic scenarios (rather than a single probabilistic projection of the future), and use them to assess the proposed measures and strategies (Jeuken et al. 2014, p. 1, 3, 10, 23; Walker et al. 2013, p.969; Jeuken and Reeder 2011). This element requires using a wide range of plausible future scenarios (diverse scenarios) to assess measures (actions) and strategies (pathways) (Jeuken et al. 2014, p.23, 1, 3). It is necessary to consider various plausible futures to assess what measures can be used to achieve the objectives regardless of how the future unfolds (Walker et al. 2013, p.970). In the DP, this element implied working with a bandwidth of 'plausible futures' so-called '*Delta Scenarios*' (DP 2011, p.48, 71; 2013, p.6).
Key-element 2: To identify 'Adaptation Tipping-points', i.e. conditions under which the current or an alternative measure fails (ceases to be effective / meet the objectives), or the current system performs unacceptably, and a new measure is needed (Walker et al. 2013, p.970; Jeuken et al. 2014, p.17; Jeuken and Reeder 2011; Zandvoort et al. 2018, p.190). In the DP, this element consisted of the identification of ATPs, i.e. conditions / points where the objectives of FRM policy (including coastal and river flood safety) are no longer met. This required analysing the vulnerability of the existing system as the starting point and examining 'what amount of change can the system handle before it runs into trouble' (Jeuken and Reeder 2011, p.3, 2).
Key-element 3: To develop and use a '*robust and flexible'* set of measures, to deal with change and uncertain future conditions, through the 'Adaptation Pathways approach' (APs) (Jeuken et al. 2014, p.23, 1, 3). This element consists of designing *robust flexible strategies* **(with measures / actions that are *robust* and / or *flexible*)**, by using the 'APs approach' (Jeuken and Reeder 2011, p.2; Restemeyer et al. 2017, p.921-922, 927, 935). It involves the development of a '*robust and flexible*' set of measures (with robust and flexible measures), and this requires considering the 'robustness' and 'flexibility', into the Plan and its measures, as well as the low-regrets' properties (Jeuken et al. 2014, p.1, 3, 23). In the DP, this element consisted of developing *robust flexible strategies* **(containing measures / actions that are *robust* and / or *flexible*)**, which was done by using the 'APs approach' (Jeuken and Reeder 2011, p.2; Restemeyer et al. 2017, p.921-922, 927, 935). A strategy can be deemed a set of measures, a pathway. In the DP, this key-element involved the development of '*adaptation paths*' in each of the Preferential Strategies and Delta Decisions (DP 2011, p.48; 2012, p.88, 81; 2013, 102; 2014). It required the design of a set of measures as '*adaptation paths':* each '*path'* is a pathway, a set of measures sequenced over time. The DP devised and applied its own adaptive planning approach – called *Adaptive Delta Management* (ADM). One of the main principles of ADM is '*working with multiple strategies between which it is possible to alternate*', which implies designing and using 'adaptation paths' (pathways) between which it is possible to switch depending on developments (DP 2011, p.48; 2012, p.88; 2013, p.102; 2014). Working with '*adaptation paths*' (pathways) is one of the principles of ADM, and one of the main elements necessary to develop *robust flexible strategies* (and, thus, *adaptive strategies*) and an adaptive programme. The ADM approach employs the method of 'Adaptation Pathways' (APs): the APs is defined as an '*approach for exploring and sequencing a set of possible actions based on alternative external developments over time*' (Haasnoot et al. 2012, p.485; 2013).
Key-element 4: to monitor changes and new information, reassess the plan in accordance, and, if necessary, adjust it (Jeuken et al. 2014, p.1, 23; Jeuken and Reeder 2011, p.7). In the DP, this element involves the monitoring of changes and new insights, and the reassessment of the plan - its strategies, measures, planned or applied - and, if necessary, its adjustment (e.g. switch of measure or strategy, or change its timing, if developments prompt so) (DP 2016, p.5, 59; 2017, p.7; 2014, p.7).
Key-element 5: the ongoing process of ADM (with its several steps) which involves planing, management, and adaptation, which is necessary to develop and implement a dynamic adaptive plan, and to operationalize a truly Adaptive Planning and Management.

Table 9. Main elements of the DP's ADM approach. Source: own elaboration based on several authors (Note 275).

[138] This section builds on the prior analysis of the DP, of ADM and its process (sections 3, 4, 5), and on studies that analysed the ADM application in the DP to extract essential elements of this approach (Jeuken and Reeder 2011), and on authors who identify the main elements an Adaptive Planning to then check if these are present in the DP (e.g. Jeuken et al. 2014; Restemeyer et al. 2017) (Note 275).

These five key-elements must be ensured to truly allow and operationalize an Adaptive Planning and Management, and they are embedded in the steps of the ADM process (Jeuken et al. 2014). The DP, and, especially the RE-D Subprogramme, contain these elements. These elements are explained next.

6.1. How these key-elements were applied in the DP, namely in the RE-D Subprogramme

Key-element #1

This element consisted of considering and preparing for and a wide range of climatic and socioeconomic scenarios and using them to assess measures and strategies (Jeuken et al. 2014, p.1, 3, 10, 14, 23).

ADM itself proposes the use of a spectrum of plausible future scenarios (Gersonius et al. 2016, p.4). It is necessary to work with various *plausible futures* (not predictions) to find and design '*robust flexible strategies*'. This required considering various scenarios when exploring measures and designing strategies (pathways) (Marchand and Ludwig 2014, p.12).

In the DP, all Subprogrammes worked with the same *plausible futures*: the four *Delta Scenarios* (*Rest, Warm, Busy, Steam*) (DP 2011, p.48, 71; 2013, p.6; 2012 p.35; Marchand and Ludwig 2014, p.12). These scenarios were generated by the scientific community, based on climatic and hydrological model calculations (Jeuken et al. 2014, p.11, 14). These scenarios address uncertainties about two issues: climate change (and its effects) and socioeconomic development (Bloemen et al. 2018):

- Regarding climate change, the DP decided to use the 'formal' Dutch climatic scenarios, which cover a large range of plausible futures but not high-end projections (these scenarios cover extreme flood events up to 1/10 000 years).[139] The main climatic parameters considered in the *Delta Scenarios* were SLR, storm surges, and river discharges. The Delta Scenarios present their figures for SLR, river discharges, and soil subsidence (Jeuken et al. 2014, p.10, 11).
- Regarding socioeconomic development, the Team generated scenarios for economic and population growth until 2100, and for land use until 2050 (Jeuken et al. 2014, p.13).

The *Delta Scenarios* are four different *plausible futures* (which describe a modest bandwidth of possible future developments, some developments may fall outside this bandwidth) (Brugge and Bruggeman).[140] The climatic scenarios are *plausible futures*, not most probable ones nor predictions (Jeuken and Reeder 2011, p.7). The DP did not assign any distribution of probability to these scenarios (DP 2014, p.138).

The Delta Scenarios served to assess possible future risks and impacts (Jeuken et al. 2014, p.10, 11; Alphen 2015, p.312; Brugge and Bruggeman, p.5; Haegen and Wieriks 2015), and support the development of the Delta Decisions and Preferential Strategies (Bloemen et al. 2018; DP 2014, p.136), namely of their *adaptation paths*. The various scenarios were used for the assessment of individual measures and strategies (Jeuken et al. 2014, p.10, 13), i.e. to test the performance of measures and strategies (*paths*) (Marchand and Ludwig 2014, p.12; Alphen 2015). The use of several scenarios played a key role in the design of *robust flexible strategies*, as it allowed the anticipation of future changes and the explicit consideration of uncertainties, assisted in identifying which measures must be taken in the short-term and which can be taken later (within a long-term strategy) (Marchand & Ludwig 2014). The *Delta Scenarios* also helped to explore the future and draw up a vision for it.

---

[139] Prior to the DP, the 2nd Delta Commission considered 'high-end' scenario of SLR of 1,3 m (Jeuken and Reeder 2011, p.7), however, it caused public debate, hence, when the DP was initiated, it was abandoned. Instead, the DP decided to use the formal Dutch climatic scenarios, which cover a large range of plausible futures but not high-end projections (Jeuken et al. 2014; Vink et al. 2013, p.97). Although worse / more extreme scenarios were available, the DP Staff decided to work with the Delta Scenarios (which are plausible scenarios) to develop the Strategies, and then the selected strategies were tested under more extreme scenarios (Restemeyer et al. 2017, p.930).

[140] For Jeuken et al., the DP worked with a moderate range of scenarios (Jeuken et al. 2014, p.1, 10-11).

Key-element #2

The 2nd key-element that can be highlighted in the ADM approach is the identification of Adaptation Tipping-Points (ATPs). The ADM approach utilizes the method of 'Adaptation Tipping-Points (ATPs) (developed by Kwadjik et al. 2010). In the ADM process (which is similar to the DAPP process), namely in the Sub-step 1b, it is necessary to identify external developments to which the objectives defined are most vulnerable to, by using scenarios (sub-step 1b). The sub-step 1b implies assessing '*what amount of change can the system handle, i.e. what is the critical level (ATP) before the objectives are not met anymore*', and examining 'when this might occur' in different future scenarios. ATPs are understood as critical levels that represent a threat to the objectives (Jeuken et al. 2014, p.5). In ADM, ATPs are a necessary to handle uncertainty about future changes and to ensure *adaptiveness* (Zandvoort et al. 2018).

In the DP, the identification of ATPs implied examining how vulnerable is the context / FRM system to climate change, how much climate change can it handle, and whether it is necessary to take new / additional measures because of climate change or socioeconomic developments (Jeuken and Reeder 2011, p.2). Hence, the vulnerability of the current system was the starting point of the analysis. To identify ATPs, it was necessary to analyse '*what (amount of) change can the system handle before it runs into trouble*' (Jeuken and Reeder 2011, p.3). In the DP, this question led to the identification of ATPs (i.e. points / conditions under which the existing management measures and policies, including FRM policy along the coast and rivers, are no longer able to meet the objectives), followed by the analysis of when these ATPs might be reached (Jeuken and Reeder 2011, p.3).[141] With the ATP method, planners could determine at which point in time new management measures are needed (ibid, p.4).

First, the DP Team sought to identify ATPs in the existing FRM system. To this end, it assessed technical and physical limits of the flood defence system, quantified its current overcapacity, and defined new design criteria based on this and on climate projections. The DP not only identified limits (thresholds) of the existing flood defence system, but also limits of the existing management measures and policies.[142] Then, various scenarios were used to determine the moment of an ATP (at earliest and at latest) and, thus the moment to adapt (to take a new measure) (Jeuken and Reeder 2011, p.6-7).

The DP identified adaption tipping-points (ATPs) by using the ATP method. In the DP, ATPs describe conditions under which the current or alternative management measures or policies might fail; ATPs are related with acceptable return periods for flood events and were translated into design criteria for the flood defence systems (in line with the DP's *risk-based approach*) (Jeuken et al. 2014, p.17).

ATPs played a key role in the phasing of the possible measures within each Strategy of the DP (in the sequencing and assembling of pathways) (Jeuken et al. 2014, p.17). The reaching of an ATP indicates that a new measure is required. The DP and the Subprogrammes first sought to identify ATP, and then analysed when these ATPs might occur (which involved examining the moment of ATPs for different FRM measures).[143] In the ADM process, the Sub-step 2b involves assessing the performance and effectiveness of each measure and determining its tipping-point.

---

141 Jeuken and Reeder (2011, p.4) define ATPs as '*points where the magnitude of change due to climate change or sea level rise is such that the current strategies will no longer be able to meet the objectives and alternative strategies are needed*'. The driver for taking measures is not climate change *per se* but being unable to meet objectives. Climate change is only one of the issues that may alter the date of an ATP, e.g. socioeconomic developments may also lead to earlier or later ATP (Jeuken and Reeder 2011, p.4).

142 When the DP was initiated, the Netherlands already had FRM and FS policies / plans for long-term in place, e.g. the 'Room for the River', the 'Coastal Defence Strategy', and the 'Water Management Programme for the 21st century (WB21)'. These policies and their measures had to be taken into account by the DP when assessing thresholds (Jeuken and Reeder 2011, p.7).

143 Scenarios were also used to determine moment to take a decision (so-called 'decision-point'), taking into account the lead-time required for planning and implementing a measure and its complexity. The 'decision-point' is reached earlier than the ATP (Jeuken and Reeder 2011, p.6). The decision-moments and implementation-moments will depend on the ATPs of measures, but also on earlier opportunities to combine measures with other objectives, investments, and agendas (Jeuken and Reeder 2011, p.5).

Key-element #3

The 3rd key element of an Adaptive Planning approach consists of developing a '*robust and flexible*' set of measures, to deal with uncertain future change, through the method of 'Adaptation Pathways' (APs) (Jeuken et al. 2014, p.23, 1, 3; Jeuken and Reeder 2011, p.2; Restemeyer et al. 2017, p.921-922, 927, 935). This element implies the development of a '*robust and flexible*' set of measures – i.e. '*robust flexible' strategies* – by using the 'APs approach' (Haasnoot et al. 2012, 2013).

In the light of the paradigm of Adaptive Planning, under deep uncertainty about future changes, a planner must develop a '*dynamic adaptive plan/policy*'. Such plan must be: '*robust'* (the plan and its strategies '*perform well under a wide range of plausible futures'*) and '*adaptive*' (the plan and its strategies '*can be adapted once the future unfolds differently than foreseen'*) (Jeuken et al. 2014, p.2). According to Jeuken et al., one of the core elements of an Adaptive Planning approach consists of using a '*robust and flexible*' set of measures (with measures that are 'robust' and / or 'flexible') to deal with uncertain future changes (Jeuken et al. 2014, p.23, 1, 3). In an *Adaptive Planning approach,* measures (actions) must be effective under the widest range of plausible future scenarios, and measures should not foreclose or unnecessarily constrain possible future options (Jeuken et al. 2014, p.3; Sayers et al. 2012). Measures should also be '*low/no-regrets'* as much as possible (with properties like robustness, flexibility, reversibility, adaptability, etc.) (Jeuken et al. 2014, p.3).

The development of a *robust and flexible* set of measures implies considering and safeguarding 'robustness', 'flexibility', low-regrets' properties, when choosing measures and developing strategies. It is important to include robustness, flexibility, and low-regret, in measures or their set. This implies choosing measures that remain flexible in relation to changing and uncertain future conditions and / or measures that create a robust system able to deal with extreme events (Jeuken et al. 2014, p.3, 10).

Restemeyer et al. claim that one of the main ingredients / conditions necessary for making long-term policies / plans 'more *adaptive*' is the elaboration of *flexible strategies*[144], and this implies: working with scenarios, the identification of tipping-points, and the design of adaptation pathways (which requires ordering various possible measures in time) (Restemeyer et al. 2017, p.921, 927, 935). In the same line of thought, Jeuken and Reeder note that a key element of the Adaptive Planning approach applied in the DP (i.e. ADM) was the development of *flexible strategies* (Jeuken and Reeder 2011, p.2-3), which was done by using the 'APs approach'.

To develop the Preferential Strategies, the DP applied the ADM approach, and ADM itself uses the 'APs approach' (Jeuken and Reeder 2011, p.6). In its process, ADM includes and employs the 'Adaptation Pathways approach' (APs) (Haasnoot et al. 2012, 2013) – the 3rd step of the ADM process is the development of adaptation pathways and APs' map. The APs is a methodological '*approach for exploring and sequencing a set of possible actions* (i.e. a set of possible measures) *based on alternative external developments over time*' (Haasnoot et al. 2012, p.485); it is one of the Adaptive Planning approaches (Haasnoot et al. 2012, 2013; Walker et al. 2013). The 'APs approach' that was applied in the DP (as part of the ADM approach) was inspired by the 'Route-map / APs approach' created by the TE2100 Project (as part of its *Dynamic Adaptive Planning approach*) (Jeuken and Reeder 2011, p.6).

Importantly, one the main elements of the ADM approach applied in the DP was the development of '*adaptation paths*' (DP 2011, p.48; 2012, p.88, 81; 2013, p.102; 2014), i.e. the design of pathways (as sets of sequenced measures) that together provide a general *adaptive strategy* (Haegen & Wieriks 2015).

---

[144] Restemeyer et al. propose 3 theoretically-defined conditions to make long-term FRM policy / plan more *adaptive*: (a) *an agile governance process* with a learning-oriented governance arrangement and *capacity to adjust based on new insights*; (b) the elaboration of flexible strategies (which requires designing APs), (c) the prioritisation of measures that avoid lock-ins (Restemeyer et al. 2017, p.935) (Note 275).

As seen, '*working with multiple strategies between which it is possible to alternate, i.e. working with adaptation paths*' is one of the principles of ADM, but also an essential element to design an *adaptive strategies* and to make the Programme *adaptable*. The 'ADM Implementation Guide' mentioned that strategies should be simultaneously *robust* and *flexible* (*in* Restemeyer et al. 2017, p.930). To develop such *robust flexible strategies*, the DP used the APs' method: the APs served to develop *robust flexible strategies* (Jeuken and Reeder 2011, p.6). In the DP, a Strategy contains a set of measures sequenced over time, i.e. a pathway. The adaptation pathways are called '*adaptation paths*'. Each *Preferential Strategy* has a map with 'adaptation path(s)' (one or more). Each *adaptation path* (pathway) is a set of (a sequence of) several sequenced measures over time.

In the DP, the robustness and flexibility of the Strategies were safeguarded by using the 'APs method'. The maps of APs identify the possible measures available, including options for switching in the future, as well as potential 'decision-moments' (Jeuken et al. 2014, p.10). With the 'APs approach', the Teams could envision alternative measures and possibilities for switching between them through adaptation pathways, and short-term measures are linked to long-term possible alternatives (options) (Jeuken et al. 2014, p.1). The *adaptation paths* were created by putting the first measures and the long-term possible options in a logical chronological order (DP 2012, p.61).

The 'APs method' served to explore possible measures and options, and possibilities for switching from one option to another in the future, and, in this way, remain flexible. This contributed to enhance the flexibility of the general Strategy. By using the APs, it was possible develop a '*robust and flexible*' set of measures (or, more precisely, sets) as *adaptation pathways*. The maps of adaptation pathways show the measures available and when it is necessary to switch of measure (Jeuken et al. 2014, p.10).

The design of the pathways implied the analysis of Adaptation Tipping-Points (ATPs, conditions under which the current or other management / policy measure fails, and a new measure is required). ATPs were essential in the phasing of the possible measures in each Strategy: consecutive measures were sequenced into pathways that show short-term measures chained with long-term options (Jeuken et al. 2014, p.17). Thus, this key element is related with the 2nd element of ADM (the identification of ATPs). To design the pathways, the 'ATPs method' was applied: once an ATP is in sight, a new measure is needed (Haegen and Wieriks 2015, p.51).

In an Adaptive Planning approach, *flexibility* should be a characteristic of the general plan / strategy, which enables it to deal with uncertain future changes (Jeuken et al. 2014, p.16). In the DP, the flexibility of each Strategy was ensured or increased in the following ways:

- **By having several possible measures and pathways available.** In the DP, each Strategy has a pathway (one or more), and it is possible to switch from a measure to another (or from a pathway to another) (Jeuken et al. 2014, p.24). The Strategies of the DP usually contain several pathways and allow the switching between different options in the future (Jeuken et al. 2014, p.18). For instance, in the Preferential Strategy for the RE-D, by using and switching between '*more dyke reinforcements'* and '*river widening'*, it will be possible to cope with the projected climate change (actually, both measures are part of the current strategy). Moreover, the DP defined measures required now to keep options open, e.g. *spatial reservations* necessary to keep '*river widening'* measures open for a long time (Jeuken et al. 2014, p.18). The *Preferential Strategies* show what pathway(s) may be followed, i.e. the possible *paths*. The pathways show diverse measures and *options ahead*, including the measures to be taken first (Jeuken and Reeder 2011, p.6).

  In each Preferential Strategy, there is a map of *adaptation paths* (pathways) that shows what measures can be taken and when a change of measure or pathway is necessary (Alphen 2015, p.313). As the lifetime of many defences comes closer (many are expected to reach the end of their technical life in the coming years), it will be necessary to implement new / additional measures, and the APs' map shows the measures available (ibid). The 'APs method' *allows for switching between measures along the pathways when needed in view of socioeconomic developments or climate change*' (Haegen and Wieriks 2015, p.56, 50, 54). Adaptation pathways are successions of measures into the future in a changing environment. The APs' map shows a range of possible measures (options) from which a decisionmaker can choose (ibid, p.50). ADM requires the design of *adaptation pathways*, and this implied the identification of various possible measures as *strategic alternatives* (Werners et al. 2016).

- **Through a stepwise implementation of several measures and keeping the possibility to switch to other measures**. The flexibility of a plan / strategy can be increased *'if measures can be implemented stepwise, or if there is the possibility of switching to other measures*' (Jeuken et al. 2014, p.18). A phased implementation of various small projects is also one way of increasing robustness (Jeuken et al. 2014, p.15). The APs method *per se* involves a stepwise implementation of various FRM / adaptation measures, and it seeks to keep the possibility to switch to other measures in the future (Jeuken et al. 2014, p.18). However, in the DP, the flexibility of some Strategies was, in part, limited by the lifetime and nature of past measures, namely flood defence structures that are implemented for many decades (e.g. barriers). In addition, measures appropriate to be implemented in small steps – e.g. 'river widening', soft protection measures (like coastal sand nourishments), flood-proofing measures – only contributed partially to the Preferential Strategy for the RE-D. This Strategy mainly consists of measures to improve the existing flood defences (e.g. barriers, dykes). Yet, the *adaptation path* seems flexible in the future because new large-scale structural measures could be postponed (Jeuken et al. 2014, p.18).

  To devise flexible strategies (and deal with uncertainty), it is necessary to '*envision and link possible short-term decisions and long-term options for adaptation and their timing*' (Jeuken et al. 2014, p.17). In the DP's Strategies, short-term measures are linked to long-term options, through adaptation pathways, which explicitly show ATPs and when it is necessary to decide to switch from one measure to another (Jeuken et al. 2014, p.24). Flexibility also means that decisions and measures planned for the near future should not foreclose future options (to act differently, switch of, or add measures) if climatic or societal changes require so (Jeuken et al. 2014, p.16). It is also important to ensure that external developments in the short-term do not foreclose future adaptation options (ibid). The development of *flexible strategies* implies finding (flexible) measures that do not block further measures that may be necessary in the future and avoiding irreversible measures as far as possible (Jeuken and Reeder 2011, p.2). An 'adaptive way of planning' requires '*maximizing flexibility'* by '*keeping options open and avoiding lock-ins*' (Alphen 2015, p.310).[145]

- **It is possible to alter the timing for implementing a measure**. In the 'APs approach', a measure can be postponed or advanced in time, as conditions change and new information emerges. In the 'APs method', flexibility is related with: (a) the possibility (flexibility) to switch to other measures or pathways when needed, in face of uncertain future developments, and thus, with the availability of other possible measures; and (b) flexibility in relation to the timing of implementation of measures (the possibility of altering the moment for implementing a measure) (Haegen and Wieriks 2015, p.54, 56, 48; Alphen 2013 *in* Zevenbergen et al. 2018; Zandvoort et al. 2018, p.191). The DP sought to ensure that the chosen strategies and measures provide flexibility to respond to new insights and

[145] The Preferential Strategies include possible options for the long-term, some may not be required after 2050 but are included anyway as an 'option'. E.g. until 2050, the DP intends to gradually adapt the existing FRM system to changing conditions (SLR, increasing river discharges). This implies gradual changes in the system, e.g. in the management, maintenance and replacement of defence structures, in spatial organization, and in specific sectors (shipping, agriculture). After 2050, larger-scale interventions in the system will be required, which will be carried out according to the then-existing climatic and socioeconomic conditions. A final decision on the post-2050 measures was not taken in 2014, but preparations were made for the case such measures are necessary. This required anticipating long-term conditions (DP2013, p.102).

changes, in terms of '*stepping up measures*' or 'changing strategy' if necessary (DP 2014, p.6). The DP also aimed at ensuring a robust FRM system, hence, it should be prepared for various scenarios and able to '*withstand the (greater) climatic extremes in a resilient manner*' (DP 2014, p.6).

- **By using a variety of measures**. A large heterogeneity of measures, and some 'planned redundancy' in solutions, help to increase the robustness and resilience of the FRM system (the risk of failure is distributed over many elements of the system, thus, if one solution fails, the whole system does not fail) (Jeuken et al. 2014, p.15). The Dutch philosophy on FRM has widened with the introduction of the ML FRM, leading to greater *flexibility* and robustness (Haegen and Wieriks 2015).
- **By taking low-/no-regrets measures first**. In the implementation of an *adaptive plan*, decisions in the short-term should be used to implement first 'low-regret actions' (Jeuken et al. 2018, p.19). Having the long-term vision in mind, the DP sought to prioritize no-regret actions (and s*cenario analysis* was useful to assess the robustness of measures under various scenarios) (Marchand and Ludwig 2014, p.2,11). In the DP, often, the first measures (in near-future) are measures that are worthwhile in any scenario, i.e. 'no-/ low-regret' measures (DP 2012, p.88). ADM seeks to avoid over- and under-investments, and insight into pathways was useful for this.[146] Prioritizing measures that prevent lock-ins is a condition for making a strategy more 'adaptive' (Restemeyer et al. 2017). The APs' map also helps to identify 'lock-ins' and how they can be avoided (Alphen 2015, p.313).
- **By combining agendas, and mainstreaming climate adaptation into decisions and investments in the short-term.** The identification of opportunities to combine the measures envisioned with other agendas and multi-objective investments was one way of increasing flexibility of the Strategies (Jeuken et al. 2014, p.1, 19; DP 2011, p.48). In the DP, long-term climate adaptation needs were considered in short-term decisions, e.g. in the definition of the new flood protection standards. In areas where dykes need to be reinforced for maintenance, the projected water level rise associated with climate change must be considered in the design; works to increase the sluice capacity for shipping must provide an extra drainage capacity (Jeuken et al. 2014). The DP sought to ensure the integration of objectives (FRM and FS, integrated with spatial planning, spatial adaptation, and nature conservation) (Jeuken and Reeder 2011). It also sought to link short-term decisions to long-term goals and to ensure the integration of agendas (in accordance with the 1st and 4th principles of ADM). The combination of measures with other objectives (through e.g. multifunctional flood defences) helps to increase public acceptance of measures and reduce costs (brings added value), but implies the synchronization of different investment agendas, new technical requirements for designing and maintaining defences, and multi-actor arrangements (Alphen 2015).
- **Inclusion of measures that are flexible and / or robust**. Adaptive strategies can benefit if they include *flexible measures*, i.e. measures that are '*easy to alter, speed up or slow down depending on the measured climate change*' (e.g. nature-based measures like beach nourishment, or vegetated foreshores in front of defences, are more flexible than 'fixed' hard defences). In other cases, it may be preferable to use *robust measures* (that can deal with high-end scenarios), namely where *'the cost of adjusting a measure later is high compared to a more robust initial design*' (Alphen 2015, p.313).

These aspects contributed to safeguard the robustness and flexibility of Strategies. In this sense, they can be deemed sub-elements of the 3rd key-element of an Adaptive Planning and Management approach (the development of *a robust and flexible set of actions*, through the 'APs method').

[146] One way of reducing the risk of over-investment is to delay a measure until more knowledge is available (a hurried implementation reduces the possibility of including new knowledge). However, it also important to avoid taking measures too late (under-investment). The lead-time required to plan and implement measures must be considered, in order to avoid under- and over-investments (Marchand and Ludwig 2014).

The APs' approach also served to identify *decision-moments* (Jeuken and Reeder 2011, p.6; Jeuken et al. 2014, p.10). In the DP, the moment for implementing a new measure and the associated *decision-moment* not only depend on thresholds and ATPs of prior measures, but also on opportunities to combine such measure with other investments (thematically and spatially), e.g. dyke reinforcements combined with urban projects, and on the lead-time required to plan and design the measure and its complexity (the *decision-moment* occurs prior to the ATP) (Jeuken and Reeder 2011, p.6-7).

ADM utilizes the APs method as a '*flexible, adaptive approach*' for designing strategies under plausible future scenarios, which '*allows for switching between measures along the pathways*' if necessary, '*in view of socioeconomic developments or climate change*' (Haegen and Wieriks 2015, p.56, 50, 54). A key step of the ADM process was '*to develop a set of measures along adaptive pathways*' (ibid, p.55).

In synthesis, in the DP, the strategy-making was based on the ADM approach. ADM builds on an important element to develop strategies: the *construction of pathways*. ADM, and the design of pathways, also require the assessment of the flexibility of measures and pathways, the scanning of options to keep open, and the combination of measures with investments and agendas of diverse actors (Zandvoort et al. 2018, p.190). These aspects are patent in the DP's Strategies for FRM.
As noted by Restemeyer et al. one of the main conditions for making a policy plan '*adaptive*' is the elaboration of *flexible* strategies, which, in turn, implies working with scenarios, identifying tipping-points, and designing adaptation pathways (by ordering various possible measures in time) (Restemeyer et al. 2017, p.921, 927, 935). ADM explicitly utilizes Scenarios, Tipping-points, and Adaptation Pathways, to make strategies *'more robust and flexible'* (Restemeyer et al. 2017, p.935, 931).[147]

Key-element #4
Other key element of an Adaptive Planning approach consists of monitoring relevant changes and new information and reassessing the Plan in accordance, which allows the adjustment / adaptation of the Plan (its strategies or measures) (Jeuken et al. 2014, p.1, 3, 10, 23). The monitoring and reassessment system should be accounted for in the Plan itself. The evolution of climatic, physical c and socioeconomic changes / developments, and the progress of scientific insights, must be carefully monitored, to evaluate if measures should be taken earlier or postponed (Jeuken and Reeder 2011, p.7).

This element is present in the DP and its ADM approach: ADM requires the monitoring of changes or developments and effects of measures, and the reassessment/review of the Plan (its strategies, or measures, planned or implemented), and their adjustment if changes prompt so (DP 2016, p.59). The DP has defined its own monitoring and evaluation system – the MAA system. The MAA systems specifies the indicators that must be monitored (to keep track of external changes, of the implementation and effects of measures, and new information), and it explains how the DP (its Preferential Strategies, Delta Decisions, Delta Plans, and their measures) must be reassessed and, if necessary, adjusted. This system will allow regularly evaluating if the work is being done *at the right pace and in the proper direction*, and adjusting the course if necessary, as changes occur or new knowledge arise (DP 2017, p.7; 2018, p.13; 2016, p.5). The MAA is essential to ensure a truly *Adaptive Planning and Management*.

In the face of the uncertainty about future changes (e.g. climate change, variability of climatic processes and extremes), ADM implies a regular reassessment of strategies and measures. The DP has also used the MAA system to evaluate results in relation to predefined goals (in ADM, goals tend to be seen as unchangeable, though the natural system is complex and dynamic) (Zandvoort et al. 2018, p.190).

---

[147] However, for these authors, the Preferential Strategy of the RE-D looks quite '*determined and not so flexible'*: it offers little room for adjustments over time, and it focusses mainly on 'prevention' through a *gradual adjustment* of the existing defences. Although the Team recognized the need for spatial adaptation measures in addition to the traditional preventive measures, in this Strategy, '*adaptability mainly gets down to gradual adjustments of certain measures*', e.g. dyke strengthening (Restemeyer et al.2017, p.932, 934-9355).

BOX 9. Since 2015, the MAA has been used to monitor developments that may affect the pace or direction (course) of the Preferential Strategies, and to evaluate if the DP is 'on track' or if it is necessary to adjust the course or pace, or reconsider targets or measures (e.g. if developments demand a switch of strategy or measures, or a modification in their timing) (DP 2017, p.8, 17). Moreover, the DP will carry a review every 6 years to check, based on monitoring results, if it is necessary to maintain or adjust the course or the pace (i.e. the measures or their timing) (DP 2016, p.6). Based on new knowledge and monitoring, the strategies and / or their measures may be anticipated or postponed, or adjusted in terms of scope and design (DP 2014, p.136).

ADM requires the monitoring of effects and changes, and, based on it, the regular evaluation of the strategies followed (and new insights must be used in this revaluation). As noted by Petersen and Bloemen, ADM is based on an approach of *Planned Adaptation* that implies two components in a policy-making process: commitment to submit the plan to ongoing revaluation, and systematic effort to use new information in that revaluation. A policy programme should *'plan for future changes in knowledge, by producing new knowledge and revising rules at regular intervals*' (Petersen and Bloemen 2015).

An essential ingredient to make a long-term FRM policy / plan more 'adaptive' is '*an agile governance process*' that ensures the '*capacity to adjust based on new insights*' and learning-oriented governance arrangements (Restemeyer et al. 2017, p.922, 935). To ensure the *adaptability* of the plan, a sound monitoring and learning system must be in place, and evaluate external developments and existing practices and detect moments when the strategies must be adjusted. It is important to clarify *what to monitor, with whom to discuss the results* and *when to take action* (Restemeyer et al. 2017).[148]

From 2015 onwards, the DP has gained experience on monitoring and reassessment [149]. Since then, the DP has clarified what should happen if its underlying assumptions change and how to establish feedbacks between the monitoring system and the learning required for policy adjustment (Note 276).

Key-element #5

The 5th main element of the ADM approach corresponds to its ongoing process of (adaptive) planning, management and adaptation, with its several steps necessary to develop a *dynamic adaptive plan / programme* and operationalize a continuous cycle of *Adaptive Planning and Management*. The ADM process includes 6 main steps. The first four key-elements are patent in the methods used in the steps of the ADM process (Marchand and Ludwig 2014, p.3,10). The DP's adaptive approach implies *flexibility* to switch to other measures or pathways, if necessary, as well as *adaptive capacity* (Haegen and Wieriks 2015, p.53).[150] This demands an ongoing process of adaptation planning, monitoring and adjustment (Gersonius et al. 2016, p.14).

In sum, the main elements / 'building-blocks' of the ADM approach are: to work with several plausible future scenarios; the develop and use a '*robust and flexible*' set of measures (i.e. *robust flexible strategies*) which requires the identification of tipping-points and the design of adaptation pathways; the monitoring of relevant changes and the revaluation of Strategies and their adaptation if necessary; and the ongoing process of steps required to achieve an Adaptive Planning and Management. Moreover, a continual investment in FRM and '*sufficient financial resources are a condition for a dynamic implementation of the DP* (DP 2013, p.120; 2014, p.120) (Note 277).

[148] The monitoring and revaluation system should be institutionalized, to increase the adaptability of the Plan and Government control. This system must regularly review, and, if necessary, update the DP's assumptions and other policy instruments. This implies ways of incorporating monitoring results and learnings into the planning and management process (preferably before reassessing Strategies) (Restemeyer et al. 2017).

[149] Importantly, prior to the MAA system, there was already a monitoring system for evaluating national water policies (Jeuken et al. 2014, p.22). Moreover, the law already defined that the condition of dykes and dunes must be checked every 6 years against projected water levels, storm surge conditions and predefined criteria (e.g. on the strength and height required). If dykes and dunes fail to meet these criteria, they must be improved considering the necessary robustness for the next 50 years. In the coast, more or less sand must be nourished depending on the results of monitoring of the coastline position. In this case, thresholds are 'a moving target': they can vary over time depending on several aspects (claims on space available, public acceptance of measures, costs, non-quantifiable aspects) (Jeuken and Reeder 2011, p.8) (Note 276).

[150] Flexibility (capacity to be flexible) may be *flexibility* to switch to other strategies when needed, in the face of uncertain future changes, it has elements of experimentation and learning. Adaptive capacity refers to capacities, attributes, and resources to undertake adaptation; it concerns the ability to anticipate, innovate and generate experience in dealing with change and learn from mistakes (Haegen and Wieriks 2015).

6.2. How the Programme is '*adaptive*'

The DP is deemed an *adaptive programme*, able to deal with under uncertain future change. The DP itself, and several studies, have explained how the Programme is adaptive, and how it conceptualizes and operationalizes 'adaptiveness' to deal with uncertainty and change. Table 10 sums up the main characteristics that make it an *adaptable* programme and the ways through which it can be adapted (its 'tools' to deal with uncertainty about the future and change). This table builds on the prior in- analysis of the DP reports (from 2010 to 2018) and on prior studies that examined the DP case (e.g. Zandvoort et al. 2018[151]; Brugge and Bruggeman; Zevenbergen et al. 2018, based on Alphen 2013).

Table 10. How the DP and its strategies are *adaptive*; how ADM delivers *adaptiveness* and *flexibility*

ADM's tools to deal with uncertainty and ensure adaptiveness: ATPs + APs	ADM primarily seeks to deal with deep uncertainties about future changes and conditions (Zandvoort et al. 2018, p.190-195; Brugge and Bruggeman, p.1), namely unknown future developments, e.g. climatic and socioeconomic changes. To deal with uncertain future change, ADM uses an *anticipatory adaptive planning*. Adaptiveness is seen as proactively adapting to possible changes through deliberate anticipation. It seeks to better deal with uncertainty about the future and ameliorate the lack of predictive capacity (Zandvoort et al. 2018) (Note 279). ADM uses two main methods to deal with uncertain future change, and to plan future adaptations: ATPs and APs (Zandvoort et al. 2018, p.183-194). ATPs are key in handling uncertainty about future change and required to ensure *adaptiveness*. ATPs make uncertainty more explicit, e.g. about the timing for a measure (ibid, p.190).
Having one or more *paths* available; having alternative measures available (a *path* is a *sequence* of possible measures / actions)	The central idea of ADM is developing diverse trajectories that the dynamic system may follow as time unfolds – i.e. pathways. *Flexibility* is ensured through Adaptation Pathways that are planned now (in anticipation) to deal with future changes (Zandvoort et al. 2018, p.190, 189). ADM '***leads to a composite strategy, or a set of alternative strategies with intermediate possibilities for revisions***' (Rhee 2012, p.14 *in* Zandvoort et al.2018); its main outcome is a set of pathways that identifies the measures available and schedules them according to uncertain drivers of change. In ADM, adaptiveness is related with: having (the availability of) different trajectories that can be applied to achieve long-term goals, in different plausible scenarios, depending on developments over time (Zandvoort et al. 2018, p.191). This required using the 'APs method', i.e.: devising possible measures, assessing their effectiveness in different plausible scenarios, and based on ATPs, designing possible pathways. A pathway is a sequence of actions over time to achieve the defined objectives (Haasnoot 2013, *in* Marchand and Ludwig 2014, p.2, 13). In the DP, a Strategy usually contains several pathways and allows switching between different measures (options) in the future (Jeuken et al. 2014, p.18). The APs allow for switching between measures along the pathways, if needed, in view of climatic or socioeconomic changes; the map shows the options available (Haegen and Wieriks 2015).
Flexibility to switch of measure or *path* (allow switching from a measure, or pathway, to another), + Flexibility to alter the timing	The DP adopted a flexible adaptive approach regarding the possible strategies and measures. Flexibility is valued in terms of: (1) allowing the switching between measures (or pathways), through Adaptation Pathways (i.e. the possibility to switch to other measures or pathways when needed, in face of uncertain future changes) (2) the possibility of altering the timing for implementing measures (Alphen 2013 *in* Zevenbergen et al. 2018; Zandvoort et al. 2018, p. 191; Haegen and Wieriks 2015). The DP sought to ensure that the chosen strategies and measures provide flexibility to respond to new insights and changes, in terms of 'stepping up measures' and / or 'changing strategy' if necessary (DP 2014, p.6). In ADM, a Strategy must be flexible in terms of: the possibility of alternating of measure or pathway (trajectory). Flexibility also refers to the possibility to alter the course if an ATP of the current measure (or a given measure) comes earlier than expected (Zandvoort et al. 2018, p.191), i.e. the flexibility to deliberately choose a different measure or pathway. A flexible approach allows the switching between strategies through APs (Zevenbergen et al. 2018). This implies having the possibility (*options*) for switching between strategies (DP 2013, p.77). ADM aims to ensure flexibility. The 'APs method' delivers flexibility in terms of having alternative measures and the possibility to switch from a measure, or pathway, to another, if developments and changes prompt so.
Flexibility to alter the timing for implementing measures	In ADM, a strategy should also be flexible in terms of timing, i.e. allow the possibility to postpone or advance a measure in time (Zandvoort et al. 2018, p.191). This means flexibility to alter the timing for implementing a measure (Alphen 2013, *in* Zevenbergen et al. 2018). ADM seeks to *take the right measures at the right moment* (when they are really needed to achieve the desired objectives). Adaptiveness and flexibility are related with the possibility to modify a decision about the timing for a measure (Zandvoort et al. 2018, p.191).

151 Zandvoort et al. (2018) analysed how adaptiveness is operationalized in ADM (Note 278). For the authors, ADM uses two types of adaptiveness: *adaptive planning* and *adaptive capacity*. Adaptive planning requires preparing short-term measures considering long-term effects and avoiding lock-ins/-outs; which implied assessing measures under different scenarios and identifying those with greater cost-benefit in the long-term. Adaptive capacity of the managed system can be enhanced by enlarging the decision space (which increases flexibility); this implies *keeping options open* / possibilities of altering the course. These types of adaptiveness are related: one enables the other (ibid, p.191).

Keeping options open / not foreclosing options; stepwise implementation of measures	In ADM, adaptiveness is also related with *keeping options open*, i.e. enlarging the decision space, which enhances flexibility and creates adaptiveness to handle *currently unknown future changes* (Zandvoort et al.2018, p.191). 'Keeping options open' means 'having possibilities of altering the course'. It implies keeping the possibility to switch to other measures, and a stepwise implementation of various measures – both contribute to increase flexibility (*dynamic robustness*) (Jeuken et al. 2014, p.18; Alphen 2015, p.310). It involves '*not foreclosing future options to react differently and switch or add actions if climate or societal changes ask for it*' (Jeuken et al. 2014, p.16), which implies finding measures that do not block further measures that may be necessary in the future (Jeuken and Reeder 2011, p.2). The DP specified measures needed to keep options open for the future, e.g. 'spatial reservations' required to keep 'river widening' measures open for a long time (Jeuken et al. 2014, p.18).
Having various measures available / alternatives Variety of measures + Multi-layer FRM approach	The DP sought to ensure that it has '*potential measures at hand'* should conditions change faster than expected, and that it has '*sufficient elbow* room for them' (DP 2014, p.150, 9). The design of adaptation pathways implied the identification of various possible measures as *strategic alternatives* (Werners et al. 2016). The DP envisioned diverse types of FRM measures, namely: classic 'dyke improvements', 'room for the river', spatial adaptation, and disaster management measures. The choice of measures depended on local conditions, and on the effectiveness, costs and benefits of the measures. Measures were customised per area and sub-area of each Subprogramme. The DP used the 'Multi-layered FRM concept', which relies on 3 layers: 1) flood prevention measures, 2) spatial planning-related measures; and 3) disaster management measures. These measures can be used in a combined way (DP 2013, p.8). The Dutch approach to FRM widened with the introduction of the ML FRM, leading to greater flexibility (Haegen and Wieriks 2015). Adaptiveness is also related with the adequacy of measures and strategies to their context, which implied assessing them under the physical, socioeconomic, and institutional conditions (Zandvoort et al. 2018, p.191).
Using measures that are themselves flexible and / or robust	Adaptiveness and flexibility are also related with using measures that allow their future adjustment, e.g. design a defence with the possibility to heighten it to deal with future flood levels (Zandvoort et al. 2018, p.191). The DP sought to ensure flexibility in its measures, e.g. in coastal areas, it was used a flexible strategy based on sand replenishments and a '*learning as we go*' approach involving pilot projects. In areas around major rivers, the DP defined spatial reservations for river-widening measures. In other areas, a strategy based on dykes was chosen (with the new standards', it is expected that a major intervention will be needed in the mid-/long-term – an '*extensive dyke improvement programme*' that will take several decades) (DP 2013, p.103-104). Some Strategies include '*flexible measures'*, i.e. measures that are '*easy to alter, speed up or slow down depending on the measured climate change*', such as nature-based measures (e.g. beach nourishment). In other cases, *robust measures* (measures that can deal with high-end scenarios) were selected (Alphen 2015, p.313).
Low-regrets actions first	In the DP's strategies, the first measures for the near-future are often *low- / no-regret actions* – i.e. actions that are worthwhile in any scenario (DP 2012, p.88; Marchand and Ludwig 2014, p.2,11; Jeuken et al. 2014, p.19). This is also related with avoiding irreversible investments as far as possible (Jeuken and Reeder 2011, p.2).
Avoidance of lock-ins / lock-outs	Flexibility is also related with avoiding lock-ins and lock-outs (Zandvoort et al. 2018; Alphen 2015, p.310). ADM seeks to avoid lock-ins. In ADM, planners make short-term decisions and interventions taking into consideration their possible long-term effects on the system (Zandvoort et al. 2018, p.191, 194, 183). To avoid lock-ins, the DP identified spatial adaptation measures in addition to the traditional prevention measures (Restemeyer et al.2017).
Allow the adjustment of the Strategies devised, through the monitoring and revaluation system	A flexible approach (that allows the switching between strategies) requires ongoing monitoring and evaluation. ADM implies clear goals with corresponding indicators and thresholds to evaluate the performance of system's components. Flexibility also depends on the '*capacity (…) to learn from the arrival of new information and (…) ability to revise investment decisions based upon that learning'* (Alphen 2013, *in* Zevenbergen et al. 2018). ADM requires an ongoing monitoring of drivers of change, and the regular reassessment of strategies and measures. The monitoring system keeps track of changes and detect ATPs in a useful timescale. The DP's *monitoring and revaluation* system specifies the variables to be monitored to allow a timely adaptation of the strategies (their measures, or timing). Adaptiveness is patent in this system and in the yearly updated DP reports (Zandvoort et al. 2018, p.191-192). The DP's approach is 'flexible' since it allows the adjustment (adaptation) of a strategy to changing conditions or new insights that may arise (e.g. climate change) (Jeuken and Reeder 2011).
Linking measures with other investments / agendas; mainstreaming adaptation; Integrated approach, institutional embedding	To operationalize ADM, the DP sought to interlink diverse investment agendas and seize opportunities to mainstream FRM measures into other investments (e.g. in urban development, nature restoration). ADM calls for *adaptive integrated* strategies that logically combine investment decisions in areas marked by uncertainty and multi-scalar complexity. By merging various investment agendas and mainstreaming adaptation into planned investments, ADM generates added value (Zevenbergen et al. 2018; Alphen 2013). The combination of proposed measures with other agendas and multi-objective investments increases flexibility and reduces costs (Jeuken et al. 2014, p.1, 19; DP 2011, p.48; Jeuken and Reeder 2011; Alphen 2015). The DP sought to ensure an *integrated* delivery of policies (to enhance legitimacy and feasibility) (Zevenbergen et al. 2018). The DP indicates which and how measures can be connected to other investments and agendas in other fields (e.g. infrastructure, industry, etc.) (DP 2017, p.22). Flexibility implies seizing opportunities to couple or integrate the proposed FRM measures with other investments or agendas (Zandvoort et al. 2018, p.191,189). ADM also explains how the Strategies should be embedded into existing institutional structures (ibid, p.194).

Table 10. The main ways through which the DP's strategies are adaptive. Source: own elaboration, based on several authors.

7. Effects and outcomes of the Delta Programme

7.1. Positive outcomes, advantages, and added value, of the ADM approach (with the APs method)

ADM and thinking in adaptation pathways were core values of the DP which changed FRM (Bloemen et al. 2018). The adoption of ADM, and particularly of the APs method, allowed a more flexible and adaptive approach regarding the possible measures, strategies, and their timing (Haegen and Wieriks 2015). The development of *adaptation paths* contributed to ensure flexibility: the pathways can be accelerated / slowed down or adjusted (e.g. by shifting from a measure to another), and options are kept open for the future (Gersonius et al. 2016 p.12).

The application of ADM, especially of the ATP method and APs method, brought positive results:

- Working with APs facilitated making choices in areas where measures were already needed in the short-term (Rhee 2012, *in* Marchand and Ludwig 2014, p.27).
- By specifying the physical thresholds that require a transition of measure, the ATP method is less sensitive to updates of scenarios that commonly emerge every few years; if new scenarios arise, it is only necessary to compare the threshold values against such scenarios (Klijn et al. 2015, p.849).
- It was possible to synchronize decisions in time, and find optimized implementation sequences, by using cost-benefit analyses (Rhee 2012, *in* Marchand and Ludwig 2014, p.27).
- It was possible to link measures with other investment agendas, which stimulated win-win situations (Rhee 2012, *in* Marchand and Ludwig 2014, p.27). ADM offered a valuable means for framing short-term decisions in the context of long-term objectives and tasks and identifying possibilities for linking measures with other planned investments or merging different investment agendas (Gersonius et al. 2016 p.13-14). ADM is an adaptive but also integrated / comprehensive approach that aims to combine various investment agendas and seize opportunities to mainstream FRM into planned investments (Haegen and Wieriks 2015).

Bloemen et al. sum up some of the added values of applying the APs method in the DP. The APs method was essential to develop strategies that can be adjusted to changing external conditions and to position measures in a timeframe (Bloemen et al. 2018). Moreover, the APs contributed to embed long-term objectives into decisions in the near future in several sectors (urban planning, water management, nature, infrastructure, shipping), and increase the awareness of uncertainties (Bloemen et al. 2018). According to parties involved in the DP, ADM is one of the aspects that brought great added value, as it renders uncertainties about future tasks more manageable (DP 2014, p.144) (Note 280).

The main innovation of the DP and recent Dutch FRM, lies in the ADM approach (Klijn et al. 2015, p.848). In the long-term, ADM will likely provide, more benefits than a more traditional planning approach, at lower cost (thus, with a greater value for money) (Gersonius et al. 2016 p.13).

The adoption of ADM, especially of the APs method, alongside the introduction of the new *risk-based approach* to FRM, acted as 'success factors' in the DP. Moreover, the creation of a 'monitoring and evaluation programme' (to allow regular revisions), the periodic reassessments of the protection provided by flood defences, are necessary to generate new knowledge required for making the respective changes / adjustments to measures (Peterson and Bloemen 2014) (Note 281).

7.2. National and international relevance of the ADM approach

The DP and its adaptive approach – ADM – have captured large interest, particularly the way of dealing with uncertainty, the way of combining several measures, and its long-term orientation (DP 2013, p.114). ADM has captured interest in the fields of FRM, climate adaptation and disaster risk management, across the world (DP 2014, p.142) (Note 282). The experience of the DP led to a wider application of the APs method nationally and internationally:

- In the Netherlands, several policy fields have considered the possible application of an adaptive approach, e.g. in the development of the *National Strategy for Climate Mitigation*, in the national programming of large infrastructure investments, etc. (Bloemen et al. 2018).
- At the international level, similar approaches to the DP's and TE2100's approaches were adopted in New York and Jakarta (both are included in the 'Delta Cities Program' on climate adaptation). The cooperation with and between the English and Dutch cases helped other communities to deal with the challenge of adapting to an uncertain climate (Jeuken and Reeder 2011). Approaches of Adaptive Planning and Management inspired by ADM have emerged to manage deltaic and coastal zones, particularly to manage climate change-related risks in these areas, e.g., the '*Mekong Delta Plan*' (Marchand and Ludwig 2014, p.37) and '*Bangladesh Delta Plan 2100*' (Zevenbergen et al. 2018).

The concept of ADM has progressively developed into an interesting new type of planning and decision-making under uncertain future change, in coastal and deltaic areas. There are several compelling reasons for using it, its theoretical basis is widening and its practical results seem promissory (Marchand and Ludwig 2014, p.2, 5, 36). However, for Zevenbergen et al., the transference of ADM to other contexts is not straightforward: ADM involves a '*relative strict methodology*' and has long-term scope, which requires a '*consistent policy for the short- and long-term'*. ADM was originally developed in the '*relatively stable context*' of the Dutch Delta, dealing with a relatively '*limited range of long-term uncertainties*'. The implementation of ADM in different regions, namely developing countries, might imply fundamental changes in the institutional capacity, e.g. the development of new knowledge, skills, and policy frameworks. A successful implementation of ADM will depend on the local socioeconomic, cultural and governance conditions – factors which must be considered in the transference and transformation process. To apply this approach in '*more volatile and complex*' contexts, it may be necessary to: modify the approach and its tools, foster a 'learning-by-doing' mindset, have pragmatism to implement a result-driven policy framework and to embrace uncertainty (Zevenbergen et al. 2018).

7.3. Barriers and difficulties in applying an Adaptive Planning approach

The main barriers that hindered the application of ADM in the DP are identified next.

- **Difficulty in working with a wide range of scenarios.** The use of a broad range of scenarios was, in general, more viable in the exploratory phase of the planning process (as in the TE2100 case) (Jeuken et al. 2014, p.1). The DP worked with a moderate range of climate scenarios that does not include high-end projections.[152] The scientific willingness to communicate uncertainties may not always be compatible with their political recognition (Jeuken et al. 2014, p.11). In the RE-D Subprogramme, experience showed that working with scenarios was easier in theory than in practice: it was too difficult for people to think about four possible futures, they tended to focus on the 'steam' and 'rest' scenarios (Restemeyer et al. 2017, p.931). The assumption that 'whatever scenario happens, the existing defence system can cope with it and it will not require radical modifications' hampered the identification of tipping-points and visualization of pathways (ibid). The Delta Scenarios disregard the institutional and governance aspects, e.g. what may be the role of the state, market and society under different scenarios (Restemeyer et al.2017, p.932; Brugge and Bruggeman).

[152] In the beginning of the DP, the consideration of an 'high-end scenario for SRL' (of 1,3m) generated scientific and public controversy.

- **Difficulty in and complexity of identifying ATPs**. One of the most difficult elements of ADM was the determination of tipping-points (Bloemen et al. 2018, p.14). The identification of TPs was deemed one of the most challenging aspects of ADM by the DP staff (Gersonius et al. 2016, p.14). Some hindrances that hampered the identification of ATPs (in the DP) were:
  - ATPs are difficult to identify where the signals of climate change are weak in relation to the natural variability of the system, as in river discharges.
  - It is not straightforward to determine threshold values in the absence of binding safety norms, which happens in unembanked areas.
  - ATPs are difficult to identify in the case of strategies that are inherently flexible, e.g. sand nourishment (which can be extended indefinitely).
  - the ATP works for slowly changing conditions, but for drivers affected by extreme events, it runs the risk of being too late (Gersonius et al. 2016; Zevenbergen et al. 2018; Haasnoot et al. 2013).

- **Political resistance to 'keep options open', and to take preparatory measures needed for keeping options open**, was found in several Subprogrammes of the DP (Gersonius et al. 2016 p.13).[153] While 'keeping options open' is logical in theory, it is often difficult for decision-makers to commit to this. The reflection on future options can lead to greater cost-effectiveness in the long-term, but the traditional focus of decision-makers on the status quo, and their risk-aversion (and uncertainty-avoidance), tend to reduce their willpower to keep options open. These are barriers to the implementation of adaptive approaches (Gersonius et al. 2016). *Keeping options open*, and using measures that allow their own adjustment over time, may also entail higher costs (DP 2011, p.49).

- **Complexity of the ATPs and APs methods *per se*.** The ATP and APs methods may become quite complex and abstract for strategic policymaking at a national or regional scale (Reeder and Ranger 2011; Haasnoot et al. 2013; *in* Restemeyer et al. 2017, p.936). In the DP, ADM was time-consuming and required detailed knowledge of the FRM system (Gersonius et al. 2016). For example, the Subprogramme for the RE-D faced several difficulties in working with scenarios, ATPs, and APs. In practice, it was quite complex to identify tipping-points and envision adaptation pathways (Restemeyer et al. 2017, p.931). Both ATPs and APs methods assume that tipping-points can be identified beforehand (or, at least, when they are reached), however, practice shows that there are limits to the forecasting capacity and it is quite difficult to define adequate monitoring parameters, namely in cases of large natural variability (Restemeyer et al. 2017, p.931).[154] In this Subprogramme, 'ATPs' were difficult to find or did not exist, thus, the exercise was more about '*spreading measures in time*' than '*exploring alternative measures to shift to*' (Restemeyer et al. 2017, p.932). Moreover, in the 'adaptation path' of Preferential Strategy of the RE-D (Figure 43), the only option (alternative) indicated is the 'adjustment of river discharge distribution', therefore, for Restemeyer et al., the Strategy looks quite '*determined'*, providing '*little room for adjustments along the way*' (Restemeyer et al. 2017, p.932). This Strategy focuses mostly on '*prevention*' through '*gradual adjustment*' (maintenance and improvement) of the existing flood defence system; it is '*predominantly preventive'* (it is strongly based on measures to reduce the probability of flooding, e.g. 'dyke improvements', 'optimization and replacement of storm surge barriers'), and the measure 'river

[153] This can be explained by: (a) lack of clearness on whether options are realistic or if they will ever be realised; (b) keeping options open usually entails 'spatial claims' that put constraints on spatial developments; (c) decision-makers' desire and habit to take visible short-term actions (rather than inaction that facilitates future action) (Gersonius et al. 2016 p.13).

[154] While some indicators can be easily monitored (e.g. SLR), others present more challenges, e.g. river discharge. River discharge shows a large natural variability (it can increase or decrease during a period without a pattern). In the DP, it was nearly impossible to distinguish climate change signals from natural variations in river discharge. Hence, the DP decided to assume a fixed value of river discharge (maximum value): 17 000 m^3/s in 2050 and 18000 m^3/s in 2100. However, as noted by the DP Staff member responsible for ADM, taking decisions and measures based on 'artificially-fixed' worst future conditions (in cases where one cannot rely on monitoring) goes against the idea of 'flexibility'. Setting a fixed value resembles more a 'predict-and-control' approach than an adaptive approach (Restemeyer et al. 2017, p.931) (Note 283).

widening' is only envisioned for Dordrecht (ibid, p.933-935).[155] Power and money issues also made the strategy-making process less rational than the APs seems to be; in cases where there are two options but there is willingness to invest now, the political reality tends to be determining (ibid, p.933). The development of Strategies followed a quite linear filtering process (ibid, p.929).

- **Gaps in the assessment of measures and pathways**. Werners et al. identified some gaps regarding the assessment of measures and strategies: the lack of criteria specific of climate adaptation, namely *flexibility* and *robustness*; measures and paths were mainly assessed quantitatively (time and costs) in detriment of qualitative aspects, some strategies were left out at an early stage due to political reasons (rather than formal appraisal criteria); in the strategy-making and in the assessment, the identification of measures could have been broader and foster consensus (Werners et al. 2016).
- **The flexibility of the Strategies may be constrained** by pre-existing structural flood protection measures. Some structural flood protection measures taken in the past do constrain future options and choices (Jeuken et al. 2014, p.1). In the DP, the flexibility of strategies was often limited by the nature and lifespan of some measures – e.g. protection measures involving barriers that are implemented for several decades (Jeuken et al. 2014, p.18). It is quite difficult to prioritise measures that prevent lock-ins when such system *is already caught in a lock-in* (Restemeyer et al. 2017, p.936).
- **Some spatial developments or investments may hamper or lock out future options.** In some situations, spatial developments contributed to narrow down future options, e.g. past investments in hard defences in the Netherlands have attracted economic activity to low-lying flood-prone areas (and this development usually does not account for long-term adaptation needs), this will hamper a switch to measures substantially different from hard defences. In the future, measures involving spatial planning instruments that shape development patterns (e.g. risk-zoning plans, spatial reservations, building codes) will become essential to reduce flood risk (Jeuken et al. 2014, p.21).
- **Difficulty in quantifying / valuating flexibility in measures.** Another aspect of the ADM approach that was difficult to apply in the DP was the *'quantification of the added-value of flexibility'* ('Real Options Analysis' was too complex in many cases) (Bloemen et al. 2018, p.14). Regarding the assessment of pathways, traditional cost-benefit analyses present shortcomings, e.g. the non-consideration of uncertainties about the future, and the non-valuation of the added value of flexibility, which can lead to suboptimal decisions. Several authors have investigated methods to valuate flexibility economically, based on 'Real Options Analysis' (Brugge and Bruggeman, p.5) (Note 284).
- **Difficulties in long-term planning, uncertainty about future changes, and complexity.** Decision-makers face difficulties in long-term planning, namely deep uncertainty about the drivers of risk and change (Jeuken et al. 2014, p.23). It was also difficult to grasp interdependences of measures in different policy-fields and in different parts of catchment areas, and to coordinate investment agendas of other actors (Bloemen et al. 2018, p.14). Uncertainty about future risk has long been deemed '*a limit to technical control, which water managers have long perceived as almost existentially threatening*', however, an adaptive approach involves the acceptance of uncertainty, hence, the term 'robustness' has been used (to refer to resilience or insensitivity to uncertainties) (Buuren et al. 2016).
- **Scarce public engagement.** The involvement of many stakeholders in a joint decision-making process was not easy. It was difficult to foster the engagement of citizens in decisions (unless

---

[155] Further attention should have been paid to the diversity of measures, including measures to reduce the probability of flooding and measures to reduce flood consequences. This Strategy reflects the old belief that authorities are able to control flooding, but in case of technical failure of a dyke, the hinterland continues to be vulnerable. In this Strategy, 'adaptability' is '*limited to the idea of gradual adjustments*' to existing defence system (i.e. '*gradual adjustments of certain measures'* like 'dyke improvement') in a business-as-usual approach, less focused on improving the capacity to deal with unexcepted events and reducing the vulnerability (Restemeyer et al. 2017, p.935).

decisions strongly affected in their 'backyards'), and public awareness of flood risk in the country is low (Haegen and Wieriks 2015; Ritzema and Steensma 2018, p.7). The DP was quite expert- and government-driven, with strong reliance on expert knowledge from water domain and scarce engagement of civil society (citizens and business had not a formal role in the strategy-making process) (Restemeyer et al. 2017, p.929; Werners et al. 2016; Seijger et al. 2017) (Note 285).

- **Difficulties in the implementation phase**. The success of ADM and the effectiveness of proposed pathways can only be measured as the future unfolds (Gersonius et a. 2016). ADM also implies an '*adaptive implementation*' of the measures proposed in the Strategies (DP 2014, p.145). Yet, a recent survey showed that some actors responsible for the implementation of Strategies in their regions are concerned about their ability to maintain, in the implementation phase, the adaptive approach and to deal with unexpected conditions as time unfolds (Bloemen et al. 2018).[156]
- **Difficulties in the monitoring and reassessment.** Monitoring and the reassessment of pathways are complicated by the fact that trends in some variables cannot be detected (Jeuken et al. 2014, p.1). For Zevenbergen et al., the detection of climate change effects within the timescales of decision-making remains difficult, and it still needs to be seen whether the adaptive approach is being effectively applied in practice.
- **Different conceptualizations of flood risk and of the FRM challenge.** According to Klijn et al., in the Netherlands, defence engineers and spatial planners have commonly relied on different conceptualizations of flood risk and of the FRM challenge, and thus, on different measures; i.e. they use different framings of risk and how it can be tackled (Klijn et al. 2015, p.860) (Note 286).[157]

BOX 10: According to Klijn et al. (2015), there are two common definitions of flood risk in the Netherlands:

- Flood risk = probability of flooding x consequences of flooding.
- Flood risk = flood hazard x vulnerability of society / an area.

The 1st definition is usually preferred by engineers and natural scientists, who seek to reduce the probability of flooding via flood protection measures (e.g. engineers of Rijkswaterstaat); it was quite aligned with the country's situation in which 3000 km of defences protect flood-prone areas). The 2nd definition is preferred by spatial planners, who assume the 'hazard' as a given and spatial planning-related measures as a means to adapt to that given. In this definition, the 'hazard' covers all flood characteristics (flood probability, extent, depth, etc). The underlying thought is 'without people, no risk', thus, it uses other measures than defence measures only (Klijn et al. 2015, p.850).

These two definitions of flood risk are present in the DP Subprogrammes, however, the most common tends to be the first one. The 1st definition is subjacent to the definition of the new protection standards and underlying the ML FRM concept. Nevertheless, in both conceptualizations, 'exposure' (which refers to flood characteristics like flood depth, extent, water inflow rate, trajectory, volume) is disregarded: defence engineers see 'exposure' as part of the 'consequences' and not their responsibility, while spatial planners see 'exposure' as part of the 'hazard' (not their responsibility). Hence, no one can be held, responsible for influencing 'exposure determinants', e.g. flood depth, extent, water inflow rate, trajectory, volume, etc. (Klijn et al. 2015). A limited understanding of dynamic interactions among diverse components of risk may hinder an effective FRM. Moreover, there is no information to discern if a decrease in risk that results from reducing the probability of flooding (with defences) is nullified by an increase in the consequences associated with a growing population and investments in floodable zones (Bloemen et al. 2018).

---

[156] It is also important to ensure that measures are enabled by legislation, however, at European level there several directives aimed at ensuring 'preservation' which can hamper an adaptive approach; thus the DP has made efforts to tackle such hindrances (DP 2011, p.54).

[157] Klijn et al. analysed the different definitions of 'flood risk' commonly adopted in the Netherlands by flood defence engineers and spatial planners. The authors criticize the bias in the Dutch conceptualization of flood risk and FRM, which results from centuries of experience in successful FRM but which may no longer be sustainable in the future (Klijn et al. 2015, p.845, 847) (Note 286). The ways in which FRM measures, and flood risk, are framed is influenced by the socio-political context and the prior sequence of measures (Vink et al. 2013, p.93).

- **Path-dependencies: mechanisms of path-dependency and '*policy stability or stickiness*'**. The term 'path-dependency' is useful to explain the stability of a flood policy, as noted by Buuren et al. (2016). Several authors have used it to understand '*why some policies are resistant to change'* and '*why some new policies are more of the same'* (Buuren et al. 2016). There are still path-dependencies rooted in the Dutch flood policy (Note 287). Until the 1990s, the Dutch FRM approach has been dominated by flood defences to protect the country from floods. Some authors denominate this continuity as 'institutional inertia' or 'regime stability' and explain it with the existence of 'path-dependency' (dependence on the past path of investment in defence structures). More recently, there has been a shift from an 'exclusive reliance on flood defences' to a more integrated FRM. [158]
- There are still several mechanisms of path-dependency (technical, cultural, financial or institutional) and 'policy stickiness / stability' in the Dutch FRM system, which hinder policy learning and change, preclude a 'system transformation', i.e. a shift to a more *resilient adaptive* FRM, and show the difficulty of changing the FRM paradigm (Buuren et al. 2016) (Note 288). These path-dependencies may constitute barriers to a truly Adaptive Planning and Management**.** Among the mechanisms of path-dependency that hinder the implementation of a truly Adaptive Planning and Management, and the use of innovative alternative measures, there can be found:
  - <u>Lack of knowledge and experience in applying alternative innovative FRM measures (other than those traditionally used</u>) namely measures that are adaptable. While the effectiveness of traditional engineering solutions can be assessed with known methods, in the case of new measures (e.g. '*building with nature'* measures) there are no 'tried-and-tested' methods yet, and it is necessary to further investigate the behaviour and protective capacity of inherently dynamic and adaptable solutions (e.g. a saltmarsh). The lack of scientific evidence on alternative measures generates uncertainty. Moreover, in coastal and deltaic systems (complex dynamic systems), it is necessary to use sophisticated (morphological, hydrodynamic and climate change) models to predict the performance of measures, and these models usually have deep uncertainty associated to them. Uncertainties regarding the future performance of new measures may easily become an excuse for not taking such options seriously (Marchand and Ludwig 2014, p.36).
  - <u>Governance problems that complicate or prolong decision-making</u>, e.g.: existence of non-integrated approaches between national, regional, and local planning levels, and strong vested interests in the engineering domain that act as counter forces and emergence of 'hydraulic bureaucracy' when proposing non-engineering measures. Moreover, business-as-usual measures are often sustained by, and engrained into, legal and financial institutions (these institutions often rely on a particular type of measure, which leads them, and the organizations they protect, to reject new solutions as less secure or more expensive (Marchand and Ludwig 2014, p.36).
  - The legacy and <u>institutional reliance on hard protection measures (defences</u>) are mechanisms of path-dependency. For Buuren et al., there is a *path-dependency of institutions and policies, but also of the measure used* in the FRM field (hard protection)[159]: past choices led to a vicious cycle of

[158] For centuries, Dutch FRM was equivalent to flood protection in the form of dykes and dams, and wetlands, marshes and intertidal areas were disregarded as 'wasteland'. The predominant paradigm has been '*to drain, dredge, build dykes, and reclaim'*, and it is deeply embodied in Dutch culture. The practice of 'draining, dredging and diking' implied modifications and adjustments of natural landscapes, but offered little flexibility. It may take several years to take forward other solutions (Marchand and Ludwig 2014, p.7, 8). This is a type of path-dependency. More recently, there has been a shift from an 'exclusive reliance on flood defences' to a more 'integrated' FRM, in the Netherlands and Western European countries (where several floods in the 2000's showed the ineffectiveness of technological and institutional arrangements). The Room for the River and the ML FRM (in 2009) represented the first steps of a shift towards a more integrated approach (Buuren et al. 2016).

[159] Geels (2004) refers to this as the "hardness" of a measure, which is related with the physical structure but also with its economic costs, e.g. sunk costs. Gerrits and Marks (2008) also demonstrated how the initial selection of hard defences (particularly dykes) tends to initiate a process of 'increasing returns' that makes it almost impossible to leave that measure: indeed dyke-based protection tends to be much cheaper than alternative options, because of its 'sunk costs', its deep interrelatedness with the landscape geometry and functions (*in* Buuren et al. 2016).

investment in more advanced dyke-technology, which limits the scope for 'softer' forms of FRM. This shows the 'strong stickiness' of policy and measures employed and leads to a conflict between those favouring the ML FRM and those favouring an exclusive reliance on defences and flood risk assessments. Despite the increasing recognition of the need to increase the spatial and societal resilience, the main principle underlying Dutch FRM has been '*it is better to prevent than to cure*' (*better safe, than sorry*) (Buuren et al. 2016). The Dutch have traditionally focused on reducing the 'probability of flooding' by reinforcing dykes; this led to a *technological lock-in, a vicious cycle of investment* (…) *to protect land against flooding'* (Ritzema and Steensma 2018, p.4). There is a tendency for framing new policy ideas and solutions into the models / approaches of the old paradigm. A strong epistemic community remains stick to '*tried and tested*' strategies (also rooted in national mindset), which hampers policy learning and change (Buuren et al. 2016).

- Difficulty in mobilizing enough impetus and resources at the right time for ML FRM. The DP created a momentum for a radical policy change, but, despite the introduction of the ML FRM concept, most efforts were directed to setting the new protection standards and defining strategies to achieve them (Buuren et al. 2016; Klijn et al. 2016). Proponents of the traditional approach exaggerated the complexity of the ML FRM, argue that the government is responsible for preventing floods (as the public expects), and emphasize the potential disastrous consequences if prevention is underestimated. Moreover, the adoption of the ML FRM approach was hindered by: administrative restrictions on the use of budgets earmarked for flood prevention (Layer 1) for spatial planning measures (Layer 2); lack of proper instruments to attribute a legal status to measures of Layers 2 and 3; and difficulty in persuading agencies about the feasibility and added value of Layers 2 and 3 (Buuren et al. 2016) (Note 289). Though the DP includes spatial adaptation measures, almost no budget is earmarked in the Delta Fund for spatial adaptation measures (the Delta Fund is mostly earmarked for protection); this shows a continuation of past practices that calls into question the strength of public support and the room for manoeuvre allowed in terms of moving away from previous practices (Seijger et al. 2017).

Despite these path-dependencies, the Dutch FRM system has gradually changed, as the limitations of the prior approach become salient (higher costs, increasing implementation problems) and climate change effects emerge on political agendas. Path-dependencies have not completely precluded that an adaptive approach slowly gains ground (Buuren et al. 2016).

- **Difficulty in articulating the new protection standards with ADM.** Although the DP worked with the four Delta Scenarios, the new protection standards were defined based on the analysis of a single, relatively pessimistic, scenario for 2050 (such scenario assumes '*the strictest of the outcomes*'), and for some stretches, the proposed standards were even stricter due to potential societal disruption. This scenario was useful for exploring how big the problem might be, but it is quite challenging to match the new standards (based on such single relatively pessimistic scenario) with the Government's claims of having adopted '*a policy of Adaptive Planning and Management*' (Klijn et al. 2016). In 2016-2017, the new standards were adopted, and gradually, the implications of adopting them have become clearer. Due to the new standards, hundreds of km of primary defences will need to be reinforced or raised. Though the ADM principles seem straightforward, their practical application in DP's policy for FRM was not without complications (Klijn et al. 2016):
  - First, the adoption of the new flood protection standards brought problems. The prioritization of measures and defence works became very difficult (especially in the *Flood Protection programme,* HWBP) (Note 290). In 2015, defence reinforcements were being analysed by the order they 'come on the list': the first reinforcements may spend much time and money while other locations may be delayed, thus, risk might not be addressed in the most effective way in the various areas. The decision-making on dyke reinforcement projects (in 2016), were marked by multiple uncertainties/

issues about future: 1) how to balance '*what is optimal from a national perspective with what is practical from a local and regional perspective'*; 2) whether one should immediately meet the new standard in each site or gradually grow towards it; 3) should one invest in cost-effective probability reduction measures or keep other options open (Klijn et al. 2016). Optimization (i.e. implementing now the most cost-effective measure) may not always be the most useful answer to the problem.

- Second, there are tensions between ADM and existing rules, regulations and legal procedures (e.g. the traditional engineering practice of designing protection measures that 'last'). The adoption of the new standards raised a dilemma between ADM (and its emphasis on the possibility of shifting to other measures or strategies as conditions change over time), and the traditional engineering practice that relies on a '*better safe than sorry*' approach and designs defence reinforcement works that last (i.e. the most cost-effective measure for a given scenario). ADM calls for prudency regarding the speed, timing, and amount, of measures: '*not too early* / *late'*, nor *too much* / *little*. Somehow, it demands a new variant of the precautionary principle, as the future effects of measures are unknown. On the other hand, the engineering practice of designing defences calls for prudency regarding performance, i.e. a '*better safe than sorry*' approach, even if it is more expensive. It is common practice to build for several decades in advance (and avoid undertaking large renewals or upgrades), thus, the initial costs of defences are usually high (there is a preference for major *'maintenance-free constructions*' and a '*tendency to negligence afterwards'* (Klijn et al. 2016).[160] The two approaches can conflict with each other due to environmental side-effects of hard defences, and the influence of reinforcement works on the possibility to apply and switch to other measures advocated in ADM. This raised a dilemma: if dykes were reinforced to the standards required for 2050, the rationale for certain measures (e.g. *making room for river*) is undermined (their benefit-cost is low in comparison to reinforcements); conversely, if dykes were reinforced to the old standards (pre-2017), it would be logic to take other measures to achieve the objectives in the long-term. In either case, it was crucial to avoid spending money twice or unwisely. Thus, lawfulness (working according to rules and laws) may undermine the intentions of ADM (Klijn et al. 2016).

- **Dilemma between 'adaptability' and the 'urge-to-control'.** The Netherlands was pioneer in the adoption of an adaptive planning approach (ADM) to an entire country, not only a region or city, but policymakers faced a dilemma between '*adaptability*' and '*the urge-to-control*' (Restemeyer et al. 2017), e.g. in the elaboration of the Preferential Strategy of the RE-D. The idea of adaptability was adopted, but partially. A major dilemma existed between the aspired '*adaptability'* and the traditional '*urge-to-control'*: the DP shows signs of an '*integrated and adaptive approach'* that seeks to deal with uncertain future change, and, on the other hand, it shows traces of a more 'predict-and-control' approach that subsists in the Dutch FRM culture resultant from centuries of '*more technocratic-inspired policies'* (Restemeyer et al. 2017, p.920, 935). ADM reflects the particular way in which the Dutch interpret 'adaptability': '*with a strong reliance on governments, experts, techniques and tools'*, and based on their past. Continuing with the traditional practice may be advantageous (continuing something that they are good at) or disadvantageous (being tied to old patterns or dismiss the need to increase adaptability on land) (Restemeyer et al. 2017) (Note 291).
- **The APs method can be complex and abstract for policymaking at national and regional scales**; it is more feasible to develop APs at a local scale, where '*specific measures can be discussed in depth and better embedded into the physical, social and political reality*' (Restemeyer etal.2017, p. 936).

These issues are some of the challenges for further work and improvement about ADM (Note 292).

[160] This also happens in US where levees are usually built by the US-Army Corps of Engineers, while their maintenance falls within the responsibility of the regional authorities. The National Committee on Levee Safety of the American Society of Civil Engineers (ASCE) estimated the cost of repairing or rehabilitating the US levees to the required level around $100 billion dollars (*in* Klijn et al. 2016).

III. SYNTHESIS FROM BOTH CASES

1. KEY-ELEMENTS OF AN ADAPTIVE PLANNING AND MANAGEMENT APPROACH

Both the TE2100 Project and the DP purposely used a methodological approach of Adaptive Planning to build an adaptive plan / programme (as noted by Jeuken et al. 2014, p.23).

	TE2100 Project + Plan	DP Subprogramme for the RE-D
Name of the *Adaptive Planning approach* that was used	*Dynamic Adaptive Planning* (also called *Managed Adaptive Approach*, or Iterative Risk Management), This approach included the 'Route-map method', also known as 'Decision Pathways approach', and later called 'Adaptation Pathways approach' (APs).	*Adaptive Delta Management* It implies the use of the 'Adaptation Pathways approach' (APs), as part of its process.

Both Reference Cases adopted a *dynamic adaptive planning approach* regarding uncertain future changes and conditions, which was based on the 'APs method'. The APs served to explore possible measures and develop a map of adaptation pathways. Though it was not easy to build consensus on *which* and *how* measures should be implemented, both cases showed that having a 'maquette' of adaptation pathways early in the planning process is useful for communicating concepts and crucial to get stakeholders' support and buy-in of the Plan / Programme (Bloemen et al. 2018). In both cases, the APs approach was crucial to enhance the political commitment with keeping options open for the future. The method stimulated decision-makers to include in their plans alternative measures (options) to adapt to uncertain and changing conditions over time. The APs served to explore 'options to keep open for the long-term', e.g. the TE2100 demarcated land areas for future flood defences, and the DP set the reservation of areas for possible future options (e.g. retention area in the Rhine). These are examples of efforts to safeguard certain zones for possible future measures and put constraints on land use despite the strong development pressures felt; they show political commitment to, and a clear articulation of, long-term pathways, which fostered initiatives to guarantee long-term financing (Bloemen et al. 2018, p.11, 2). Influencing spatial development patterns through planning instruments like risk zoning, spatial reservations or building codes, is one of the measures to reduce flood risk (Jeuken et al. 2014, p.21). Nevertheless, there are differences between TE2100 and DP approaches. To a certain extent, the Dutch policy on coastal and river flood defences was already adaptive before the DP was initiated. Moreover, ADM seeks to ensure a 'combination of objectives' of FRM, FS, and spatial adaptation, and it had to ensure the articulation between the national and regional scale (Jeuken and Reeder 2011).

Drawing on both Reference Cases, it was possible to identify and systematize five key elements of an Adaptive Planning approach: (1) the use of a range of scenarios, namely to assess the effectiveness of measures and strategies, (2) the identification of thresholds or tipping-points, (3) the development of *robust and flexible* sets of measures to deal with uncertain change, through the 'Adaptation Pathways approach' (a pathway is itself a set of various measures sequenced over time), (4) the definition of a monitoring and revaluation system to allow the timely adjustment of the Plan / Strategy, and (5) the ongoing cycle/ process of steps to adapt the Plan and studied system. **Table 11** offers a synthesis of the key-elements of the Adaptive Planning approach used in each case, which were essential to design a '*dynamic adaptive plan*' and it describes how they were applied in each case.

Several diagrams are presented in the next pages. **Diagram 1** sums up the main elements of an Adaptive Planning approach. **Diagram 2** identifies the main sub-elements of the Adaptation Pathways approach (APs) that grant and enhance *adaptiveness* and *dynamic robustness* (*flexibility*) in the general Plan / Strategy, and **Diagram 3** describes their application in each Case. **Diagram 4** systematizes the main steps / stages of the process that may be followed in an Adaptive Planning approach (the scheme was developed based on the processes of the Reference Cases).

Key-elements of Adaptive Planning approach	TE2100 Project + Plan	DP, and particularly the Subprogramme for the RE-D
K1: To consider and work with a wide range of plausible future scenarios (diverse climate, physical, SLR, socioeconomic scenarios), and use them in the assessment of measures and strategies (pathways) on their effectiveness (Jeuken et al. 2014, p.1, 3, 10, 14, 23; Sayers et al. 2012; Jeuken and Reeder 2011; Walker et al. 2013, p.969-970; Restemeyer et al. 2017)	The TE2100 Team addressed the issue of FRM in the context of the possible climatic and socioeconomic scenarios that may develop over the next 100 years. The Team considered various plausible 'climatic and socioeconomic scenarios' (Jeuken and Reeder 2011, p.6, 2-3). The Team developed and worked with a wide range of plausible future scenarios of water level rise until 2100, rather than a single '*most probable*' scenario (Jeuken et al. 2014, p.10, 11; Jeuken and Reeder 2011, p.6). The range of scenarios includes e.g. '*high-impact, low-probability*' scenarios and '*moderate*' scenarios. Later in the Project, the '*most likely*' scenario was identified. Moreover, socioeconomic scenarios were specifically developed for the TE (Jeuken et al. 2014). Scenarios were generated based on outputs from GCMs, past observations, evidence from additional sources, expert inputs (Ranger et al. 2013, p.233, 239, 258). The main climate parameters considered in the scenarios were SLR, storm surges and river discharges, but projections showed no trends in river discharges (Jeuken and Reeder 2011, p.11,14, 6). The scenarios served to: • analyse the current and future FRM needs and issues '*in the context of the climatic and socioeconomic scenarios that may develop over the next 100 years*' (Jeuken and Reeder 2011, p.2; 6); explore the plausible range of long-term extreme water levels (Ranger et al. 2013, p.233, 239, 258, 243; Reeder and Ranger 2011, p.7), analyse flood risk now and in the future, set the long-term adaptation requirements and limits for measures (Ramsbottom et and Sheppard 2017, p.7, 9). • Assess the measures and pathways (i.e. test the effectiveness of measures, develop pathways, and appraise them) (Ranger et al. 2013, p.233, 239, 258, 243; Reeder and Ranger 2011, p.7; Ramsbottom et and Sheppard 2017, p.7, 9). The Team worked with a wide range of scenarios of SLR until 2100, including '*high-end*' and moderate scenarios (Jeuken et al. 2014, p.10). The high-end scenario was used for exploratory purposes, moderate scenarios were used for the appraisal of pathways.	The DP Teams worked with a bandwidth of four 'plausible futures', so-called '*Delta Scenarios*' (*Rest, Warm, Busy, Steam*); all subprogrammes worked with the same plausible futures (DP 2011, p.48, 71; 2013, p.6; 2012 p.35; Marchand and Ludwig 2014, p.12). ADM itself proposed the use of a spectrum of plausible future scenarios (Gersonius et al. 2016, p.4), in order to find robust and flexible measures (Marchand and Ludwig 2014, p.12). These scenarios address uncertainties about two main issues: climate change and socioeconomic development. Regarding climate change, the DP decided to use the 'formal' Dutch climatic scenarios, which do not cover high-end projections (only extreme events up to 1/10 000 years). These scenarios present figures for SLR and river discharges (Jeuken et al. 2014, p.10, 11). Regarding socioeconomic development, scenarios for economic and population growth until 2100, and for land use until 2050, were generated (Jeuken et al. 2014, p.13). The Delta Scenarios served to: • assess possible future risks and impacts (Jeuken et al. 2014, p.10, 11; Alphen 2015, p.312; Brugge and Bruggeman, p.5); • support the development of the Delta Decisions and Preferential Strategies (Bloemen et al. 2018; DP 2014, p.136), namely the design of *adaptation paths*. The various scenarios were used for assessing individual measures and strategies (Jeuken et al. 2014, p.10, 13), i.e. to test the performance of measures and strategies (Marchand and Ludwig 2014, p.12; Alphen 2015). The Delta Scenarios were generated by the scientific community, based on climatic and hydrological model calculations (Jeuken et al. 2014, p.11, 14). The *Delta Scenarios* consist of four different plausible futures (not predictions) but describe a modest bandwidth of possible changes (some developments may fall outside this bandwidth) (Brugge and Bruggeman p.3). Overall, the DP considered a moderate range of scenarios for SLR, river discharge and soil subsidence, until 2100. Initially, it was considered a high-end scenario of SLR, but then it was abandoned. The climate scenarios include extreme events up to 1/10 000 years (Jeuken et al. 2014, p.10).
K2: To identify critical thresholds / ATPs, i.e. 'conditions under which does the current system, or the current or other measure, performs unacceptably / fails / no longer meet the objectives (Jeuken and Reeder 2011, p.3; Jeuken et al. 2014, p.17; Walker et al. 2013, p.969-970)	The TE2100 Team identified critical thresholds. Critical thresholds describe conditions under which the current system, or current or other management measures or policies, fail (Jeuken et al. 2014, p.17). The critical thresholds represent 'limits' that would be disruptive for the existing flood defence system (thresholds in the sensitivity / vulnerability of the system, e.g. values of SLR, limits of adaptation of the existing system, etc.) and which would require new measures (e.g. the modification of existing defences) (Ranger et al. 2013, p.242; Reeder and Ranger 2011, p.6). They indicate conditions under which the current system (or current or other FRM measures / policies) no longer meets the objectives and new measures are needed (Jeuken and Reeder 2011, p.4; Bloemen et al. 2018, p.7, 8). The definition of critical thresholds / tipping-points required analysing '*what (amount of) change can the system handle (cope with) before it runs into trouble*' (Jeuken and Reeder 2011, p.3). The TE2100 focused on analysing what increases in the sea level and in peak river discharge could cause a technical failure or overtopping of the flood defence system (including its embankments, floodwalls, and the Thames Barrier) (Jeuken and Reeder 2011, p.3, 2). The Team started by identifying critical thresholds in the existing flood defence system in the TE; it assessed the technical/physical limits of the existing defence system, quantified its overcapacity, and it defined design criteria for defences (considering climate projections) (Jeuken and Reeder 2011, p.6). The thresholds are related to '*acceptable flood probabilities*' (acceptable return periods for flood events) which were translated into '*design criteria*' for flood defence structures (Jeuken et al. 2014, p.17; Sayers et al. 2012, 282, 285). More specifically, the Team examined '*what are the thresholds where interventions will be needed*' (flood probability will increase until a certain threshold level is reached and new measures are needed to reduce such probability). Scenarios helped to determine the moment of *thresholds when measures are needed to keep the flood probability within acceptable limits* (Ramsbottom et and Sheppard 2017, p.4,5). The thresholds played a key role in the phasing of the possible measures within the plan (Jeuken et al. 2014, p.17). The analysis of thresholds was the starting point for exploring measures and pathways (Jeuken and Reeder 2011, p.2-3). The thresholds were used to sequence possible measures into *packages* of sequenced measures, i.e. pathways (Jeuken et al. 2014, p.17).	The DP sought to identify 'Adaptation Tipping-points' (ATPs) (Kwadijk *et al.* 2010) as part of the ADM process. ATPs refer to conditions under which the current or alternative management measures or policies might fail, they are also related with acceptable return periods for flood events, in line with the *risk-based approach* of the DP (Jeuken et al. 2014, p.17). The ADM approach itself employs the method of ATPs (Jeuken and Reeder 2011, p.3). In its process of steps, ADM requires the identification of external developments to which the objectives are most vulnerable for, under diverse scenarios. This implied assessing '*what is the critical level (ATP) before the objectives are not met anymore*', and assessing '*when this might occur*' by using the scenarios. ATPs represent critical levels that are a threat to the objectives. The Teams used the scenarios to examine what were the main vulnerabilities (Jeuken et al. 2014, p.4-5). In the DP, the identification of ATPs required examining 'how vulnerable was the existing FRM system to climate change, how much climate change can it handle, and whether it is necessary to take new / additional measures because of climatic or socioeconomic developments. The Subprogrammes' Teams sought to identify 'ATPs', i.e. points under which management measures and policies (including FRM policy and FS policy, along the coast and rivers) are no longer able to meet the objectives. Then, it was necessary to analyse when these ATPs might be reached, and when new measures are needed (Jeuken and Reeder 2011, p.2-4). The Teams sought to identify tipping-points in the existing flood defence system, by assessing technical/physical limits of the existing system, and by defining design criteria for defences (taking into consideration climate change projections). Various scenarios were used to determine the moment of an ATP (at earliest and at latest), the moment to take a decision (decision-point). Not only the limits of the pre-existing 'water system', but also limits of the existing water management policies (already in place when the DP was initiated), were identified. The decision-moments and implementation-moments will depend on the ATPs of measures, but also on earlier opportunities to combine measures with other objectives, investments, and agendas (Jeuken and Reeder 2011, p 6, 7,5). ATPs played a key role in the phasing of possible measures within each Strategy: consecutive measures were sequenced and assembled into pathways that connect short-term measures to long-term options (Jeuken et al. 2014, p.17). The reaching of an ATP indicates that a new measure is required.
K3: To develop a 'robust and flexible' set of measures (i.e. *robust flexible strategies*), to deal with uncertain future changes and conditions, through the 'Adaptation Pathways approach' (APs) (Jeuken et al. 2014, p.1, 3, 23; Sayers et al. 2012; Jeuken and Reeder 2011, p.2-3; Walker et al. 2013, p.970).	This element consists of developing and using a 'robust and flexible' set of measures to deal with uncertain future changes, which, in the TE 2100, was done by using the 'Route-map / Adaptation Pathways approach' (Jeuken et al. 2014, p.23,1,3; Jeuken and Reeder 2011, p.3, 2; Ranger et al. 2013, p.233, 249, 239). <u>In the TE2100</u>, this element involved the design of *robust flexible strategies*, with the 'APs approach' (Jeuken and Reeder 2011, p.2-3). A strategy is itself a set of measures, i.e. a pathway, and several pathways were designed. The TE2100's *Dynamic Adaptive Planning approach* aimed to build a '*dynamic adaptive plan / strategy*' that was '*dynamic robust*' and '*flexible / adaptable*'. This '*Dynamic Adaptive Planning approach*' contained an innovative method to construct a '*dynamic adaptive plan/strategy*': the 'Route-map / Adaptation Pathways approach' (APs) (Ranger et al. 2013, p.249). A pathway is a *package* of measures sequenced and implemented over time to manage flood risk (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8). Five different pathways were designed in the route-map; together, such pathways are expected to cover the estimated plausible increases in water level until 2100. In the APs approach, not only is each pathway flexible (as it is possible to move from one measure to another depending on developments), but it is also possible to move from one pathway to another, as changes occur or new knowledge arises. By using the 'APs approach', the TE2100 developed several possible pathways; and the APs approach allows for switching between diverse measures over time, as well as switching between different pathways. In the 'APs approach', measures are implemented iteratively over time to maintain risk below the target levels, and, at the same time, keeping open alternative measures (options) to manage future risk, in this way, maintaining *flexibility*. In the APs' map, short-term measures are linked to possible measures (options) for the long-term (Jeuken et al. 2014, p.1, 24). The APs' map shows possible measures and the thresholds at which it will be necessary to switch from a measure or pathway to another. In the TE2100, the Plan and its strategies (pathways) '*are designed to be adjusted over time as more is learnt about the future*' or as changes occur (Ranger et al. 2013, p.249). In the 'APs approach', the timing of new measures, and the measures themselves, can be changed (adjusted) over time (Ranger et al. 2013, p.249). The Plan, its strategies, their measure, or their timing, can be adjusted / changed, as conditions change, and to manage evolving flood risk over time. Each pathway can be adapted throughout the century according to the rate of change (water level rise) that is experienced. In the 'APs approach', if new insights emerge, it is possible to adjust the pathways and / or switch to other alternative measures (Jeuken et al. 2014, p.18). The 'APs' served to: identify possible measures, and explore their the timing and sequencing over time under different scenarios, and, in this way, develop various pathways to manage flood risk over time (Ranger et al. 2013, p.233, 249). The 'APs approach' implied the analysis of thresholds (points at which a measure no longer meets the defined criteria and a new measure is needed.	This element consists of developing a 'robust and flexible' set of measures (containing measures that are *robust* and / or *flexible*), to deal with changes and uncertain future conditions, through the 'Adaptation Pathways approach' (APs) (Jeuken et al. 2014, p.23,1,3). This element implies the development of a '*robust and flexible*' set of measures – i.e. the design of '*robust flexible*' *strategies* – which in the DP, was done by using the 'Adaptation Pathways approach' (APs) (Jeuken et al. 2014, p. 23, 1, 3; Jeuken and Reeder 2011, p.2-3; Restemeyer et al. 2017). To develop the Preferential Strategies, the DP used the ADM approach. One of the main principles of ADM is working with '*adaptation paths*', i.e. pathways (DP 2011, p.48; 2012, p.88; 2013, p.102; 2014). The ADM approach and its process employ the method of APs. The DP Teams developed their Strategies by using the APs method. Each Preferential Strategy has a map of an '*adaptation path*' (with one or more pathways). Each '*adaptation path*' is a sequence of measures over time. Each Strategy contains a set of measures sequenced over time, i.e. a pathway. The DP used the 'APs approach' to identify what measures were available, including possible measures (alternatives) for the long-term, to explore options for switching between measures, and, in this way, remain flexible. The maps of adaptation paths show the measures available and when it is necessary to switch of measure (Jeuken et al. 2014, p.10). Each DP's Strategy contains (one or more) pathways and allows the switching between different options in the future (Jeuken et al.2014, p.18). The APs' maps show short-term measures connected to possible measures for the long-term, and identify points in time at which it will be necessary to switch from a measure to another (ibid, p.24). Flexibility is related with: (i) the possibility (flexibility) to switch from a measure to another, or from a pathway to another, when needed, and thus, with the availability of other possible measures (i.e. keeping option open for the future); and (ii) the possibility of postponing or advancing the timing for implementing a measure. The APs 'allow for switching between measures along the pathways when needed in view of socioeconomic developments or climate change'. In ADM, the design of adaptation pathways implied exploring possible management measures and options, identifying their ATPs (in time), and through an iterative assessment, select successful measures and construct possible pathways (sequences of measures) (Jeuken et al. 2014, p.4). The design of pathways implied the identification of ATPs: once an ATP is in sight, a new measure is needed (Haegen & Wieriks 2015). In the 'APs approach', a planner envisions possible measures and possibilities to switch between them, through adaptation pathways (Jeuken et al. 2014, p.1). In the DP, the 'APs' served to explore possible measures and options, and possibilities for switching between them, and, in this way, remain flexible (Jeuken et al. 2014, p.10). This contributed to enhance the flexibility of the general Strategy. By using the APs, it was possible develop a '*robust and flexible*' set of measures, as *pathways* (Jeuken et al. 2014, p.18). The 'APs' also served to determine potential '*decision-moments*', but, in the DP, such moments depend on ATPs of prior measures, but also on opportunities to combine a measure with other investments or goals (thematically and spatially), on the complexity of the measure, and on the lead-time required to plan and design it.
K4: To monitor relevant changes, continuously reassess future scenarios; review / revaluate the Plan accordingly and, if necessary, redefine / adjust it (its pathways, and / or measures, or their timing) (Jeuken et al. 2014; Walker et al. 2013; etc.).	The Team defined a monitoring and evaluation programme, including key-indicators to be monitored, and *decision-points* (in terms of trigger-values in the indicators) (Jeuken et al. 2014, p.10). The 'decision-points' serve to guide the implementation of measures and are triggered by observations of key-indicators (Ranger et al. 2013, p.233, 239, 258). The TE2100 Plan specifies key indicators / variables that must be monitored to assess if a switch of pathway will be needed in the future. It explains that the timing of the measures may be adjusted depending on the monitoring of key indicators. The evolution of the climate and scientific insights must be monitored to see if decisions need to be adjusted, postponed, or taken earlier (to update the estimated dates when measures are implemented and the dates of decisions) (Ramsbottom et and Sheppard 2017). Monitoring is essential '*so that the plan can be updated in the future, based on the most up-to-date estimates of climate change and any new government guidance on climate change*' (ibid, p.5). Moreover, the Plan addressed the need of periodic updates of the pathways: the outputs of monitoring will inform the review of the Plan every 10 years, and there will be a mid-term monitoring review every 5 years.	Since 2015, the DP has defined its 'monitoring and evaluation system', so-called Monitoring, Analysing and Acting system (MAA), which specifies indicators to be monitored and trigger values. The evolution of the climate and scientific insights must be monitored to see if decisions need to be postponed or taken earlier (Jeuken and Reeder 2011, p.6). Moreover, the DP recognised the need to periodically update the Strategies and pathways: a systematic review of the Preferential Strategies was set out every 6 years, and an analysis to see if the flood protection standards need be revised will occur every 12 years (Bloemen et al. 2018). Importantly, monitoring was already a common practice in Dutch FRM (Jeuken et al. 2014, p.10). ADM requires an ongoing monitoring of drivers of change, and the regular reassessment of strategies. This implied indicators and thresholds to evaluate the performance of system's components. The DP's monitoring and revaluation system specifies variables to be monitored to allow a timely adaptation of the Strategies (measures, or timing). It allows the adjustment / adaptation of a Strategy to changing conditions or new insights.
K5: The ongoing process of Adaptive Planning and Management (planning, learning, and adapting)	The Dynamic Adaptive Planning approach of the TE2100 is associated to an ongoing 'iterative risk management' (also called Managed Adaptive approach). It involves an ongoing process of planning, implementation, monitoring and adapting. The TE2100 Project has followed a decision-centred planning process which entails several steps: i) the assessment of risk and potential impacts; 2) identification of possible measures and development of strategies (pathways) considering a wide range of scenarios; 3) selection of Options (preferred pathway) and decision-making; 4) application; 5) monitoring of changes, measures applied, and new information; 6) the reassessment of the Plan and, if necessary, its review (i.e. correct, alter, or change the Plan, its measures, or their timing). This iterative process helps to ensure ongoing learning and safeguards the adaptability of the general Plan over time, so that it can better deal with change and uncertain future conditions.	The Adaptive Delta Management approach adopted by the DP involves a process of several steps to develop a dynamic adaptive plan and to operationalize a truly 'adaptive delta planning and management'. The ADM process contains 6 main steps, which the DP has followed in the development of its Strategies: 1) analysis of vulnerabilities and opportunities under different plausible future scenarios (which implies the definition of objectives and the examination of critical thresholds and tipping-points in the existing system and management measures); 2) identification of measures and options, and assessment of their efficacy; 3) development of adaptation pathways and its map; 4) design of an adaptive plan (an action plan with the preferred pathways) and definition of a monitoring system including indicators and trigger values; 5) implementation of the plan; 6) monitor external changes and implemented actions, and regularly reassess the plan, and, if necessary, adjust it (its strategies, measures, or their timing). Overall, ADM involves a continuous cycle / process, which allows that monitoring results and new information are feedback into the reassessment of the DP's strategies.

Table 11. Synthesis of the key-elements of the Adaptive Planning approaches developed and applied in the TE2100 and in the DP, i.e. the Dynamic Adaptive Planning approach, and the Adaptive Delta Management approach (ADM), respectively. Source: own elaboration based on several authors.

Key-elements of an Adaptive Planning approach and necessary to develop a 'dynamic adaptive plan'

Diagram 1. Key-elements of an Adaptive Planning approach, and essential for designing a dynamic adaptive plan. Sources: own elaboration based on several references (Jeuken et al.2014; Jeuken and Reeder 2011; Walker et al. 2013; Ranger et al. 2013; Reeder and Ranger 2011; Ramsbottom et and Sheppard 2017; Zandvoort et al. 2018; Sayers et al. 2012; Restemeyer et al. 2017; DP 2016, 2017, 2014; TE2100 Appendix L 2009; etc.)

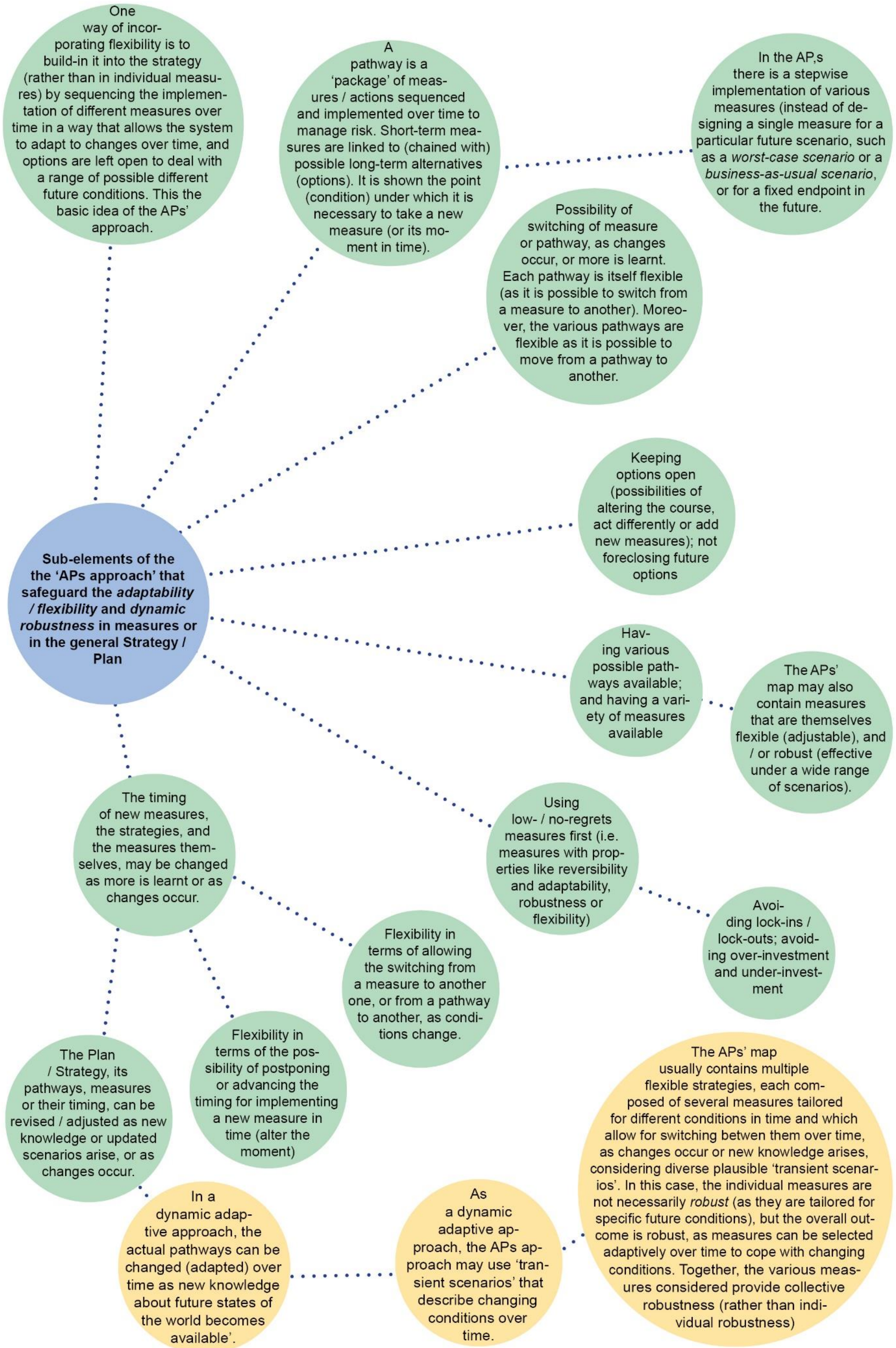


Diagram 2. Sub-elements of the Adaptation Pathways approach that deliver and ensure dynamic robustness (flexibility) and enhance the adaptability of the general Plan / Strategy. Source: own elaboration based on several references.

TE2100 case

How the Plan is adaptive? Sub-elements of the 'APs approach' that contribute to safeguard and improve the 'dynamic robustness' ('flexibility') and adaptability in the Plan and of managed system

Flexibility to switch to a new measure	Each pathway is itself flexible, as it is possible to move from one measure to another. Each pathway is a 'package' of measures sequenced and implemented over time. The APs' map shows when each action ceases to be effective and a new action is needed.
Flexibility to switch from a pathway to another	In the 'APs approach', not only are the pathways themselves flexible, but it is also possible to move from one pathway to another depending on the rate of change that actually occurs. The 'APs approach' allows the switching from one pathway to another, if the rate of change requires so (to cope with the new conditions).
Having various pathways available	More than one pathway is available to manage flood risk over the century. The Plan identifies various pathways to cope with different levels of water level rise and indicates the thresholds at which each pathway will be needed. Together, the various pathways were designed to span the estimated range of plausible future scenarios of water level rise until 2100.
Stepwise implementation of measures + Keeping options open	In the APs, measures are implemented iteratively over time to maintain risk below target levels (stepwise), while keeping options (alternative measures) open to manage future risk. Keeping options open is a way of maintaining 'flexibility' to cope with possible future change. Given the uncertainty about future water levels, it would be risky to commit to a given pathway or measure for the long-term based on the best projection available at a given moment. The choice of the option for the long-term will be made in a future review of the Plan.
Possibility of adjusting / adapting the pathways	In the 'APs approach', the Plan / Strategy can be changed over time: the pathways are designed to be adjusted over time or as more is learnt about the future or as conditions change. The timing of measures, and measures themselves, can be changed over time. Each pathway can be adapted to the rate of change that is experienced over time.
Possibility of changing the timing of new measures	The timing of actions may be altered as new climate scenarios arise or changes occur over time; thus, the decision date and the implementation date may be advanced or postponed. The 'APs approach' allows for changing the timing of new actions, according to the rate of change observed. If conditions change faster, actions are brought forward; if conditions change slower, actions are delayed. The Plan *'can be adjusted when the rate of change is either faster or slower than originally predicted'* , e.g. if monitoring suggests that SLR is occurring at a faster or slower rate than projected.
Adaptability / Flexibility to adapt the Plan, its pathways, measures, or their timing, to changes over time, through the monitoring and revaluation system	The Plan is adaptable to change, e.g. to changes observed in indicators. The Plan can be adapted in the following ways: by adjusting the timing envisaged for a new measure (implementation-point and decision-point); by switching to a new measure or to another pathway; or by modifying / changing a measure itself. These are the main ways of addressing changes as these are monitored, or each time the Plan is reviewed. To ensure that the Plan remains adaptable and 'fit for purpose', indicators will be monitored throughout its lifetime, and a review of the Plan must be conducted every 10 years at least and be informed by monitoring results. Certain values in the indicators will act as triggers, and, e.g. require the anticipation or postponing of measures. The monitoring and revaluation system is crucial to allow the adjustment of the Plan: if monitoring indicates that SLR is happening faster/slower than predicted, a decision point may be anticipated / delayed; or, when the Plan is reassessed, measures may be brought forward or postponed. Monitoring and Plan's reviews are essential to see if a switch to other action or pathway is needed, in light of changes observed in indicators and new insights.
Diversity / variety of measures	The Plan (and its pathways) contain diverse FRM measures, e.g.: measures to adapt and improve existing defences, building new defences, 'making space for water', resilience-increasing measures for new and existing urban areas, flood forecasting, warning systems, emergency preparedness responses, etc. The Plan contains measures to reduce the probability of flooding, but also measures to reduce flood impacts and to make the floodplain safer.
Inclusion of low-regrets measures in near-term	The Plan proposes 'low-regret' measures (measures that work through the whole range of change) in the near-term. Such measures reduce risk cost-efficiently under a wide range of climate scenarios. They cost-beneficially reduce risks while leaving open *options* for the future and 'buying time' to monitor and learn before making a major investment.
Safeguarding land for future measures	Some FRM measures will require land (e.g. new barriers, areas for habitat creation or flood storage). The allocation of land through the spatial planning system must be guided by the requirements of the *pathways*, to guarantee that such pathways remain viable. The TE2100 Plan recommends the safeguarding of land via land-use planning.
Mainstrem adaptation into new projects	Some projects expected for the TE have major implications for future FRM Options, e.g. the new London Gateway Port. These projects must be used as opportunities to integrate adaptation / FRM actions. Some actions of the Plan may be brought forward, if this is justified by synergies and funding opportunities from other stakeholders.
Structural / engineered flexibility	Engineering structures can be designed so that they can be adapted / adjusted in the future to changing conditions, e.g. by constructing foundations of defences that withstand higher flood water loadings. Structural flexibility is present in some measures of the Plan.

Delta Programme case

How the DP and its Strategies are adaptive? How ADM operationalizes and delivers adaptiveness and flexibility (dynamic robustness)

Tools to deal w/ uncertainty+ deliver adaptiveness	ADM seeks to deal with deep uncertainty about future changes, e.g. climatic and socio-economic changes, and to do this, it uses an anticipatory adaptive planning. Adaptiveness is seen as proactively adapting to possible changes. ADM uses two methods to handle uncertain changes and ensure adaptiveness (and plan adaptations): ATPs and APs.
Having alternative measures available + Having one or more pathways available	The central idea of ADM is to develop diverse trajectories that the dynamic system may follow as time unfolds, i.e. pathways. Flexibility is ensured via APs. ADM *'leads to a composite strategy, or a set of alternative strategies with intermediate possibilities for revisions'*. The set of pathways identifies the measures available and schedules them over time. Adaptiveness is related with having diverse trajectories that can be applied to achieve the long-term goals in different plausible scenarios, depending on changes over time. Using the 'APs method', the Teams devised possible measures, assessed their effectiveness in different scenarios, and based on ATPs, designed possible pathways. A pathway is a sequence of actions / measures over time to achieve defined objectives. A Strategy contains one or more pathways and allows switching between different measures, if needed, in view of changes that occur over time.
Flexibility to switch from a measure, to another, or from a pathway to another	The DP adopted a flexible approach regarding strategies. Flexibility is valued in terms of: (1) allowing the switching between measures or between pathways, through APs (i.e. the possibility to switch to other measure or pathway when needed, as conditions change) (2) the possibility of altering the timing for implementing measures. The DP sought to ensure that the chosen strategies and measures provide flexibility to respond to new insights and changes, by 'stepping up measures' and / or 'changing strategy' if necessary. Flexibility often refers to the possibility to alter the course, i.e. the flexibility to deliberately choose a different measure or pathway. This implies having possibilities (options) for switching between strategies.
Flexibility to alter the timing of a measure	In ADM, a strategy should also be flexible in terms of timing, i.e. allow the possibility to postpone or advance a measure in time. Adaptiveness and flexibility are also related with the possibility to modify / alter the timing for implementing a measure.
Stepwise implementation of measures + Keeping options open	Adaptiveness is also related with a stepwise implementation of various measures and with *'keeping options open'* (having the possibility to switch to other measures). Both aspects contribute to increase flexibility (*dynamic robustness*), and, thus, adaptiveness to handle unknown future changes. 'Keeping options open' requires *'not foreclosing future options to react differently and switch or add actions if climate or societal changes ask for it'*, and finding measures that do not block further measures that may be needed in the future. The DP specified measures needed to keep options open for the future, e.g. 'spatial reservations' to keep 'river widening' measures open for a long time.
Having various measures available; variety of measures (diversity)	The DP sought to ensure that it has *'potential measures at hand'* and *'sufficient elbow room for them'*. The design of adaptation paths implied the identification of various possible measures as strategic alternatives. The DP envisioned diverse types of measures, e.g.: dyke improvements, room for the river, spatial adaptation, disaster management measures. The DP used the 'Multi-layered FRM concept', which relies on 3 layers of measures: flood prevention, spatial planning / adaptation; and disaster management. These measures can be used in a combined way. The approach to FRM widened with the ML FRM and increased flexibility.
Using measures that are themselves flexible or adaptable, and / or robust	Adaptiveness also means using measures that allow their future adjustment, e.g. designing a defence that can be heightened in the future. The DP sought to ensure flexibility in some measures. E.g., in coastal areas, a flexible strategy based on sand replenishments was adopted. In other areas, a strategy based on dykes was chosen (to meet the new standards'). Some Strategies include *flexible measures*, i.e. measures that are *'easy to alter, speed up or slow down depending on the measured climate change'* (e.g. beach nourishment); in other cases, robust measures (that can deal with high-end scenarios) were selected.
Low-regrets actions first	In the DP's Strategies, the first measures for the near-future are often low- / no-regret actions – i.e. actions that are worthwhile in any scenario.
Avoid lock-ins/ lock-outs	In ADM, flexibility is also related with avoiding lock-ins / lock-outs. To avoid lock-ins, the DP sought to identify spatial adaptation measures in addition to prevention measures.
Allow the adjustment of the Strategies devised, through the monitoring and revaluation system	A flexible approach (that allows switching between measures) requires ongoing monitoring and evaluation. Flexibility demands *'capacity to learn from the arrival of new information'* and *'ability to revise investment decisions based upon that learning'*. ADM requires an ongoing monitoring of drivers of change, and the regular reassessment of strategies. This implied indicators and thresholds to evaluate the performance of system's components. The DP's monitoring and revaluation system specifies variables to be monitored to allow a timely adaptation of the Strategies (measures, or timing). It allows the adjustment / adaptation of a Strategy to changing conditions or new insights. The monitoring system must keep track of changes and detect ATPs.
Linking measures to other agendas	The DP sought to integrate FRM measures into other investments (e.g. in urban development, nature restoration) and agendas and seize opportunities. The combination of measures with other agendas and multi-objective investments increases flexibility, and reduces costs.

Diagram 3. The main sub-elements of the Adaptation Pathways approach (APs) that grant and enhance *adaptiveness* and **dynamic robustness** (*flexibility*) in the general Plan / Strategy, and how they were applied in each Reference Case.

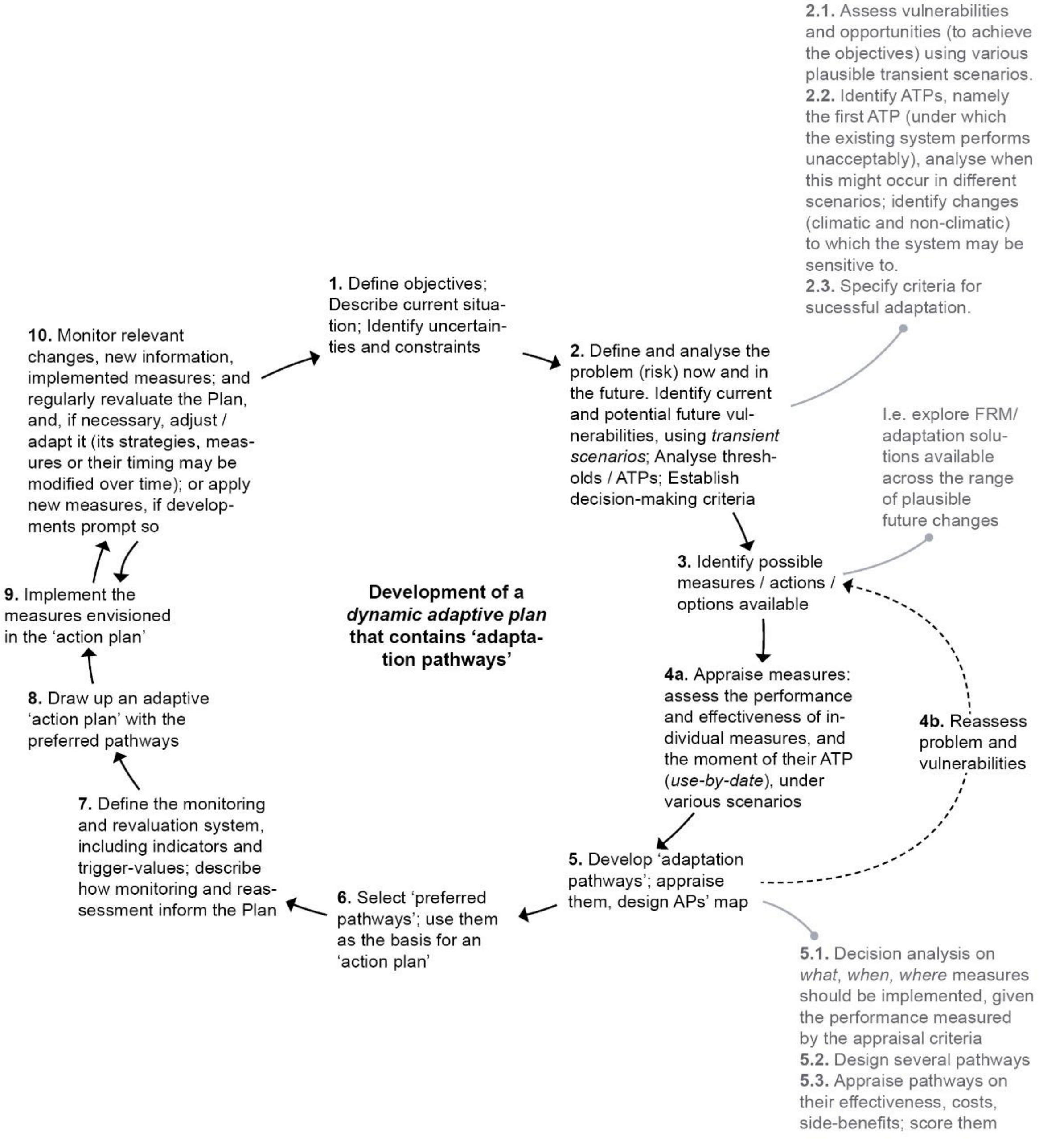


Diagram 4. A possible process of steps to develop a *dynamic adaptive plan* containing adaptation pathways. Source: own elaboration, based on the analysis of the Reference Cases and on several authors.

2. Positive outcomes from, contributions, advantages of using the APs approach

The experiences of the two cases demonstrate that the APs' approach was effective in and useful to:

- Improving the awareness and the management of uncertainties about future changes and about (new) dynamics of climate change, and inter-temporal complexities, at the local scale. By showing how long-term objectives and tasks can be related to short-term decisions and investments, the APs stimulates policymakers to '*incorporate*' uncertainties about future changes in their plans.
- Providing a way of visualizing multiple alternatives. The APs served to position measures in time (a *timeframe*) and in the physical space. It allowed the development of strategies / plans that can be adjusted to changes and fostered political commitment to *keep options open for the long-term*.
- Moving the decision process forward to the approval of the long-term plan, improving the pace and quality of decision-making processes under uncertain future changes (Bloemen et al. 2018, p.2, 21).

From the two cases, it is possible to derive that the APs approach brings an added value, especially if developed at a strategic level of decision-making and considering the long-term (Bloemen et al. 2018).

3. Barriers and difficulties in applying an Adaptive Planning approach and APs

Drawing the cases of the TE2100 and DP, some authors have identified barriers to the use of Adaptive Planning approaches, and difficulties that arose found in both cases, which constitute key-challenges for further development of the Adaptive Planning approaches, especially of the APs approach:

1. It is difficult to determine tipping-points in cases where: a) there is large natural variability, b) intrinsically flexible strategies are used, c) there are not clear policy goals. In the APs, it is implicitly assumed that some physical parameters that influence flood risk (e.g. climatic conditions that influence the probability of floods, or socioeconomic developments that influence the consequences of a flood) change gradually and allow societal systems to react and shift to a new measure. This works well in situations characterized by gradual trends / slow changes, e.g. SLR, however, evidence shows that, in situations of large natural variability, the determination of tipping-points is challenging. For instance, there is usually a great difficulty in monitoring changes in the patterns of storms, droughts, etc., in conjunction with a lack of observations of extreme events. The detection of climate change-induced changes in certain parameters, e.g. in river discharges, requires detailed monitoring data and model calculations and often shows that the natural variability is so high that it may take 3 or 4 decades before climate change signals are distinguished accurately. Further research is needed to discern climate change signals from 'common' monitoring measurements, through approaches that use observations and future projections, scenarios and modelling; there is a need of methods to distinguish climate signals from highly variable measurements of physical condition (Bloemen et al. 2018, p.14) (Note 293). Moreover, '*the potential for monitoring and reassessment of options is hampered by the fact that trends in some variables cannot be detected*' (Jeuken et al. 2014, p.1). It is also difficult to determine ATPs where there are not precise goals, and when strategies are inherently flexible. The DP's strategy to manage coastal flood risk is beach nourishment, which is flexible: the sand volume supplied per year can be increased / decreased according to the observed SLR rate (Bloemen et al. 2018, p.14). Yet, in the three situations mentioned (a, b, c), the monitoring and detection, in a timely way, of tipping-points, although challenging, will be essential. This implies the development of a monitoring and evaluation system able to detect tipping-points in such situations (Bloemen et al. 2018).

2. It is difficult to untangle relationships between measures that are implemented in parallel (i.e. simultaneously, in time). A difficulty presented to the APs approach lies in understanding and disentangling interdependences between measures that are defined for the same time period, but in different zones of an area or in different fields. As seen, in the Preferential Strategies of the DP, several '*parallel trajectories*'[161] were often drawn (at the same time). These different trajectories often concern different actors, hence, the interrelatedness of their outcomes tends to be disregarded and their successful implementation becomes more uncertain. In addition, while the assessment of the effectiveness of individual measures is a complex issue *per se*, the use of simultaneous measures in 'parallel trajectories' further complicates it. Bloemen et al. suggest that the effectiveness of the general Strategy could be examined by evaluating (ex-ante) how the different 'trajectories of action' strengthen/ weaken each other, and by recombining or eliminating trajectories (measures). The DP shows that, in the preparation of a strategy that contains several *parallel trajectories* (i.e. parallel / complementary measures), it would be useful to assess if such trajectories perform well under diverse conditions, and examine if the general Strategy (with its measures) covers a wide spectrum of plausible futures evenly, or if it is skewed towards a specific scenario and compensation is needed (Bloemen et al. 2018 p.14-15).

3. In situations of lower predictability / deeper uncertainty, it is quite difficult to maintain societal commitment to prepare and decide on possible measures for the long-term(options). The APs define measures to taken in the short-term and indicate possible future measures for the long-term for which decisions will be taken in due time. However, decisions on the implementation of such measures are often postponed until the (climatic, physical, socioeconomic) conditions that justify them are reached or predicted with greater certainty. This hinders the adequate anticipation of these measures. The postponing of decisions about future options is usually related to avoiding the 'unwanted anticipation' of long-term measures (Bloemen et al. 2018, p.15). On the other hand, taking a decision in the short-term to do not implement a certain future measure can lead some actors to search for other measures. Thus, postponing decisions about future options can be advantageous or disadvantageous depending on the nature of the measure, costs and benefits of anticipating it for diverse actors, the direction that the anticipation follows in relation to the direction intended by the measure, etc. These aspects must be considered when taking decisions about, and planning, future measures.

4. It has been difficult to prepare shifts from incremental to transformational measures. Both the TE2100 and the DP sought to secure the possibility to shift from incremental to transformational measures, however, this point could be further improved and contribute to improve the APs approach, by clarifying how such shifts can be enabled. In both cases, often, the selected pathway contains incremental measures in the short-term, firmer measures in the mid-term, and 'system-changing' transformational measures in the long-term. Incremental measures usually correspond to investments in further / gradual improvement of the protection level provided by the current system. Yet, continuing in a path of incremental measures can lead to an increase or a transference of costs to a future system, greater path-dependency and sunk-costs (by augmenting the point for switching from incremental to transformational measures). Further research is needed on this issue, namely to compare alternative pathways in a cost-benefit analysis that covers the entire period of the pathways, sunk and transfer costs. Under climate change, a shift to more transformational measures will be required at some point. The difficulties of making such shift in a planned way must be tackled (Bloemen et al. 2018, p.17).

5. A key challenge in the 'APs approach' is to detect eventual increases in path-dependency on certain measures and increases in the 'transfer costs' (costs of switching from one measure to another, in the same pathway or in a different one). There are '*mechanisms of path-dependency'* that hinder shifts from incremental to more transformational measures, or block transformational pathways, e.g. '*conservative powers'* or '*the intricate complexity of flood policies'* (Bloemen et al. 2018, p.17), but it is difficult to notice them. The necessary shifts from incremental to transformational measures must

161 'Parallel trajectories' are not alternative pathways but measures planned for different locations in the same time period, which interact with each other (e.g. complementary). In the DP, a 'path' usually contains several 'parallel trajectories'. A trajectory (horizontal line) is often made of one measure that is adjusted over time. In the TE2100, parallel measures are grouped in 'portfolios of measures' planned for a certain period.

be prepared, which implies the identification and avoidance of situations where incremental measures increase path-dependency or hinder the transition to transformational measures (Bloemen et al. 2018). Often, structural flood protection measures carried out in the past do constrain future options (Jeuken et al. 2014, p.1). Moreover, certain investments or autonomous developments can hamper / lock out future measures, e.g. some past spatial developments contributed to narrow down possible options (by attracting economic activity to low lying areas). Some developments '*may make it difficult to switch to pathways that promote substantial different solutions*' (Jeuken et al. 2014, p.21). It is important to build an evidence base with examples of overcoming lock-ins and of transformative and radical adaptation of the physical environment (e.g. small-scale pilots and experiments) (Restemeyer et al. 2017, p. 936).

6. Little attention has been paid to the institutional and governance issues surrounding adaptation planning and decision-making, and to the political and sociocultural conditions required for the implementation of certain measures. In adaptation realms, it is often assumed that decision-making is a more-or-less rational, scientific data-driven process, however, real-life decision-making is often marked by institutional and political considerations and power issues (Bloemen et al. 2018, p.17). Although decisions to implement a given measure or pathway are substantiated on a cost-benefit analysis of measures, political considerations can lead to decisions to implement measures with low benefit-cost (ibid, p.5) (Note 294). The APs approach (like other approaches that seek to rationalize decision-making in the face of uncertainty) does not explicitly address the political aspects of decision-making. Moreover, the institutional and sociocultural conditions can be critical constraining factors, especially in situations of transfer that entail larger changes. 'Resistance to change' in the social-technical system should not be disregarded (Bloemen et al. 2018). Certain measures or pathways will require institutional changes (as the climatic and socioeconomic scenarios that favour a given measure may not necessarily contain the sociocultural and institutional conditions required for its implementation); and governance challenges will have to be addressed 'to keep options open for future' (a sub-element of the APs of the DP). Hence, it is necessary to analyse the institutional and political issues that plague transformational pathways. The APs should stimulate a 'free-thinking space' that does not restrict measures, including measures that are not politically or financially acceptable in the short-term and innovative solutions.

Restemeyer et al. (2017) also note that there is scope to use 'optimisation methods' in the development and assessment of pathways, such as Real Options Analysis. Key challenges for planning of adaptation / FRM are: (i) to minimize regret and maladaptation stemming from over- / under-investment; (ii) to seize opportunities to mainstream adaptation into other agendas and provide other benefits (than adaptation), e.g. increased biodiversity, liveability, competitiveness (Gersonius et al. 2016). Research is needed on: the conditions required for the implementation of options (e.g. financial arrangements, maintenance requirements, etc.); the integration of measures and pathways into new or existing plans / management strategies; and implementation constraints and opportunities (Marchand & Ludwig 2014).

Despite the recent signs of a transition to more adaptive planning approaches (and ongoing steps towards more adaptive forms of planning and management of deltas and coastal zones), with approaches inspired by the cases of the TE2100 and DP being adopted in several countries, the practical implementation of Adaptive Planning approaches requires much more effort to realize a shift to a new paradigm of delta and coastal management. There are still several barriers and difficulties in applying an Adaptive Planning approach. The aspects previously describe not only constitute barriers to the application of Adaptive Planning approaches but also shortcomings / gaps of the APs method that require further research and study (Note 295). There is a great potential to learn more from the analysis of other cases of Adaptive Planning and Management in coastal and deltaic regions in different sociocultural and governance contexts. This will generate a wider body of knowledge on adaptive coastal and delta planning and management (Marchand and Ludwig 2014, p.36-37).

4. Findings and results of Part A: answering the specific research questions

The first part of this research (Part A) focused on the two main existing cases of application of Adaptive Planning approaches for coastal climate adaptation / coastal risk management planning purposes – the Thames Estuary 2100 Project (TE2100) and the Delta Programme 2014 (DP2014) – to analyse:

- How the Adaptive Planning approaches were applied in the Reference Cases (in line with the **Specific Research Question I**)
- What were the key-elements of the Adaptive Planning and Management approach applied and required to develop a *dynamic adaptive plan* (ingredients / requisites that a plan must meet to be *adaptive*) (in line with the **Specific Research Question II**).

4.1. Answering the Specific Research Question I

To answer the Specific Research Question I, it was necessary to analyse the following aspects: the main drivers that led to the need of designing a *dynamic adaptive plan* (or using an Adaptive Planning approach), the requisites that were previously set for the plan (how it should be); the definition and conceptualization of the Adaptive Planning approach that was created in each case (e.g. how such approach was devised and defined and what are its main features), how the 'Adaptation Pathways method' was applied within such Adaptive Planning approach, and the process of development of the TE2100 Plan and of the DP2014 by using such Adaptive Planning approach.

The TE2100 Plan is a long-term plan to manage flood risk in the Thames Estuary until 2100, and which addressed coastal climate adaptation as a central issue (one of the goals of the Project was analysing whether and when the existing flood defence system would need to be modified and develop a plan up to 2100). The Delta Programme (DP) is a Dutch policy programme aimed at ensuring flood risk management (flood safety), sufficient freshwater supply and water-robust spatial planning (a climate-proof land-water system), now and in the future; it is a national programme which is subdivided into 9 sub-programmes (3 specific nation-wide subprogrammes and 6 regional sub-programmes). Both the TE2100 and the DP2014 have developed Adaptive Planning approaches. The TE2100 Project has created and used an innovative planning approach called '*Dynamic Adaptive Planning*', which included the 'Route-map / Adaptation Pathways method' (APs). The DP2014 has also devised its own Adaptive Planning approach, so-called '*Adaptive Delta Management*' (ADM), inspired by the TE2100's Dynamic Adaptive Planning approach, which also employs the APs' method.

<u>Drivers: why to develop and apply an Adaptive Planning approach</u>

In both cases, the main drivers for developing and using an Adaptive Planning approach were: the recognition of deep uncertainty about the future conditions and changes (uncertainties associated to the projection / prediction of future climate change effects, their scale and rate, namely of SLR), the need to act now (a proactive attitude towards future risks, and urgency to anticipately plan for and tackle risks in a timely way, otherwise the consequences of doing nothing, little or later will be worse); the existence of high stakes involved (investments in flood defences and other investments that might take place in these areas will have strong implications in future vulnerability and are highly sensitive to the effects of climate change) but, at the same time, it was expected that investments in expensive coastal and riverine flood defence infrastructures would be necessary in the near future; and the acknowledgment that an improper consideration of future climate change effects and adaptation needs could lead to maladaptation (irreversible, over- or under-investments). All these factors called for a different planning approach: an Adaptive Planning that allowed the adaptation of the *plan* (and of the systems under consideration) to uncertain future conditions and changes over time.

Requisites set for the Plan and for the Planning Approach

In both the TE2100 case and the DP2014 case, the Teams have defined concrete requisites that the Plan / Programme must meet. In the TE2100, the Team decided that the Plan should be *long-term*, *proactive*, *risk-based*, and *sustainable* (in the face of changing conditions and evolving risks throughout the next 100 years). Hence, it was decided that the TE2100 Plan should be '*robust*' and '*adaptive*': i.e. able to deal with future risk under different plausible futures throughout this century, and, at the same time, adaptable to change (namely to climatic changes), in order to remain 'fit for purpose' over this century.

On the other hand, the DP has established the requirements that its new planning approach (Adaptive Delta Management - ADM) should meet: it should be able to *handle* deep uncertainties about future climatic and socioeconomic conditions and changes through an *anticipatory* and *adaptive* planning (ensure adaptiveness in planning). To be *anticipatory*, the planning approach should anticipate plausible changes in the climate, society and economy and have a long-term horizon. It should be able to deal with uncertain future changes, but also allow wise decisions and investments in the short-term in the face of highly uncertain future risks. Importantly, the DP's adaptive approach should be *flexible* enough to adapt the plan / strategy to changing and unforeseen future conditions. Hence, it should ensure and maximize the 'flexibility' of the Programme (DP). Moreover, the DP's approach should be *risk-based* (include various measures to reduce hazard probability, vulnerability, exposure, and potential impacts. The DP and its ADM approach set requisites for the DP's strategies: it was necessary to develop '*robust flexible strategies*' (for FRM and freshwater supply). *Robust* strategies should ensure that the country is prepared for various plausible scenarios (e.g. by keeping options open for the future, namely for more drastic changes that might happen in the future), while *flexible* strategies should ensure *flexibility* to cope with changing conditions and new insights (e.g. by stepping up measures, or changing of measure or strategy, or by altering the timing of measures, i.e. anticipating or postponing it).

Conceptualization and characteristics of the Adaptive Planning approach

The TE2100 Project developed a new planning approach (to plan for FRM) based on the concept of 'Dynamic Robustness'. Dynamic Robustness aims at developing a plan that is *robust* (i.e. performs well and a wide range of plausible futures) and *flexible* (i.e. can be changed over time, as conditions change or new information arises, and thus, it is *adaptable*). Drawing on the concept of 'Dynamic Robustness', the TE2100 developed a '*Dynamic Adaptive Planning approach*' in which a plan is designed to be adapted (adjusted) over time as changes occur or as more is learnt about the future, and is implemented iteratively. This *Dynamic Adaptive Planning approach* contained a new method for designing a *dynamic robust adaptive plan*: the 'Route-map approach', later called 'Adaptation Pathways approach' (APs).

In its turn, the DP has developed its own adaptive planning approach called '*Adaptive Delta Management*' (ADM), which was devised based on the DAPP approach created by *Deltares* and *TU Delft* and presented by Haasnoot et al. (2013), and also inspired by the approach of the TE2100. To support the application of ADM in the DP, the DP staff provided to the Subprogrammes the '*ADM Implementation Guide*', which recommends the use of 'Scenarios', 'Tipping-points' and 'Adaptation Pathways'. ADM was put at the heart of the DP: the DP has used ADM to address flood risk management (FRM) under uncertain future conditions and change, and to manage risks and potential future problems '*in a timely and adaptive manner*'. ADM provided a practical way of dealing with deep uncertainties about future changes within policymaking and decision-making on FRM (namely uncertainties about future effects of climate change and socioeconomic developments). By using ADM, the DP seeks to remain '*adaptable*' to changing climatic, physical, and socioeconomic conditions and under an uncertain future.

ADM is substantiated into four main principles: 1) linking short-term decisions with long-term tasks on FRM and FS; 2) incorporating flexibility into possible *solution strategies*, where effective; 3) working with '*multiple strategies that can be alternated between*', that is, working with *adaptation paths* (pathways) between which it is possible to switch depending on developments; and 4) linking FRM and FS measures with other investment agendas. The 3rd principle, in particular, involves the design of adaptation pathways. Moreover, ADM seeks to develop strategies that are both *robust* and *flexible*. A *robust strategy* is one that works in all plausible futures, while *flexibility* is related with the possibility to cut a measure or strategy off and switch to another, but also with the capacity of being easily adapted to changing or unforeseen future conditions, which required solutions able to adapt to new insights and circumstances, and keeping open sufficient options for the future.

The DP applied the ADM approach (and its principles) in the development of its *Delta Decisions* and *Preferential Strategies*.

Adaptation Pathways approach as part of the broader Adaptive Planning approach

In the TE2100, the 'Route-map / Adaptation Pathways approach' (APs) involved the development of several possible pathways (routes) that were represented in a route-map. Each pathway is a *package* of various measures sequenced and implemented to manage risk over time. In the APs approach, measures are implemented over time to keep risk below acceptable levels, *and, at the same time, keeping open options to manage future risk* (instead of optimizing a certain solution for a particular risk level).

With the APs method, the TE2100 Team could identify the timing and sequencing of possible FRM measures over time and under different future scenarios of water level rise. The APs approach required sequencing diverse measures in a way that allows the (FRM) system to be adapted to changing conditions over time, and in which alternative measures (options) are kept open to cope with multiple plausible futures. By using the APs method, the Team could design a series of pathways in a route-map, which, in their whole, can cope with the plausible range of climatic changes that might occur until 2100 (i.e. span the estimated range of plausible water level rise).

The TE2100 Project developed a route-map with five possible pathways. With the route-map, the TE2100 has elaborated an '*adaptive plan*' for managing flood risk over the next 100 years: the plan contains various possible pathways to cope with the expected future increases in the water levels in the TE. Moreover, in the TE2100 Plan, the timing for new measures, and the measures themselves, might be changed (adjusted) over time, e.g. it is possible to move from a given measure to other (within a pathway), or from a given pathway to another, depending on the actual rate of change that is experienced.

The design of the pathways required the identification of critical thresholds (for the existing system) and conditions under which a measure no longer meets the defined objectives and a new measure is needed. Then, the diverse possible measures identified were assessed on their effectiveness and performance under different plausible scenarios of SLR: when a measure ceases to be effective, a new measure is needed, and thus, a pathway emerges. In the TE2100, each pathway contains several measures that are implemented in a staged way to prevent that a certain 'probability of flooding' is exceeded.

In the case of the DP2014, the ADM approach implies the design of adaptation pathways – denominated '*adaptation paths*' in the DP. ADM itself, and, in specific, its 3rd principle (working with adaptation paths), imply the use of the methods of Adaptation Tipping-Points (ATPs) and Adaptation Pathways (APs). According to the *ADM Implementation Guide*, to develop *robust flexible strategies*, it is necessary to identify tipping-points and design adaptation pathways.[162] The DP has applied the ADM approach to develop *robust flexible strategies*, and to support its application, it used the methods of ATPs and APs.

In ADM, ATPs are '*points where the magnitude of change due to socioeconomic developments, climate change or sea-level rise is such that the current strategy (measure) will no longer be able to meet the objectives*'; an ATP indicates conditions under which a given measure fails (becomes unacceptable or ineffective) and a new measure is needed (e.g. a level of SLR at which a flood barrier ceases to function).

The 'APs approach', as understood in ADM, is an adaptive planning method to design *flexible robust strategies* under different plausible future scenarios. The APs approach that was used in ADM (and in the DP) was based on the 'Route-map / APs approach' of the TE2100. In ADM, adaptation pathways are like '*successions of measures over time*' towards the future in a changing environment. Each pathway is a sequence of actions over time to achieve the defined objectives. The various adaptation pathways provide '*coherent sequences of measures and potential options, which may be triggered before an ATP occurs*'; i.e. possible trajectories.

In the DP, the 3rd principle of ADM has translated into the design of '*adaptation paths*' in the Preferential Strategies and in some Delta Decisions. Each Preferential Strategy presents a map of 'adaptation path(s)', with the pathway (or pathways) to be followed. This map shows what measures can be taken and when they are expected to be necessary (including measures required now to ensure that options that may be needed in the long-term can be implemented by then).

The DP valued the *'flexibility of solution strategies*', and it developed *'multiple strategies that can be alternated between'* (i.e. measures or paths). Each map of 'adaptation paths' indicates the conditions under which it is reasonable to change of measure or path. A key aspect is having options (possibilities) *'for switching between strategies*'. The APs' method allows possible shifts (switching) between different measures or pathways (i.e. switching from a measure or pathway to another), if necessary, in view of climatic or socioeconomic changes, and ensures that options for the long-term are kept open. Moreover, each map of 'adaptation path(s)' includes measures for the short-, and options for mid- and long-term (possible measures that may be used after 2050). The *adaptation paths* of the DP contain diverse measures sequenced over time which can be implemented according to the changes that occur and new information that emerges. Depending on the climatic and socioeconomic developments, it may be necessary to switch of measure, and measures might be taken sooner or later.

In the DP, the design of *adaptation paths* required the identification and sequencing of various possible measures as *strategic alternatives*. ADM implied the development of diverse trajectories that the system may follow as time unfolds and changes occur. The APs approach used in ADM (and in the DP) involved: mapping the measures available, specifying their tipping-point (the degree of change under which each measure begins to perform inadequately) and analysing when this might occur at the earliest and the latest, and assessing whether it is necessary change / adjust the existing measure or shift to other measure. With the APs, it was possible to assemble sequences of measures and plan their activation.

The design the *adaptation paths* required the use of the ATPs method (i.e. analysing at which level of a climate-related variable or other parameter a given measure is no longer suitable or acceptable and must be substituted by other measure). Then, to identify the moment in time of an ATP, it was necessary to

[162] According to the ADM Implementation Guide, to develop *robust flexible strategies*, it is necessary to identify tipping-points and design adaptation pathways. To make strategies *flexible*, it is important to know '*when to take action or change course*', and thus, when an ATP might be reached. The Guide explains that '*thinking about the first decision, and potential follow-up decisions in the long-run, is important to be prepared on time for the long-term challenges regarding flood safety and freshwater supply. Being able to adjust flexibly to changing social and climate conditions is necessary to prevent the so-called lock-in and lock-out situations*' (Rhee 2012).

place the ATPs against different (climatic and socioeconomic) scenarios. In line with the 1st principle of ADM, the DP's strategies should coherently link the short- and long-term. This implied analysing when the tipping-point of a given measure will be reached, examining if a transition of measure is needed, identifying possible measures and assessing them, and planning alternative strategies (pathways).

Process of steps necessary in an Adaptive Planning approach to develop a *dynamic adaptive plan*
The TE2100 Project followed a *decision-centred* planning process, which started from the adaptation problem itself (the need to reduce flood risk) rather than with the analysis of climate projections / scenarios. Such process stimulated decision-makers to focus on the decision problem and its characteristics (objectives, actors' interests, constraints, system's vulnerability, decision criteria) and on the solutions s (choice of, and between, measures to reduce risk). Thus, measures were planned based on in-depth understanding of the problem, rather than of climate projections. The process of development of the TE2100 Plan (followed in the TE2100 Project) involved the following steps:

1) Structuring the problem, which included: (1a) the definition of objectives and relevant constraints and decision criteria, (1b) the assessment of current and future risks and vulnerabilities of the system, and (1c) the specification of thresholds in the system's vulnerability, and definition of FRM policies for different areas of the TE. In the sub-step (1b), the analysis of future flood risk required studies to develop a range of plausible scenarios of SLR for the TE, and such studies occurred in parallel to the development of options; in the meantime, the Team used four 'interim scenarios' of SLR for 2100.
2) Identification of measures, and development and assessment of pathways, including the following sub-steps: (2a) exploration and definition of possible measures and 'response options'; (2b) assembling of pathways (routes / strategies, in which a new measure is activated once its predecessor ceases to be effective / perform well); 2c) appraisal of pathways under different scenarios and on several criteria, and ranking of pathways (comparison).
3) Deciding on the plan and definition of the monitoring and review system, including the following sub-steps: (3a) choice of the 'preferred pathway(s)' and elaboration of the 'implementation plan(s)', and (3b) definition of the monitoring, evaluation and review system.
4) Implementation of the plan.
5) Monitoring, evaluation of external conditions and outcomes, and, if necessary, review of the Plan. This implies feeding back information to Steps 1 and 2 (namely 1c and 2c).

The DP2014 has followed the process of steps that was provided by the ADM approach. The ADM approach describes the process of steps necessary to develop an *adaptive plan* and to ensure an 'Adaptive Delta Management'. The process of ADM is based on the process of the DAPP approach (presented by Haasnoot et al. 2013 and Jeuken et al. 2014). It involves a circular cycle with 6 main steps:

1) Analyse vulnerabilities and opportunities under different plausible future scenarios. This step includes the definition of the main objectives for now and the future, and an analysis of critical levels / thresholds that the system can handle, i.e. the identification of relevant ATPs.
2) Identify measures and options and assess their efficacy (the performance of each measure is assessed in the light of the objectives, to determine its tipping-point.
3) Develop adaptation pathways and the APs' map. This step consists of the design of 'adaptation pathways', which requires assembling various possible adaptation pathways (sequences of measures) by using the promising measures (identified in Step 2), and representing such pathways in a map.
4) Design an *adaptive plan* (action plan), and define triggers. This step requires: (a) the selection of one or more preferred pathways as input for an adaptive plan (an 'action plan'), and (b) the specification of indicators / signposts and triggers (i.e. critical values at which it is necessary to activate actions, and which act as warning signals for the implementation of actions or reassessment of the plan). Step 4 requires the definition of a monitoring system to collect information on indicators and triggers.

5) Implement the plan (i.e. the planned measures).
6) Monitor, reassess the plan (its strategies or measures), and adjust it, if necessary. This step requires a monitoring and evaluation system to keep track of climatic and socioeconomic developments, and to assess if and when it is necessary to review or adjust the plan (e.g. change its strategies or measures). It implies the monitoring and evaluation of external changes, implemented measures and progresses in knowledge, the reassessment of the plan, and, if necessary, its review / adjustment. This Step is essential to allow a truly adaptive planning and management.

In general, the DP Subprogrammes have applied the ADM process to elaborate the *Delta Decisions* and the *Preferential Strategies*. The Subprogrammes have carried the steps of the ADM process, namely the design of adaptation pathways. Each *Preferential Strategy* of the DP specifies the objectives, measures to achieve the objectives, and the associated '*adaptation path*', i.e. a set of measures displayed in a timeline, a map of adaptation path(s). Therefore, in the DP2014, the *Delta Decisions* and *Preferential Strategies* were created based on ADM approach – its principles and process. ADM explained how to develop adaptation pathways to address the objectives and tasks for FRM and FS.

4.2. Answering the Specific Research Question II

In line with Specific Research Question II, this research has then focused on identifying what are the main elements of Adaptive Planning approach (including APs) required to develop a *dynamic adaptive plan* and carry an adaptive planning and management process. Drawing on the analysis of the two Reference Cases, and on a review of scientific literature on the requisites / elements of Adaptive Planning approaches (that use the APs method), five main elements were identified as essential to develop a *dynamic adaptive plan* and necessary to operationalize an adaptive planning and management:

- **Key-element 1: To consider, and prepare for, a wide range of *plausible future scenarios*** (diverse climatic, physical, and socioeconomic scenarios), rather than a single probabilistic projection of the future, and use them to assess measures and strategies on their effectiveness. It is necessary to work with various plausible futures to assess what measures can be used to achieve the objectives regardless of how the future unfolds. Scenarios should represent the main uncertainties about future changes.
- **Key-element 2: To identify critical thresholds (also called *Adaptation Tipping-points*),** i.e. conditions under which the current or a given measure fails (ceases to be effective / meet the objectives), or the current system performs unacceptably, and a new measure / action is needed.
- **Key-element 3: To develop and use a *'robust and flexible'* set of measures, to deal with uncertain future changes, through the 'Adaptation Pathways approach' (APs)** (also called 'Route-map approach'). This element involves developing / designing of *robust flexible strategies*, by using the 'APs approach' (a strategy can be itself a set of measures, a pathway).
  One of the main elements of an Adaptive Planning approach is '*to respond to uncertain change with a robust and flexible set of actions* (Jeuken et al. 2014). This requires preparing a set of actions / measures that are *robust* and *flexible*, and which should also contain '*low/ no-regrets*' properties as much as possible (Jeuken et al. 2014). Thus, the 3rd key-element requires designing *robust flexible strategies* (containing *robust measures* and / or *flexible measures*), which can be done by using the 'Adaptation Pathways approach' (APs). The APs is a methodological approach for '*exploring and sequencing a set of possible actions based on alternative external developments over time*' (Haasnoot et al. 2012, p.485). It belongs to the family of Adaptive Planning approaches. In the APs, a planner envisions short-term measures chained with possible alternatives (options) for the long-term, and envisages possibilities for switching between them, through pathways.

- **Key-element 4: To continuously monitor relevant changes and new information, and reassess / review the Plan, and, adjust (adapt) it accordingly**. This requires: a targeted monitoring of relevant changes (in external conditions, effects of measures) and continual evaluation of new information (e.g. updated scenarios); and the regular reassessment (review) of the Plan, and, in accordance, the adjustment of the Plan (i.e. updating, redefining or modifying policies, measures, pathways, and / or implementation plans, according to the monitoring outputs). This will allow the adjustment (adaptation) of the Plan and its measures. Important changes are continuously observed and foreseen through targeted monitoring and future scenarios are reassessed; and the Plan is regularly revaluated, and its policies, measures or pathways are appropriately adjusted / adapted. The monitoring and reassessment system must be accounted for in the Plan itself.
- **Key-element 5:** the ongoing process of Adaptive Planning and Management (associated to the continuous process of coastal climate adaptation and iterative risk management) which is learning-oriented and allows the adaptation of the Plan over time, and under uncertain future change.

The analysis of the Reference Cases also allowed the identification of important sub-elements / ingredients of the Key-element 3 that provide *dynamic robustness*, *flexibility*, and *adaptability* to an *adaptive plan* (or its strategies), namely:

- By having the possibility to switch of measure and / or pathway, if developments prompt so. The APs' method allows switching of measures (i.e. changing, adding additional measures, or shifting to a new measure) and of pathways (i.e. switching from a pathway to another), to manage changing levels of risk over time.
- By having (availability) of various possible measures and options (pathways) available, i.e. more than one option for the future.
- By keeping open options for the future, which implies not foreclosing future options unnecessarily, avoiding lock-ins, and selecting measures required now to keep other options open in the future.
- By linking measures envisioned for the short-term to options in the long-term.
- Through a phased / stepwise implementation of a measure / strategy, in several incremental steps or smaller projects (e.g. several operations of beach nourishment programmed over time).
- By using robust measures (that perform well under a wide range of plausible future scenarios, or which increase the robustness of a system).
- By using flexible measures (measures that are inherently *flexible*, e.g. that can be easily changed / modified / altered).
- By using low-/no-regret measures (with properties like reversibility, correctability, flexibility, that are cost-beneficial regardless of how the future unfolds), e.g. win-win measures.
- By using a diversity of measures (in the case of flood risk management, a variety of measures can be used, (namely measures to reduce flood probability, to reduce the vulnerability and potential impacts and to reduce the exposure), in the case of coastal climate adaptation (soft and hard protection measures, accommodation measures, and planned retreat measures). This implies including various measures (structural, non-structural, physical and institutional, across different scales and sectors).
- By having the possibility to alter the timing of measures (i.e. postponing or anticipating a given measure) in accordance with the monitored / observed changes in certain indicators and in function of critical thresholds / tipping-points previously defined. The monitoring and reassessment system allow switching of measure or pathway, or postponing / anticipating a measure in time.
- By mainstreaming FRM and coastal climate adaptation measures into other investments and agendas (integration of measures into other planned or expected investments).

These are the main ways of delivering and enhancing *dynamic robustness*, *flexibility*, and *adaptability* in a plan (and its strategies) – which are key principles underlying the paradigm of Adaptive Planning.

Table 12 sums the key-elements of an Adaptive Planning approach that are essential to develop a *dynamic adaptive plan* (i.e. *dynamically robust and adaptive* plan), which were extracted and derived from the analysis of reference cases (TE2100 and DP 2014) and related scientific literature, in Part A.

Table 12. Key-elements of an approach of Adaptive Planning and Management (based on reference cases and related literature)
Key-element 1: To consider a wide range of *plausible future scenarios* (different climate, physical, and socioeconomic scenarios), rather than a single probabilistic projection of the future, and use them to assess the proposed measures and strategies on their effectiveness (Jeuken et al. 2014, p.1,3, 23, 10; Jeuken and Reeder 2011, p.2, 6; Walker et al. 2013, p.969-970). This key-element consists of working with a wide range of plausible future scenarios and using them in assessment of measures and strategies (pathways) regarding their effectiveness (Jeuken et al.2014, p.3, 10). It is necessary to consider various plausible futures to assess what measures can be used to achieve the objectives regardless of how the future unfolds (Walker et al. 2013, p.970). The scenarios should represent the main uncertainties about future conditions and changes. In the TE2100 case, the range of plausible future scenarios (of future water level rise) was used to test the effectiveness of measures, develop, and appraise the pathways (Ranger et al. 2013, p.233, 239, 258). In DP 2014 case, the Team worked with several 'plausible futures' called '*Delta Scenarios*' (DP 2011, p.48, 71; 2013, p.6).
Key-element 2: To identify critical thresholds or *Adaptation Tipping-points*, i.e. conditions under which the current or an alternative measure fails (ceases to be effective / meet the objectives), or the current system performs unacceptably, and a new measure is needed (Walker et al. 2013, p.970; Jeuken et al. 2014, p.17; Reeder and Ranger 2011, p.5; Ramsbottom and Sheppard 2017, p.4; Zandvoort et al. 2018, p.190). The TE2100 Team analysed 'what amount of change can the system cope with before it runs into trouble' (Jeuken and Reeder 2011, p.2), and, in this way, identified thresholds in the vulnerability of the existing FRM system, which were the starting point for the planning of measures and pathways (Jeuken and Reeder 2011, p.3, 2; TE2100 Appendix L 2009, p.5). In the DP case, this element involved the identification of ATPs, i.e. points where the objectives of the FRM policy (including coastal and river FRM) are no longer met. This required analysing the vulnerability of the existing system as the starting point and examining 'what amount of change can the system handle before it runs into trouble' (Jeuken and Reeder 2011, p.3, 2).
Key-element 3: To develop a '*robust and flexible* set of measures', to deal with uncertain future changes, by using the 'Adaptation Pathways approach' (APs) (Jeuken et al. 2014, p.23, 1, 3). This element involves developing (designing) *robust flexible strategies* (with measures that are *robust* and / or *flexible*), by using the APs approach, to cope with uncertain future change (Jeuken and Reeder 2011, p.2-3). Here, a strategy is itself a set of sequenced measures, a pathway. One of the main elements of an Adaptive Planning approach is '*to respond to uncertain change with a robust and flexible set of actions'* (Jeuken et al. 2014, p. 23, 1). In an Adaptive Planning approach, measures (actions) must be *robust*, *flexible* (Jeuken et al. 2014, p.3; based on Sayers et al. 2012), and should also be '*low/ no-regrets'* as much as possible (Jeuken et al. 2014, p.3). The development a '*robust* and *flexible* set of measures' requires the consideration of *robustness*, *flexibility* and low-regrets properties (reversibility, adaptability, etc.) in the selection of measures and in development of strategies (ibid, p.3). In simple terms, this key-element consists of designing *robust flexible strategies* (Jeuken and Reeder 2011, p.3, 2), which, in the Reference Cases, was done using the 'Adaptation Pathways approach' (APs, also called Route-map approach). This requires the development (design) of *robust flexible strategies*, through the 'APs approach' (Jeuken and Reeder 2011, p.2-3). The 'Adaptation Pathways approach' (APs) is a methodological approach for '*exploring and sequencing a set of possible actions based on alternative external developments over time*' (Haasnoot et al. 2012, p.485); it is an Adaptive Planning approach. The APs offers a method to construct a '*dynamic adaptive plan / strategy'* that is *robust and flexible* (Ranger et al. 2013, p.249). The APs approach involves '*envisioning different options and possibilities for switching between them, through adaptation pathways*', thus, in this approach, '*short-term decisions are coupled with long-term options*' (Jeuken et al. 2014, p.1). The 'APs approach' allows switching between different options in the future (Jeuken et al. 2014, p.10). In the APs approach, a pathway / route is a *package* of measures that are sequenced and implemented over time (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8). Each pathway consists of a set of measures (individual measures or groups of measures) that are sequenced and implemented to manage risk over time. Several pathways are usually designed in an APs' map. Each pathway is itself flexible (e.g. it is possible to switch from a measure to another), and it is also possible to move from a pathway to another, depending on the rate of change that actually occurs (Reeder and Ranger 2011, p.9; TE2100 Appendix L 2009, p.4; Lowe et al. 2009, p.89; Jeuken and Reeder 2011, p.4; Jeuken et al. 2014, p.18). In the APs, measures are implemented iteratively over time to keep risk below the target levels, and, at the same time, keeping open options (alternatives) to manage future risk (Ranger et al. 2013, 247, 249, 239; Reeder and Ranger 2011, p.13). In the APs approach, the Plan and its strategies are '*designed to be adjusted over time as more is learnt about the future*' or as changes occur (Ranger et al. 2013, p.249). The timing for new interventions, and the interventions themselves, can be changed (modified) over time, therefore, flexibility is built-in into the long-term strategy itself (Ranger et al. 2013, p.249). In the TE2100, this element involved the design of *robust flexible strategies* – as pathways– by using the 'Route-map / APs approach' (Jeuken and Reeder 2011, p.2-3), i.e. the development of '*robust flexible strategies*' (sets of measures) required the design of pathways / routes with the 'APs approach'. As seen, the TE2100's '*Dynamic Adaptive Planning approach'* contained a new method to construct a '*dynamic adaptive plan/strategy'* that was '*robust'* and '*flexible'*: the 'Route-map / Adaptation Pathways' approach' (APs) (Ranger et al. 2013, p.249). The 'APs approach' resulted in a *dynamic adaptive plan* that is:

dynamically robust to uncertain future change and *adaptable* to change (the pathways can be adapted as changes occur in climatic, physical or socioeconomic conditions) (EA 2012, p.1, 29, 35, 39; TE2100 Appendix L 2009, p.3; Ranger et al. 2013, p.239; Bloemen et al. 2018, p.12; Jeuken et al. 2014, p.2,4,19, 21).

In the DP 2014 case, this key-element consisted of the development of '*adaptation paths*' (DP 2011, p.48; 2012, p.88, 81; 2013, 102; 2014), i.e. the design of sets of measures as pathways. Each '*path'* is a pathway, a set of measures sequenced. One of the main principles of Adaptive Delta Management (ADM) was working with 'multiple strategies between which it is possible to alternate', so-called 'adaptation paths' (i.e. pathways) (DP 2011, p.48; 2012, p.88; 2013, p.102; 2014); which also one of the main elements required to design an adaptive programme. ADM uses the APs method (Haasnoot et al. 2012, 2013).

Key-element 4: To continuously monitor relevant changes and new information, and reassess the Plan, and adjust it accordingly. This requires: a targeted monitoring of relevant changes (in external conditions, effects of measures) and continual evaluation of new information (e.g. updated scenarios); and the regular reassessment (review) of the Plan, and, if necessary, its adjustment (i.e. updating, redefining or modifying policies, measures, pathways, or implementation plans, according to the monitoring outputs) (Jeuken et al. 2014, p.1, 23, 3; Sayers et al. 2012, p.282; Walker et al. 2013; Bloemen et al. 2018; Jeuken and Reeder 2011, p.7). This allows the adjustment (adaptation) of the Plan and its measures.

Important changes are continuously observed and foreseen through targeted monitoring and future scenarios are reassessed; and the Plan is regularly revaluated, and its policies, measures or pathways are appropriately adjusted / adapted (Jeuken et al. 2014, p.3; Sayers et al. 2012, p.282). The monitoring and reassessment system must be accounted for in the Plan itself (Jeuken et al. 2014, p.3). The monitoring of local and global changes is necessary to examine if decisions should be taken earlier or postponed, revised or altered (Jeuken and Reeder 2011, p.6). This implies the capacity to alter (adapt) the Plan (its policies, measures, or the timing for applying measures), as new information and knowledge arise or as changes occur.

In the TE2100, this required the definition of a monitoring system, which specifies indicators to be monitored as well as decision-points that trigger the implementation of measures based on the observation of indicators (Ranger et al.2013, p.233, 239, 258). The decision-points help to ensure that measures are timely taken and cost-effective (Ranger et al. 2013, p.233, 239, 258; Jeuken and Reeder 2011, p.6; Ramsbottom and Sheppard 2017, p.5, 12).

In the DP case, this element consists of the monitoring of developments and new insights, and of the reassessment of the plan (its strategies, measures, or choices, planned or implemented), and, if necessary, their adjustment / review (if developments prompt so) (DP 2016, p.5-6, 59; 2017, p.7; 2014, p.7).

Key-element 5: the ongoing and *decision-centred* planning process, which associated to an iterative risk management cycle (and to the continual process of coastal climate adaptation), and which involves several steps necessary to develop a *dynamic adaptive plan* and essential to operationalize an Adaptive Planning and Management: 1) definition of objectives and analysis of risks , vulnerabilities and potential impacts now and in the future; 2) examination of critical thresholds and tipping-points); 3) identification of possible measures and 4) development of various strategies/ pathways under a wide range of scenarios; 4) choice of preferred pathway (decision-making) as input for designing an 'action plan') and the definition of the monitoring and reassessment system of the Plan; 5) implementation of planned actions, and 6) monitoring of external conditions and reassessment of the Plan and, if necessary, its review (correct or alter) the Plan, its measures or their timing. This continual iterative process seeks to ensure ongoing learning and it is essential to safeguard the adaptability of the general Plan over time, so that it can better deal with change and uncertain future conditions.

Table 12. The five key-elements of an *Adaptive Planning and Management approach* that were identified in Part A, drawing on the Reference Cases and scientific literature on Adaptive Planning and Management approaches. Source: own elaboration. See more in Note 296.

According to the **paradigm of Adaptive Planning**, in face of deep uncertainties, planners need to design *adaptive plans / policies* or '*dynamic adaptive plans*', i.e. plans that are robust across a wide range of future scenarios and that can be adapted to changing conditions over time, so that they 'survive change' (Haasnoot et al. 2013, p.485; Walker et al. 2013). Such plans / policies must be *robust* and *adaptive*: a robust plan / policy performs well (*satisfactorily*, *successfully*) under a wide variety of plausible futures, while an adaptive plan / policy can be adapted over time to unforeseen and changing future conditions (Haasnoot et al. 2013, p.496; Walker et al. 2013, p.956, 955, 972; Kwakkel et al. 2015, p.374; Ranger et al. 2013, p.247; Gersonius et al. 2016, p.1; Jeuken et al. 2014, p.2; Maier et al. 2016, p.159). According to Walker et al., a robust plan is '*one that yields outcomes that are deemed to be satisfactory according to some selected assessment criteria across a wide range of future plausible states of the world*'; and an adaptive plan is '*a plan that can adapt to changing conditions*', and which '*is developed in light of the multiplicity of plausible futures that lie ahead, and is designed to be changed over time as new information becomes available*'; it '*allows for its adaptation over time to meet changing circumstances, and can thus be considered a sustainable plan*' (Walker et al. 2013, p.958).

Several approaches to develop 'adaptive plans' have emerged, within the paradigm of Adaptive Planning (Jeuken et al. 2014, p.2), among them the 'Adaptation Pathways approach' (APs, also called Route-map approach).

Jeuken et al. identify three main elements of Adaptive Planning: 1) *to prepare for a wide range of plausible future scenarios (climate, subsidence, socio-economic)*, 2) *to respond to uncertain change with a 'robust and flexible set of actions'*, and 3) *to monitor critical changes to be able to reassess the plan accordingly*' (Jeuken et al. 2014, p.23, 1). Based on Sayers et al. (2012), the authors explain that, in an Adaptive Planning approach, '*responses to changes are effective under the widest set of all plausible future scenarios*', and '*responses do not foreclose future options or unnecessarily constrain future choices*'; and '*relevant changes are foreseen through targeted monitoring and scenarios of the future are continuously being reassessed; and policies, strategies and structure plans are appropriately redefined*' (Jeuken et al. 2014, p.3, based on Sayers et al. 2012).
Jeuken et al. (2014, p.3) add to this, *no- / low-regret'* actions (with properties like *robustness, flexibility, reversibility*).
All this implies considering robustness, flexibility, and low-regret properties, in the selection of actions that a Plan contains.

Robustness* and *flexibility

The idea is to safeguard the robustness and flexibility of the Adaptive Plan / Policy (Jeuken et al. 2014, p.6, 10). As referred, the robustness of a Plan concerns its capacity to '*perform well under a wide range of plausible futures*', while the flexibility of a Plan is related to its ability to be '*adapted if the future unfolds differently than foreseen*' (Jeuken et al. 2014, p.2). These characteristics may also apply to the Plan's actions (measures).

In the context of Adaptive Planning, 'flexibility' is '*a characteristic of the plan that enables coping with uncertain futures*', which implies that '*decisions in the near future on concrete actions for adaptation to climate change should not foreclose future options to react differently and switch or add actions if climate or societal changes ask for it; and on the other hand, when it is decided to postpone adaptation actions (i.e. there is no urgency yet), developments that take place in the near future should not foreclose future options for adaptation*' (Jeuken et al. 2014, p.16).

Actions (measures) should be '*chosen to remain flexible with respect to uncertain future changes and/or to create a robust system that may better cope with extreme events*' (Jeuken et al. 2014, p.3). Working with a wide variety of scenarios aids in exploring the long-term robustness of the plan (Jeuken et al. 2014, p.14). The challenge is also '*to design actions that are also able to cope with potential future conditions (robust actions) or design actions that leave room for adaptation if needed, and seize opportunities once they arise*', thus, it is important '*to link (potential) future actions to current problems, for example by searching for win-win options*' (Jeuken et al. 2014, p.24). Measures are also robust if they increase a system's resilience (capacity to '*cope with and recover from uncertain future flood hazards*'), or '*incorporate large safety margins and increase the resistance of the system*' (ibid). Flexibility can also be delivered through: a) a phased / stepwise implementation of many adaptation measures or various smaller projects (though there may be cases where a single large-scale investment is more cost-effective); b) the use of a diversity of measures (across sectors and actors); c) the integration of adaptation with coastal planning and management (*mainstreaming*) (Jeuken et al. 2014, p.10, 16, 18).

One way of ensuring flexibility of a Plan and in its strategies and actions, it to use the 'Adaptation Pathways approach' (APs, also called 'Route-map approach'. The APs can be used to develop '*a robust and flexible set of actions*'.

In the APs approach, '*short-term decisions are coupled with long-term options*', and it involves '*envisioning these options and possibilities for switching between them through adaptation pathways*' (Jeuken et al. 2014, p.1). The APs approach '*allows switching between different options in the future*', and, in this way, remaining flexible (Jeuken et al. 2014, p.10). The cases of the TE 2100 and DP 2014 show that, the Plan's flexibility is increased if it contains '*multiple pathways* (which *allow switching between different options in the future*)', and '*if measures can be implemented stepwise or if there is the possibility of switching to other measures*' (Jeuken et al. 2014, p.18). In both cases, short-term actions are explicitly linked to long-term options, and the APs' maps show '*clearly marked thresholds defining when to decide to switch from one action to another*', which '*ensures maximum flexibility*' (Jeuken et al. 2014, p.24).

In the APs, measures are implemented iteratively over time to keep risk below target levels, while *keeping open options* (alternatives) to manage future risk (Ranger et al. 2013, 247, 249, 239; Reeder and Ranger 2011, p.13) (see Note 297).
A pathway is a *package* of measures sequenced and implemented over time (Ranger et al. 2013, p.249; Reeder and Ranger 2011, p.8). Each pathway contains a set of measures (individual or grouped) that are implemented over time to manage risk. Several pathways are usually designed in an APs' map. Each pathway is itself flexible (e.g. it is possible to switch from a measure to another), but it is also possible to move from a pathway to another, depending on the rate of change that actually occurs (Reeder and Ranger 2011, p.9; Lowe et al. 2009, p.89; Jeuken and Reeder 2011, p.4; Jeuken et al. 2014, p.18). In the APs, a Plan and its strategies are '*designed to be adjusted over time as more is learnt about the future*' or as changes occur. The timing for new interventions, and the interventions themselves, can be changed (modified) over time, therefore, flexibility is built-in into the long-term strategy itself (Ranger et al. 2013, p.249).

Part B: Portuguese Case-Studies

ANSWERING THE SPECIFIC RESEARCH QUESTIONS III, IV, AND V

INTRODUCTORY NOTE

In this section, the study-cases are two Portuguese coastal management programmes (*Programas de Orla Costeira – POCs*): 1) the Coastal Programme Caminha-Espinho (*Programa da Orla Costeira Caminha-Espinho POC-CE*, which is under approval), focussing on the coastal zone of the Metropolitan Area of Porto; 2) the Coastal Programme Alcobaça-Cabo Espichel (*Programa da Orla Costeira Alcobaça-Cabo Espichel, POC-ACE*), focussing on the coastal zone of the Metropolitan Area of Lisbon.

Importantly, both cases (the two POCs selected) claim that they have purposely adopted and followed an approach of 'adaptive planning and / or management' to develop and implement the Programme and its strategies, namely its strategies of coastal climate adaptation.

This section focussed on these two cases in order to analyse and answer the following research questions:

III. Is an Adaptive Planning and Management approach being introduced and applied in the Portuguese cases, to address coastal adaptation / coastal risk management? Did the selected cases apply approaches of Adaptive Planning and Management? How do these cases define their approach of adaptive planning and management?

IV. Whether, and how, are the five key-elements of an Adaptive Planning and Management approach being used in the two cases? Are the key-elements essential to develop an 'adaptive plan / programme' present in each case*?*

V. What barriers can be found in the two cases that hinder a truly *Adaptive Planning and Management* of the coastal zones, and a *more adaptive* approach to coastal climate adaptation (its planning, implementation, and monitoring)?

This chapter seeks to answer the specific research questions III, IV and V, first in relation to the case of POC-CE, and then in relation to the POC-ACE, and finally, it provides synthesis and a common answer to the question VI drawing on both cases [1].

Part B is structured as follows:

- Chapter I provides a description of the framework of coastal planning and management in which the POCs (2nd generation of Portuguese coastal management plans) have emerged. It includes an analysis

[1] This answer to the question VI will be delivered in the end of March in conjunction with the delivery of the POC-ACE case.

of all major references to Adaptive Planning and Management of coastal zones found in the Portuguese literature, including guidance documents that served as benchmarks for the elaboration of the selected POCs.

Then, each study-case is structured in the following way:

- **Section 1** presents the POC-CE / POC-ACE, and its main characteristics (objectives, drivers, requisites, etc.)
- **Section 2** presents the Adaptive Planning / Management approach that was adopted in each case and describes how is conceptualized and framed.
- **Section 3** outlines the process of elaboration of the POC and the most relevant phases.
- **Section 4** provides an overview of the contents of the POC (Territorial Model, Directives, Program of Actions, and Monitoring and Evaluation System), and then discusses some of the main contents.
- **Section 5** analyses whether the five key-elements of an Adaptive Planning and Management approach (essential to develop an ‘adaptive plan / programme’) are present in the POC. It compares each study-case against the five key-elements that were identified in Part A as characteristic and crucial in an Adaptive Planning and Management approach (drawing on the reference cases).
- **Section 6** identifies barriers to, and difficulties in, the real introduction and application of an Adaptive Planning and Management approach in the POCs.

In terms of methodology, this section results from an in-depth analysis of each the two Portuguese cases, an analysis of guidance documents that were used by the Project teams that elaborated the POCs as references for their elaboration, and a review of scientific literature referring to coastal management and planning in Portugal focussing on the topics (keywords) of adaptive planning / adaptive management.

I. COASTAL SPATIAL PLANNING FRAMEWORK IN PORTUGAL

1. PLANNING AND MANAGEMENT OF COASTAL ZONES, AND COASTAL RISK MANAGEMENT

The Portuguese spatial planning system, including the Programmes of the Coastal Zone (*Programas da Orla Costeira – POCs*) – which are the main spatial planning instruments for coastal planning and management and coastal risk management – is presented in Figure 1. It shows the relation between the various spatial planning instruments, namely *national programmes*, *regional programmes*, *and municipal plans*, and other *strategies* and plans at the national, regional and municipal level), and where the POCs fit in this structure. The POCs fit within the '*Special Programmes*'. For more on the Portuguese spatial planning system, see Note 300.

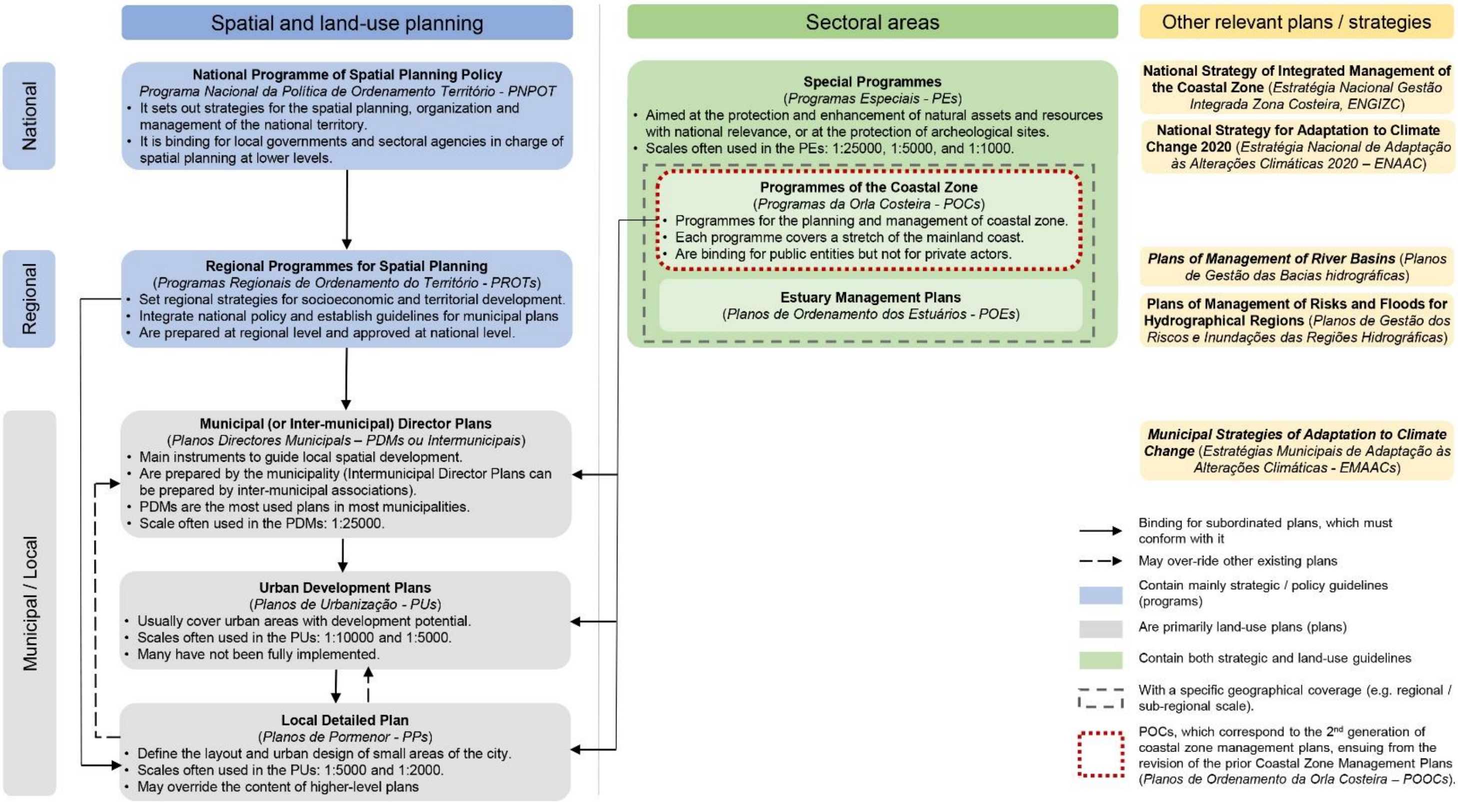


Figure 1. The Portuguese spatial planning framework, and the location of the POCs within it. Source: own elaboration based on OECD 2017, p.173-178; POC-CE 2018 f, p.105; POC-CE 2015, p.24; POC-ACE 2018, p.171-184.

The main laws and decree-laws that constitute the reference framework of the elaboration of POCs are:

- *Decreto-Lei n.º 80/2015* (it approves the review of the '*Regime Jurídico dos Instrumentos de Gestão Territorial*'). According to this Decree-Law, the Programmes of the Coastal Zone (POCs) are 'special programmes'. *Special programmes* aim at the prosecution of objectives indispensable for the guardianship of national interests and resources with territorial repercussion, including the management of coastal risks / coastal adaptation. The *special programmes* must establish regimes of safeguard of natural resources and values, through the definition of actions that are allowed, conditioned and forbidden. The *special programmes* superimpose over (subordinate) intermunicipal and municipal spatial plans (POC-CE 2018, p.7; POC-ACE 2018, p.19).[2]

[2] The Special Programmes aim to safeguard objectives of national interest with territorial incidence and assure conditions for the permanence of systems indispensable to the sustainable utilization of the territory. For concretizing such objectives, the Special Programmes establish regimes of safeguard of the natural resources and values and a regime of management compatible with the sustainable utilization of the territory, through the establishment of actions allowed, conditioned or interdict, in function of the respective objectives (POC-ACE 2018 d, p.49).

- *Artigo 21.º, da Lei n.º 58/2005, de 29 de dezembro*. It defines the area of intervention of the POCs.
- Law nº31/2014 (which approves the *Lei de Bases Gerais da Política Pública de Solos, de Ordenamento do Território e de Urbanismo – LBSOTU*). It explains that the first POOCs (*Planos de Ordenamento da Orla Costeira*, i.e. Coastal Zone Management Plans), which were *special spatial plans*, must be reviewed as POCs (Programmes of the Coastal Zone), i.e. *special programmes*.
- *Decreto-Lei n.º 159/2012, altered by the Decreto-Lei n.º 132/2015.* It explains that the new POCs must encompass all areas of the coastal zone, as such, they must include port areas. The limit of the land area of the POCs can also be extended from 500m width to 1000m width. It identifies the objectives for the management of the coastal zone, which must guide the elaboration of the new POCs. According to this Decree, the POCs must carry out *'the identification of 'risk strips / bands' and establish the respective regimes of safeguard, considering the diverse uses and occupations, in a mid- and long-term perspective* (*in* POC-CE 2020, p.13). This Decree-Law altered the rules for the elaboration and implementation of the coastal management plans (POC-CE 2015 b).

Other planning and policy documents regarding coastal risks and coastal adaptation

The main policy and guidance documents, national strategies / plans, that served as a reference for the POCs and guided their elaboration, and which contain objectives related to coastal climate adaptation / coastal risk management, are identified in Figure 1. In addition, the following documents were important for the elaboration of the POCs (according to POC-CE 2018 f, p.105; 2015, p.24; see also Note 301):

- Situation Plan of the National Maritime Space (*PSOEM*).
- National Water Plan (*Plano Nacional da Água – PNA*).
- Plan of Action 'Plano de Ação Litoral XXI' (*PAL XXI*). It stems from the ENGIZC and it defines the actions for the development of the coastal zone in the next 20 years (in CEZCM / APRH 2020).
- Report of the *Working Group for the Littoral* (GTL 2014). After the extreme storms of 2013-2014 Winter, and in the face of expected aggravation of the risks of coastal erosion and flooding, the Government decided to create a Working Group for the Littoral (*Grupo de Trabalho para o Litoral – GTL*) with the aim of developing an in-depth reflexion on the coastal zones that leads to the definition of a set of measures that allow, in the mid-term, altering the exposure to risk, including in this reflexion the sustainable development under scenarios of climate (*in* POC-CE 2018, p.19; and POC-ACE 2018, p.40).
- Assessment Report of the Implementation of the 1st POOCs (*Relatório do Balanço da Implementação dos POOCs de 1ª geração*).

Institutions responsible for coastal planning and management, and coastal risk management

In Portugal, the management of coastal risks has traditionally fallen within the public responsibility, and particularly as one of the various functions of the spatial planning system. Currently, the responsibility for coastal management and planning is under the Portuguese Environment Agency (*Agência Portuguesa do Ambiente – APA*). Moreover, in Portugal, the cost of coastal protection works has been borne, almost exclusively, by public money (national budget) and Community funds (these correspond to 70% to 100%) (according to the GTL 2014 b). Since 1995, the Community funds for coastal protection have exceeded the national funds, particularly in the last decade (GTL 2014 b).

Given the diversity of uses, activities and resources located on coastal zones, these territories and their governance are characterized by a great complexity and the overlapping of jurisdictions, which has constituted a strong obstacle to the resolution of systemic problems that require integrated approaches and institutional coordination (POC-CE 2018, p.42).

1.1. RECENT CHANGES IN THE LEGAL FRAMEWORK WITH REGARD TO THE SPATIAL PLANNING OF COASTAL ZONES

The Programmes of the Coastal Zone (*POCs*) correspond to the review of the prior Coastal Zone Management Plans (*Planos de Ordenamento da Orla Costeira, POOCs*) which correspond to the first coastal management plans implemented in Portugal (mostly approved in the 1990s). Since the publication of the POOCs, there has been a reform in the legal and institutional framework regarding spatial planning and management of coastal zones and the protection and valorisation of water resources. Moreover, the conditions that led to the elaboration of the 1st POOCs have evolved and changed, and, thus, it was necessary to update and adjust the contents of the POOCs (POC-CE 2018, p.7).

In accordance with the new Law n.º 31/2014 (*LBSOTU*), the prior Special Plans (*Planos Especiais de Ordenamento do Território*) must be reconfigured as 'special programmes' (*Programas Especiais*), thus, the prior Coastal Zone Management Plans (POOCs) must be reviewed and redefined as 'Programmes of the Coastal Zone' (*Programas da Orla Costeira – POCs*) (POC-CE 2018, p.7).

The new legal framework brought important changes to the planning and management of coastal zones:

- According to the Decree-Law n.º 159/2012, the '*Terrestrial Protection Zone*' may be extended from the (prior) 500m to 1000m width, whenever this is justifiable by the need to protect biophysical systems (POC-CE 2018, p.7, 8). Thus, the new POCs may extend their area of intervention up to the 1000m width whenever the protection of coastal ecosystems justifies it (POC-ACE 2018, p.20).
- According to the Decree-Law n.º 159/2012, the new POCs must encompass all the areas in the coastal zone, namely port areas (POC-CE 2018, p.7, 8). Thus, the new POCs must ensure the conditions necessary for the development of port activity (POC-ACE 2018, p.20).
- In line with the DL n.º 159/2012, and given the expected aggravation of coastal risks associated to the effects of climate change, the POCs are obliged to identify 'risk zones / strips' (*faixas de risco*) and define the regimes of safeguard for such strips, considering the diverse uses and occupations, with a mid- and long-term perspective (POC-CE 2018, p.7, 8, 20).
  The POCs should ensure a more effective application of the principle of precaution. The aggravation of coastal erosion during the first decade of the 21st century and recognition of an increase in the frequency and intensity of extreme weather events associated to climate change, required new responses from public policies, namely the adoption of adaptation measures (protection, accommodation, and relocation / planned retreat) that reduce the exposure of people, activities and infrastructures to risks (POC-ACE 2018, p.20).
- The new POCs' regime is no longer binding for private actors (the prior POOCs were suppletive spatial management instruments which had a regulatory character and were binding of public and private entities). Regardless of this, the new POCs must contain a normative (regulatory) content (referring to the safeguard and management of natural resources and values) that must be incorporated in the intermunicipal and municipal spatial plans (POC-CE 2018, p.7-8). With the new legal framework, the planning and management of coastal zones must be ensured through the POCs, and the new POCs are only binding for public entities (no longer for private actors, as the prior POOCs were), therefore, their content must be integrated in the spatial plans at intermunicipal and municipal levels (POC-ACE 2018, p.20).
- Finally, the new legal framework introduced a paradigm shift in relation to the old POOCs: the new POCs are given a more strategic character (POC-CE 2018, p.8) (see more in Note 302).

1.1.1. Principles to be considered in the new POCs

The Decree-Law n.º 159/2012 (altered by the Decree-Law n.º 132/2015, de 9 de julho) sets seven general principles to be observed in the elaboration of the POCs:

1) Sustainability and intergenerational solidarity, which involves promoting the compatibilization, in the territory, between socioeconomic development and the conservation of nature, biodiversity and geodiversity, in a framework that ensures the quality of life of current and future populations.
2) Cohesion and equity, by ensuring social and territorial balance and a balanced allocation of resources.
3) Prevention and precaution, by predicting and anticipating consequences and adopting a precautionary attitude, by minimizing risks and negative impacts.
4) Subsidiarity, by coordinating the procedures at the various levels of the Public Administration, by considering the regional and local levels and their specificities, in a way that allows decisions to be taken closer to the citizen.
5) Participation, which implies enhancing the involvement of the public, institutions and local actors, and their access to information and intervention during the elaboration, execution, evaluation and review of POCs.
6) Shared responsibility / accountability, which implies the sharing of responsibilities among the community, economic agents, citizens, and social organizations, for the management options.
7) Operationality, by creating efficient and effective mechanisms (legal, institutional, financial and programmatic mechanisms) able to ensure the achievement of the objectives and the realisation of the respective interventions (DL n.º 159/2012, *in* POC-CE 2018, p.29; POC-ACE 2018, p.33).

The principles of subsidiarity, participation, shared responsibility, and operationality, are related with the way of preparing the POCs and influenced the elaboration and definition of their management and follow-up model. The principles of sustainability, intergenerational solidarity, cohesion and equity, and prevention and precaution, guides the conception of the Strategic Model, Territorial Model, and normative content that delivers the Regimes of Safeguard (POC-ACE 2018, p.33).

1.1.2. Objectives set for the new POCs

The DL n.º159/2012 defines that the elaboration of the POCs must attain to the following **general objectives** (DL nº159/2012, *in* POC-CE 2018, p.8; 32; and *in* POC-ACE 2018, p.20-21):

- Public fruition of the Public Maritime Domain (*Domínio Público Marítimo*) in safety.
- Protection of the biophysical integrity of space, conservation of environmental and landscape values.
- Valorisation of the resources existing in the coastal zone.
- Flexibilization of the management measures.
- Integration of the local identities and specificities.
- Creation of conditions for the maintenance, development and expansion of coastal activities relevant for the country, namely port activities and other socioeconomic activities dependent on the sea or coast, and emergent activities that contribute to local development and to counteract seasonality.

According to the Decree-Law n.º159/2012, the **specific objectives** of the POCs are:

- *Establish regimes of safeguard of natural resources and values, as well as the regimes of sustainable management of the territory of the coastal zone.*
- *Promote the sustainable development of the coastal zone through a prospective, dynamic and adaptive approach that boosts competitiveness as a productive space and generates wealth and employment.*

- *Ensure the compatibilization of the different uses and activities specific of the coastal zone with the aim of promoting the utilization of resources of this zone considering the carrying capacity of the natural systems and sewage systems.*
- *Promote the requalification of hydric resources, with attention to the connections and interdependencies between coastal and inland hydric resources and natural systems associated.*
- *Valorise and qualify the beaches, namely those strategic for environmental and touristic reasons.*
- *Classify and regulate the use of beaches (bathing beaches).*
- *Protect and valorise marine and land ecosystems, ensure conservation of nature and biodiversity.*
- *Identify and establish regimes of safeguard of the 'risk strips' in the face of the diverse uses and occupations in a mid- and long-term perspective.*
- *Ensure the articulation between spatial planning instruments, plans, programs at the local, regional, and national level, applicable to the area of the POCs.*
- *Ensure, in the port areas, the conditions for the development of port activity and respective maritime and terrestrial accessibilities, in line with the spatial planning instruments applicable* (DL nº159/2012, *in* POC-CE 2018, p.34).

1.2. Factors that led to the development of the new POCs

This section outlines the main factors that led to the need to develop the new POCs (and revise the 1st POOCs). Over the last decades, several changes have contributed to increase coastal risks, namely: socioeconomic and urban development pressures, and climate change and its effects, especially SLR.

Increasing risk of coastal erosion and coastal flooding

Since the middle of the 20th century, the Portuguese mainland coastal zone has suffered increasing coastal erosion phenomena, largely resultant from unbalances generated by anthropic actions. Such erosive trend will progressively be aggravated by climate change in the mid-term (2050) and long-term (2100). It will be increasingly necessary to protect the littoral, and the costs of such protection will likely increase throughout the 21st century and beyond (GTL 2014 b). Importantly, the issue of climate change on coastal zones was already highlighted in the '*2009 National Strategy of Integrated Management of the Coastal Zone*', namely in the Measures 1, 7, 8 and 11 (ENGIZC 2009).

In the west coast, the wave patterns are highly energetic (it is one of the most energetic coast of Europe), with high values of littoral sediment transport. This strong sediment transport, in conjunction with the decreasing supply of sediments to the littoral, which has initiated since the 1950's (due to human activities in river basins and coastal zone), have led to significant erosion problems which are being aggravated with climate change effects, namely SLR (GTL 2014 b).

Currently, the main problem is erosion, which, in conjunction with the intensifying occupation, constitutes a risk for human systems as well as a risk of loss or degradation of coastal natural systems. The risk of coastal erosion is obviously greater where there is human occupation of vulnerable zones, particularly where occupation results from bad spatial planning. The excessive and disordered occupation of the coastal zone continues to occur, especially by means of urbanization associated to 'vested rights' (many of them prior to the POOCs and sometimes prior to the PDMs), and by means of illegal occupations of the littoral areas (GTL 2014 b).

The GTL analysed the recent evolution of the mainland Portuguese coastline: it examined the sediment balance for a 'reference situation' and for the 'current situation'. The mainland Portuguese coastal zone was divided into 8 'sediment cells'[3], and for each of them, it was calculated the sediment balance for the 'reference situation' and the 'current situation'. The 'current situation' is representative of the last two decades, and the 'reference situation' corresponds to the situation prior to the existence of strong anthropic disturbance on the sediment balance associated to the construction of dams in rivers, engineering works on the coast, namely breakwaters at the entrance of ports in river mouths, sand extraction in rivers and in the coast, etc. (similar to the situation that might have existed in most of the Portuguese coast in the 19th century) (GTL 2014 b, *in* POC-CE 2015, p.426; POC-ACE 2018, p.40). In other words, the GTL estimated the magnitude of sediment imbalance of the various sediment cells; for each cell, the GTL carried a geomorphological characterization and assessed the sediment balance in a 'reference situation' and in the 'current situation' (through the quantification of the entrances (sources) and exits (sinkholes) of sediments) (POC-ACE 2018, p.40) (Note 303).

The GTL analysis of the recent evolution of the mainland Portuguese littoral showed that there are significant sediment deficits in some areas (GTL 2014 b, *in* POC-CE 2015, p.426; POC-ACE 2018, p.40).[4] Given this, the GTL emphasized the central role that sediment management should assume in the strategies of intervention and mitigation of erosion to be taken in the POCs (POC-ACE 2018, p.40).

Sediment deficit and *artificialization pattern* (urban development), as drivers of increasing risks

There has been '*an increasing sediment deficit (due to the retention of sediment in dams and the dredging works undertaken in ports*)', but also into '*an intense, and often deregulated, urban growth, observed since the 1970's*' (GTL 2014, *in* POC-CE 2018, p.48). Moreover, there has been a 'pattern of artificialization', which is described in the GTL Report: '*the history of coastal defence interventions the low-lying coastal zones has followed a pattern that leads to an increasing artificialization and which demonstrates a predominantly reactive policy. In the coastal stretches with significant coastal drift, the response to erosion started with the construction of groynes in the attempt to fix sediments in the front of the human settlement. With the increasing sediment / sand deficit, the beach has continued to retreat, and given this, a new defence (adherent structure) was constructed. With the continuing increase of the sediment deficit, the defence work has degraded and was then reinforced and / or extended, and eventually, complemented with sand nourishment*' (*in* POC-CE 2018, p.50).

Climate change and its effects, namely SLR

The GTL notes that '*climate change effects, namely SLR, are inducing to a greater frequency of extreme values in the sea level. Such trend contributes to greater coastal erosion, and it allows the waves to break closer to the shore and the transference of more energy to the littoral. In the mid-term and long-term (time-horizons of 2050 and 2100, respectively), SLR will become an important aggravating factor*

[3] The GTL developed a model to understand the sediment balance in the mainland Portuguese coastal zone which divides the coastline in 'sediment cells' (POC-CE 2018, p.19). The 'sedimentary cell' corresponds to 'an autonomous unit in terms of sediments', it is '*an appropriate unit to coherently manage the sediment balance (the sediment balance is calculated as the difference between the sedimentary sources and the 'sinkholes': when such balance is negative, then the shoreline presents a retreat / regressive tendency (erosion), and when the balance is positive, the shoreline tends to advance towards the sea (accretion)*' (GTL 2014 b, *in* POC-CE 2015, p.426, and in POC-ACE 2018, p.40).

[4] The results of the analysis of the sediment balance for the 8 sediment cells are presented in the GTL Report. However, the GTL recognizes that, due to important constraints, lack of information and data, the values presented must be seen as 'representative' of the order of magnitude of the sediment volumes involved (GTL 2014 b). In this regard, Veloso-Gomes (2014) underlines that the existence of a sharp sediment deficit has been recognized for more than 30 years, this is communicated but not completely assumed as a topic that deserves more attention. The values presented by the GTL should be deemed representative because there is deep uncertainty about this, namely uncertainty around the methodologies and scientific tools used for quantifying the sediment transport (Veloso-Gomes 2014).

of (the risks of) coastal flooding, overtopping inundation, and erosion. Although there is uncertainty about what will be the rise of the sea-level until the end of the century, it is quite likely that it is higher than 0,5m and it might reach even 1m. Such variation in the sea-level will have serious effects in the littoral of Portugal. There is still a considerable deficit of knowledge about these impacts and the costs associated' (GTL 2014, *in* POC-CE 2018, p.24; 2015, p.436; 2018 f, p.190). Thus, the current projections indicate an aggravation of coastal erosion. In addition, it is likely to occur an increase in the occurrence of extreme weather events (POC-CE 2018 f, p.190).

As POC-CE mentions, '*the aggravation of coastal erosion, and the broad recognition of the increase in the frequency and intensity of extreme weather events, associated with climate change, require new answers from public policies, namely the adoption of adaptation measures (protection, accommodation, and planned retreat) that reduce the exposure of citizens, activities, and infrastructures to risks*' (POC-CE 2018, p.8).[5]

The need to review the first POOCs

It was long recognised the need to review the first POOCs. Such plans were created with the intention of being integrally reviewed every 10 years, but, in fact, that did not happen. Although the 1st POOCs had, in general, positive results, after more than 20 years of their publication, there have been major changes (POC-CE 2018f, p.37) (see Note 302). Between the prior POOCs and the new POCs, there has been a paradigm shift in the philosophy underlying the regime of coastal management; one of the main modifications brought by the new legislative frame concerns the fact the POCs should assume a more strategic character and no longer qualify the soil (land uses), and cease to be binding for private actors (*in* POC-CE 2018, p.45).[6] Furthermore, the imponderability surrounding environmental factors, namely climate change impacts on land uses, is increasingly recognized (POC-CE 2018f, p.38).

[5] Here, adaptation measures are deemed measures to reduce the 'exposure' to risks. This points to the potential misunderstanding of the concept of 'risk', as the product of probability x consequences, or probability x vulnerability x exposure.

[6] Between the prior POOCs and the new POCs, there has been a paradigm shift in coastal management: the prior regime of land uses (which was based on the delimitation of classes and categories of space according to the dominant uses) was replaced by a regime for safeguarding (protecting) natural resources and values and regime of management that is compatible with the sustainable use of the territory (which is based on the definition of *general norms* and *specific norms* that define the actions allowed, conditioned, and forbidden) (POC-CE 2018, p.46).

1.3. Claims and calls for an approach of 'adaptive planning and management' of coastal zones

During the development of the new POCs, and even prior to it, several guidance documents that recommend an Adaptive Management approach have emerged in Portugal. Besides this, in the last decades, diverse actors and entities have called for the use of an approach Adaptive Management in coastal zones. Some of these claims are discussed next.

- **Calls for a new approach of *Adaptive Management* for the coastal zone in the Law**

The Decree-Law nº 159/2012 promotes a '*new approach for the coastal zone*' based on '*a greater flexibility and on an integrated and adaptive management, by giving to the POCs not only a normative and regulatory character, but also means for the identification and programming of measures of management, protection, conservation, and valorisation of the hydric resources and natural systems associated*' (DL n.º 159/2012). Importantly, this Decree-Law explicitly mentions that POCs should have a more strategic scope and role, and should promote '*the sustainable development of the coastal zone through a prospective, dynamic and adaptive approach*' (DL nº159/2012, *in* POC-CE 2018, p.34).

- **Claims in the *National Strategy on Integrated Management of the Coastal Zone* (ENGIZC)**

The '*National Strategy on the Integrated Management of the Coastal Zone*' (ENGIZC) also advocates a '*prospective and adaptive management approach*' (ENGIZC 2009, p.6070, 6074, 6076). It highlights that '*the capacity to anticipate and prevent risk situations and follow-up the evolution of natural phenomena (based on mechanisms of continuous evaluation) is essential for the prosecution of a prospective and adaptive management of the coastal zone*', and it '*should support decisions about planned retreat or the interdiction of new construction in risk or vulnerable areas, or the adjustment of uses and functions of the territory to the evolutive characteristics of the coastal systems, ecosystems and landscapes*' (ENGIZC 2009, p.6070).[7] For more on the ENGIZC, see Note 304.

The thematic objectives of the ENCIZC are (ENGIZC 2009):

a) To conserve and value the natural, cultural and landscape resources and heritage.
b) To anticipate, prevent and manage risk situations and impacts (environmental, social, and economic impacts).
c) To promote the sustainable development of activities and the valorisation of resources specific of the coastal zone.
d) To deepen scientific knowledge about the coastal systems, ecosystems, and landscapes.

It is also worth mentioning that the 'Recommendation n.º 2002/413/CE of the European Parliament and of the Council concerning the implementation of Integrated Coastal Zone Management in Europe' (2002/413/EC), which served as a reference to the ENGIZC, already called for an adaptive management approach. The Recommendation defines general principles for integrated coastal management that the Member States should follow in the formulation of their national strategies, namely:

- '*a long-term perspective that takes into account the precautionary principle*'.
- an '*adaptive management during a gradual process that facilitates adjustment as problems and knowledge develop*', which implies '*a sound scientific basis on the evolution of the coastal zone*'.
- the consideration of '*local specificity*' through '*specific solutions and flexible measures*'.

[7] The ENGIZC calls for a '*preventive management of risks*', and mentions that '*the great vulnerability of the coastal zone, which has a fragile equilibrium and quite complex dynamic, and the great challenges presented to its integrated management, namely those related to climate change, require the adoption of measures that are sustainable and adaptive and prevent or reduce the negative impacts of natural phenomena* (…)', and that coastal management should favour '*naturalized and adaptive options that better fit with an integrated approach to the social, economic and environmental issues*' (ENGIZC 2009, p.6070, 6067).

Moreover, it recommends Member States to '*include adequate systems for monitoring and disseminating information* (…) *about their coastal zone*' (2002/413/EC) (see Note 305).

- **Claims in the *National Strategy for Adaptation to Climate Change* (ENAAC)**

The '*National Strategy for Adaptation to Climate Change*' (ENAAC 2010) was elaborated between 2010 and 2013 and approved in 2015 (APA 2021 b). Its vision proposes '*a country adapted to the effects of climate change, through the continual implementation of solutions based on technical-scientific knowledge and good practices*'. The ENAAC aims to deepen knowledge on climate change, implement adaptation measures, and promote the integration of adaptation into diverse sectors, namely 'spatial planning' and 'coastal zones' (APA 2021 c). One of its specific objectives is '*to reduce the vulnerability and increase the response capacity of the country'* (ENAAC 2010, p.1093). This objective, which lies at the heart of the Strategy, requires the identification of adaptation measures – namely measures to reduce the vulnerability of the various sectors to climate change, and / or increase their response capacity to the impacts of climate change and extreme weather events (ENAAC 2010, p.1093; APA 2021 b).

The ENAAC contains a methodology for the identification of adaptation measures (Figure 2; Box 1) (ENAAC, p.1094). APA also provides this methodology in its website (APA 2021 c).[8]

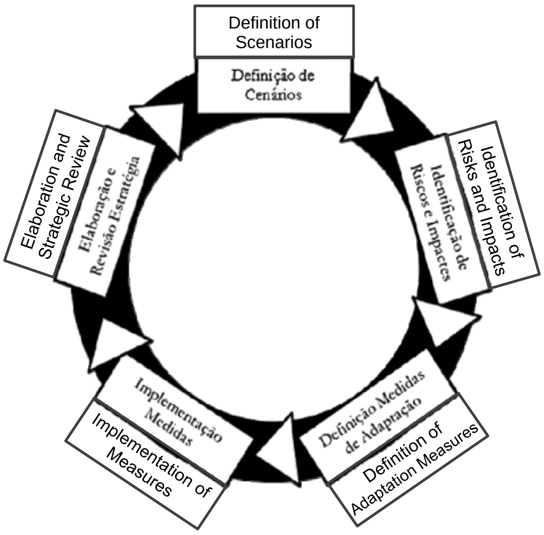


Figure 2. The ENAAC's methodology for the identification and definition of adaptation measures. Source: ENAAC 2010; also available at APA 2021 c, based on CECAC (Executive Committee of the Commission for Climate Change).

This methodology involves an iterative process of risk management / adaptation with several steps: it starts with the definition of climatic and socioeconomic scenarios, which are then used to identify possible future risks, impacts, and opportunities; followed by the identification and definition of adaptation measures[9], including an analysis of the expected benefits and of the costs of each measure; then the implementation of measures, and, finally, it is carried out a review and evaluation (namely to evaluate the success of the implemented measures) that feedback information to the first step (APA 2021c). The last step involves an evaluation of the benefits provided by the implemented measures, the monitoring of how the climate is modifying and how scientific knowledge is evolving (namely climate scenarios and assessments of potential impacts), and it might require corrections in measures. This

[8] Importantly, the coordination of the implementation of the ENAAC is under the responsibility of APA, which must provide guidelines and reference tools to private and public entities that aim to initiate their own adaptation processes (APA 2021 a).
[9] Adaptation measures are deemed measures to tackle the risks and impacts associated to climate change, which annul or reduce risk or potential negative impacts, or seize benefits, and minimize or mitigate the consequences of extreme weather events and alterations (APA 2021 c).

evaluation will lead to a dynamic process where the measures identified and applied are successively refined and suited to the pace of the climatic changes (and their effects) as these occur (APA 2021 c).

Using this methodology, the various sectors could develop their adaptation plans / strategies and identify the '*lines of action and adaptation measures*' to reduce or avoid risks and negative impacts (ENAAC 2010, p.1104). For more on ENAAC and on its methodology, see Note 306.

BOX 1: the ENAAC's methodology for the identification and definition of adaptation actions / measures

1. Definition of scenarios. The methodology starts with the definition of the climate and socioeconomic scenarios that will be used to anticipate future risks and impacts (ENAAC 2010, p.1104). To address the deep uncertainty and unpredictability of future climate change effects, the initial stage involves construction of climatic and socioeconomic scenarios, followed by the assessment of the exposure of a given sector / activity to climate patterns different than the current one (ENAAC 2010, p.1094)

2. Identification of Risks and Impacts. This step consists of identifying / analysing risks and potential impacts. The impacts are usually negative, but there may also be positive impacts / opportunities to be identified (ENAAC 2010, p.1104). The effects of climate change on society and sectors must be characterized in terms of risk, that is, the combination between the probability of occurrence and the potential severity. Drawing the climatic and socioeconomic scenarios considered, it is necessary to undertake analysis of risks and potential impacts (ENAAC 2010, p.1094).

3. Definition of adaptation measures. Adaptation measures are responses that can be taken to deal with risks and impacts of climate change (previously identified). The objective of measures can be: to annul or significantly reduce the risk of damages, to promote the benefits, to reduce or limit the consequence of phenomena resultant from climate change (ENAAC 2010, p.1104). In this step, it is necessary to identify adaptation measures, and assess them. The ENAAC provides clues:

- it recognizes the value of 'no-regrets actions', i.e. actions whose application makes sense even if the predicted climatic changes do not fully occur. Other criteria that can be used are: urgency, cost-efficacy, potential irreversibility.
- It mentions that 'as far as possible, it is necessary to search for solutions that constitute adaptive responses with interest for more than one sector or region, and (…) with capacity to be replicated and transversal character'.
- It promotes the integration of adaptation in the various sectoral policies and spatial planning instruments (local and regional), and recognises that this will be a gradual process dependent of the cycles of revision of such instruments.
- It refers that the environmental assessment of plans and programs and Environmental Impact Assessments are instruments that should be used to validate plans, programs and projects in terms of climate adaptation.
- The identification and construction of cost-effective solutions will require the allocation of responsibilities to various actors involved, and thus, public participation and engagement (ENAAC 2010, p.1094).

This step also requires the assessment of the adaptation measures, based on an analysis of expected benefits (which depend on the risk and impacts that are being addressed and their probability of occurrence) and costs of each measure (ENAAC 2010, p.1104). This involves assessing adaptation options against criteria such as: availability, benefits, costs, efficacy, efficiency, feasibility, etc. The benefits of adaptation concern the costs of avoided damages and other benefits that stem from the application of adaptation measures. The costs of adaptation concern the costs of planning, preparing, and applying adaptation measures (ENAAC 2010, p.1095).

4. Implementation of measures. Measures are applied.

5. Further elaboration and strategic revision. Once the measures are applied, their success must be evaluated. Such evaluation should focus on the success / efficacy of the measures, their effects (including benefits), the need for technical corrections, as the climate changes, and the ways through which science has evolved (namely the scientific work of elaboration of climatic scenarios and analysis of potential impacts). This evaluation will lead to a dynamic process where the identified and applied measures are successively refined and tailored to the pace of climate change and its effects, as they are felt in an area. Adaptation involves an iterative process of risk management (ENAAC 2010, p.1104).

It is possible to observe that the ENAAC's methodology contains several aspects that are similar to the key-elements (or their sub-elements) identified in this Thesis as essential for an Adaptive Planning and Management approach, namely: working with climatic and socioeconomic scenarios (in line with the Key-element 1), the search for no-regret measures within the definition of adaptation measures (which is part of the Key-element 3), the step of evaluation of the success of implemented measures, emerging knowledge, and new scenarios that may arise (which forms part of the Key-element 4), and the ongoing, learning-oriented and iterative process risk management (which corresponds to the Key-element 5).

- **ESAAC-RH (the ENAAC's *Sectoral Strategy of Adaptation to Climate Change for Hydric Resources, including coasts*)**

The ENAAC's Sectoral Strategy of Adaptation to the Impacts of Climate Change related with the Hydric Resources (ESAAC-RH) mentions that adaptation requires '*an open and long-term vision and* *commitment to the search of better solutions that allow the development of an effective and flexible policy, able to evolve as knowledge progresses and rapidly adjust to specific situations*' (ESAAC-RH 2013, p.i). The definition of an adaptation program / plan requires the acceptance of a significant level of uncertainty and the capacity to make decisions under such conditions. Given the uncertainty around the climatic scenarios currently available, '*it is preferable to adopt a precautionary approach, based on flexible actions that do not restrict future options and that are periodically reviewed as new information arises*'. Thus, there is '*a continuous and cyclical process of planning and management (…), in which any proposed and implemented action is periodically revised to evaluate if the desired results are being achieved or if it is necessary to apply corrective measures*', or review or complement the implemented measures (ESAAC-RH 2013, p.3; APA 2013 a, p.125). This allows a gradual adjustment of the policies. In such *progressive adaptive approach*, the options with greater impact, costly investments, or more uncertain effects, can be postponed to a moment in time where the knowledge about climate change effects on each region and in the socioeconomic conditions is more detailed, and where the adaptation alternatives are better characterized (ESAAC-RH 2013, p.4; APA 2013 a, p.126).

The ESAAC-RH calls for '*a program of flexible actions, which does not restrict future options and is able to cope with the uncertainty associated to climatic scenarios*' (ESAAC-RH 2013, p.5; APA 2013 a, p.126). This requires identifying flexible measures that do not block-in future options, as well as *win-win* and *low-regret* measures (which produce benefits even in a scenario of low or null climate change), and measures that address effects that are expected with a greater level of certainty (e.g. SLR) (ESAAC-RH 2013, p.17). *Win-win* and *no-regret* measures are valuable *per se* and justifiable in any climatic scenario, therefore, they should be used as priority measures in the adaptation plan / strategy; and other *low-regret* measures (*that entail a low risk of not working well)* can be included in a second stage of the plan / strategy (ESAAC-RH 2013, p.33).[10] Thus, a good principle is to '*adopt flexible, no-/low regret, cost-effective* (…) *solutions*' (ESAAC-RH 2013, p.17).

Moreover, the ESAAC-RH proposes measures to influence different factors that determine the systems' vulnerability to climate change, namely: i) their exposure to climatic conditions; ii) their robustness (capacity to perform under new climatic conditions); and iii) their resilience (capacity to recover from adverse conditions) (ESAAC-RH 2013, p.5; APA 2013 a, p.125).[11] Relocation of people and structures from flood-prone areas is an example of an action to reduce the exposure to climatic factors.

The definition of Adaptation Programmes / Plans / Strategies must include cost-benefit analyses to determine which measures have benefits that exceed the costs. In this scope, the benefits consist of costs associated to avoided damages by a measure (APA 2013 a, p.129).[12] The scheduling and programming of a measure not only depends on its cost-benefit ratio, but also on the analysis of the appropriate timing for implementing it, its lifespan, its evolving performance over time, the projected evolution of climate change effects (ESAAC-RH 2013, p.33; APA 2013 a, p.130).

[10] Given the uncertain future climatic and SLR projections, it is essential to favour adaptation actions that are *no-regret*, i.e. that ensure efficacy and benefits even if the climatic changes that will occur do not coincide with the climatic scenarios currently projected (APA 2013 a, p.198). The measures with higher costs or more uncertain benefits can be relegated to further moments in time (APA 2013 a, p.129).

[11] The ESAAC-RH defines robustness as the 'capacity of resisting (or sensitivity) to the effects of climate change', resilience as the 'capacity to recover from states of deficient functioning or non-operationality', and adaptability as 'the capacity of a system to adapt to climate change and its effects, and it depends on the characteristics of the system, namely its resilience, socioeconomic and institutional conditions, etc.'. According to it, an adaptation strategy must be based on 3 axes: 1) reduction of the exposure of systems and activities to climatic phenomena; 2) increase the robustness and resilience of the exposed system to climatic phenomena; 3) deepening and dissemination of knowledge about the evaluation of the effects of climate change, possible adaptation actions, technical, social, institutional barriers (ESAAC-RH 2013, p.42).

[12] In a cost-benefit analysis of measures there is always an asymmetry between the current costs (calculatable and known) and the value of the future benefits (that are potential and uncertain). The risk of over- and under-investment is real, especially in the cases of infrastructures with long lifespans, not easily relocatable. Thus, the selection of measures must give priority to those measures that present greater flexibility to receive subsequent adjustments and no-regret measures (ESAAC-RH 2013, p.139). Even when uncertainty is high, it is possible to carry out a qualitative assessment of the benefits of measures and assess if a decision is sensitive to the different scenarios (ESAAC-RH 2013, p.35).

The ESAAC-RH underlines that, considering the lifespan of certain measures, whenever possible, it should be envisioned a phased implementation of several measures or projects within the Adaptation Programme / Plan, to ensure that risk is kept under adequate levels, and which allows delaying the more costly and risky investments until there is more knowledge about the effects of climate change (ESAAC-RH 2013, p.34; APA 2013 a, p.131) (Figure 3, which was extracted by APA from the TE2100).

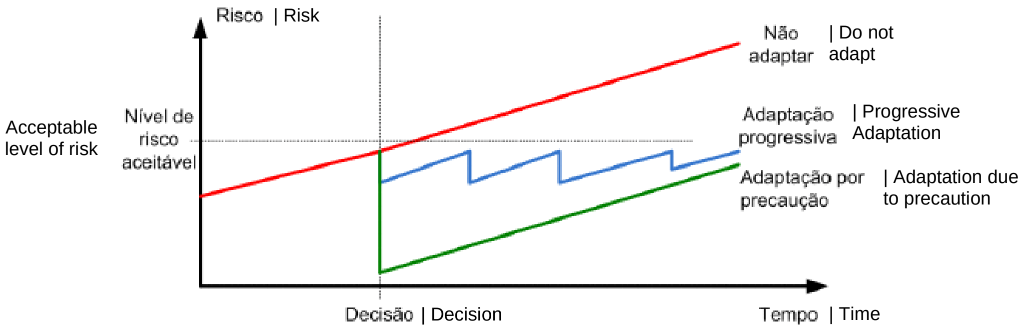


Figure 3. Levels of risk and the scheduling of an adaptation project / plan.
Source: ESAAC-RH 2013, p.34. This image was clearly extracted from the TE2100 Plan.

According to the ESAAC-RH, the complexity and deep uncertainty about climate change effects have led to the adoption of an adaptive management in the field of water management. Adaptive management can be defined as a systematic process of improvement of policies and management practices, through an ongoing learning and evaluation of the results of management strategies previously implemented (Pahl-Wostl et al. 2007, *in* ESAAC-RH 2013, p.37). The current uncertainty around climate change effects, their magnitude and impacts on diverse sectors, calls for '*the definition of adaptation strategies that are flexible (...), and that include structural and non-structural measures, and for procedures of adaptive management*' (Oliveira et al. 2013, *in* ESAAC-RH 2013, p.86). The need for flexibility has led many experts to advocate for gradual adjustments to the current methodologies of planning and management of hydric resources. Such a flexible approach helps to avoid irreversible investments (ESAAC-RH 2013, p.155; APA 2013 a, p.154).

An Adaptation Plan should contain concrete targets for each of the objectives defined that allow the evaluation of their level of implementation and efficacy. As new knowledge on climate change arises, and as the results of implemented measures are evaluated, a new cycle of planning is initiated to validate or adapt the actions underway or identify new measures. Adaptation is itself a process of implementation of measures that keeps up with the evolution of climate change and knowledge about it. In this process, *flexible measures* and *measures that can be implemented in a phased way* should be favoured, in detriment of measures that restrict or significantly condition future options (ESAAC-RH 2013, p.36).

The efficacy of adaptation measures requires a continual adjustment to the evolution of scientific knowledge and socioeconomic conditions (ESAAC-RH 2013, p.149; APA 2013 a, p.197).

The ESAAC-RH highlights that the key for dealing with deep uncertainties about future changes and conditions lies in '*the capacity to develop a strategy that is sufficiently flexible to allow, at each moment, adequate solutions to tackle the multiplicity of scenarios that might occur*' (ESAAC-RH 2013, p.154; APA 2013 a, p.154). It is also necessary to ensure mechanisms of revision of the Strategy and the existence of a culture of continual learning from the experience acquired.

The adaptation strategies proposed in the ESAAC-RH follow the options defined in the Project SIAM I – *protection* (to reduce the risk of an event, by reducing its probability of occurrence), *retreat* (to reduce the risk of an event, by limiting its potential effects), and *accommodation* (to increase the societal capacity to deal with the effects of the event) – and such measures should be subjected to cost-benefit analysis (APA 2013 a, p.197). An important adaptation measure proposed by the ESAAC-RH is: ZC 3.1 – introduction of the concept of '*strip of safeguard from coastal risks*' in all spatial planning instruments in the national coastal zone (APA 2013 a, p.199). For more on ESAAC-RH, see Note 307.

In synthesis, the ESAAC-RH contains several ingredients that are related to the 5 key-elements of Adaptive Planning and Management approach, as it calls for:

- The development of a flexible policy / strategy that is able to evolve and adjust as information emerges and situations change, including '*flexible measures that do not block future options and that are periodically reviewed as new information arises*', '*measures that can be implemented in a phased way'*. It also calls for *a flexible strategy* that allows taking *'at each moment, adequate solutions to tackle the multiplicity of scenarios that might occur*', which is related to robustness. These aspects are crucial sub-elements of the Key-element 3.
- The scheduling of measures to keep risk bellow an acceptable level (depicted in Figure 3), related to the Key-elements 2 and 3, which is clearly related with the TE2100's approach.
- The continual cyclical process '*in which the proposed and implemented actions are periodically revised to evaluate if the desired results are being achieved or if it is necessary to apply additional measures*'. This explicitly refers to the Key-element 5.

- **APA's guidance**

APA also developed a methodological guide to support the development of adaptation strategies by sectors, organizations, and companies. This methodological guide is based on the structure and contents of the publication '*Identifying Adaptation Options*' of the UK Climate Impacts Programme (UKCIP 2007, *in* APA 2021 f) (see Note 308). It provides a structured approach for developing adaptation measures to climate-related risks, including guiding principles for an effective adaptation (APA 2021f). As the APA's Guide stems from the UKCIP (2007) publication, it is quite similar to it, and contains specific references to the key-elements of an Adaptive Planning and Management approach that were identified in the Part A of this Thesis. The Guide calls for the use of an Adaptive Management approach to cope with uncertainty and presents several aspects that concern each of the five key-elements.

In specific, the APA's Guide provides several principles to support and inform the process of identification of 'good adaptation measures', among them:

- '*Understand and identify critical thresholds*'.
- *'Use a '<u>flexible or adaptive management approach</u>*', which involves *'implementing the required adaptation measure(s) in a phased manner'*. In a flexible adaptive approach, adaptation measures are introduced in time and space, in a sequenced way, as the climatic risks occur, and the adequacy of the measures is confirmed (*in* APA 2021 f). Such adaptive management approach (including the phased approach) is needed to cope with uncertainty (*in* UKCIP 2007).
- Recognize the value and use *'no/low regrets' and 'win-win' adaptation measures / options, in terms of cost-effectiveness and multiple benefits'*, and *'avoid actions that foreclose or limit future adaptations or restrict actions of others*'. This requires assessing measures in terms of cost-effectiveness and benefits.
- '*Review the effectiveness of adaptation decisions by adopting a continuous improvement approach that includes monitoring and re-evaluations of risks*' (*in* APA 2021 f, based on UKCIP 2007).

In addition, the Guide explains that uncertainty 'should not be used as an excuse for taking appropriate action', and that 'an effective way of dealing with uncertainty is adopting flexible approaches that involve the phased application of adaptation measures' (APA 2021 f). It also refers that *in practice, adaptation will often involve a mixture of several strategies, probably introduced in a pre-established* *sequence*: some actions aimed at building resilience (e.g. enhanced design specifications or construction codes), other actions aimed at increasing the capacity to 'live with risks' (e.g. increased preparedness and contingency planning), and some actions aimed at accepting losses (e.g. accepting occasional losses or reductions in quality of some services), etc. Hence, to appropriately address a climatic risk, usually, several strategies or measures can be used. To choose the measures that will be implemented, it is necessary to assess their costs and benefits. Adaptation measures should meet several criteria, e.g.: be cost-effective, efficient, fair, feasible, justifiable in the context of the current climate variability and further justifiable in the context of future climate change. Some measures that easily contain such properties are: 'no- and low-regrets options' and 'win-win options' (the Guide explains these concepts). Moreover, it is possible to use a '*flexible and adaptive approach*', which '*consists not of searching for 'the solution' for a given climatic risk, but adopting and introducing various adaptation measures in a sequenced way, as the climate risks occur or the adequacy of the measures if confirmed*' (APA 2021 f).

Despite the existence of this Guide, which offers specific guidelines for the use of an Adaptive Planning and Management approach and its main elements, including and recommendations regarding the several steps of the elaboration of an adaptation plan, and although the two studied POCs claim to use an approach of 'adaptive planning / management', the process of development of two POCs was not based on, nor supported by, this APA's Guide. The above-mentioned principles are valuable, and they could have been used in the elaboration of the new POCs (the coastal zone is one of the sectors that demands climate adaptation). However, and although APA is the same entity that provides this Guide (and several guidance on adaptation, in its website) and is responsible for steering the POCs, these principles were not fully incorporated in the elaboration of the POCs and in their rationale.

- **GTL Report**

As referred, after the 2014 winter storms, and considering the expected aggravation of coastal risks, the Government created the Working Group for the Littoral (GTL), which was charged of the definition of measures to reduce (the exposure to) coastal risks, under climate change scenarios (POC-CE 2018, p.19). According to the GTL, in the mainland Portuguese coast, '*until now, the main response to the coastal risks of flooding, overtopping inundation, erosion, and slope instability, has been coastal protection. Due to the intensification of such risks and to the increasing impacts of climate change on the coastal zone, especially those resulting from SLR, the most adequate response will progressively be adaptation – a broader concept that not only includes protection but also other type of responses such as planned retreat (relocation) and accommodation. The most adequate solutions often result from a combination of the three adaptation strategies (relocation, accommodation, and protection), which allows a greater sustainability of the options in social, economic, and environmental terms*' (GTL 2014 b, p.2).[13]

The GTL recommends '*the elaboration of adaptation studies, including combined strategies of protection, accommodation and planned retreat, especially for the stretches at greater risk, based on the modelling of coastal processes and on cost-benefit analyses and multi-criteria analyses. To this end, it is urgent to undertake integrated assessments of the adaptation measures and of the costs associated to different '<u>adaptation paths / pathways</u>', up to temporal horizons of long-term (2100)*' (GTL 2014 b, p.3; GTL 2014, p.55). In addition, it recommends '*studies on alternative financing models (different from the current model) to fund adaptation on coastal zones*', including the possibility of shared

[13] The 1st POOCs already proposed several interventions of planned retreat (relocation), but most were not carried out. Besides this, the POOCs proposed the non-expansion of built-up areas and built-up forefronts on vulnerable / risk zones, and this measure was incorporated by most municipal spatial plans, and, in general, accomplished. Controls on the buildable zones and constructability and the definition of *non-aedificandi zones*, can be deemed accommodation measures. Relocation and accommodation strategies were enshrined in the 1st POOCs, and in the ENGIZC (Measures 11, 7, 10). Thus, it is important to examine why such measures have not been implemented (Veloso-Gomes 2014).

responsibility between the central government, local governments, and private actors (GTL 2014 b, p.3, *in* POC-CE 2015, p.426). Importantly, ENGIZC already called for the engagement of private actors in the financing of coastal adaptation (as noted by Veloso-Gomes 2014). Furthermore, the GTL does not mention which scenarios should be considered in such 'adaptation studies' and assessments of measures and costs associated to different 'adaptation paths / pathways' (also noted by Veloso-Gomes 2014).

According to the GTL, '*in the coastal zones where there is a high risk of coastal flooding, overtopping inundation, erosion, or instability of slopes, it should be recommended the consideration of relocation as priority response. The strategy of relocation presupposes henceforth the non-occupation of the coastal zone, including urban areas and urbanizable areas, with new constructions or extensions of existing constructions*' (GTL 2014 b, p.6). Moreover, relocation should '*favour expeditious mechanisms of transference of construction rights (constructability) to adequate zones, in articulation with municipalities*' (GTL 2014 b, p.7). The GTL recommends the development of prospective studies on relocation in areas of greater risk of coastal floods or erosion, based on cost-benefit analyses and multi-criteria analyses that include the mid- and long-term (GTL 2014 b, p.7, *in* POC-CE 2015, p.426). Although the GTL recommends planned retreat as a priority action for zones at high risk, it did not explain what should be the spatial limit of the areas subjected to planned retreat; yet, this issue will be determinant: it will influence the number of constructions that must be demolished and relocated (which might vary from thousands to tens of thousands, with their associated costs) (Veloso-Gomes 2014).

BOX 2: recommendations of the GTL Report

The **GTL Report** provides several recommendations for the coastal zone. Regarding adaptation strategies (i.e. protection, accommodation and relocation) under scenarios of climate change', the GTL recommends: i) the elaboration of studies of adaptation carried simultaneously to integrated assessments of measures of adaptation and of the costs associated to different 'adaptation pathways' up to the time-horizons of long-term (2100); ii) the development of studies on alternative models for financing coastal adaptation (POC-ACE 2018, p.179). The GTL proposes a strategy of planned retreat for the coastal zones where there is a high risk of sea overtopping inundations and coastal floods, coastal erosion, or cliff instability (in these areas, relocation should be considered as a priority response). The strategy of relocation presupposes the non-occupation of the coastal zone, including urban or urbanizable areas, with new construction or expansions of existing constructions. The Report also proposes the development of prospective studies about relocation for areas at great risk, based on cost-benefit analyses that include the mid- and long-term. The GTL Report also highlights that 'information, dissemination, training and participation' are conditions necessary for an effective adaptation, thus, it recommends the production and dissemination of information about the coastal problems and the various options of adaptation, including cost-benefit analyses (*in* POC-ACE 2018, p.179).

According to the GLT, the recent evolution of the littoral shows the existence of significant sediment deficits, hence, 'sediment management' should assume a primary role in the strategies of intervention and mitigation of erosive process.

In addition, the GTL considers that it is urgent to develop a national policy of '*integrated management of sediments*' on the coastal zone, based on the needs of nourishment identified, namely in the cells where the risk of erosion is critical, and based on the availability of sediments resultant from inert extraction and exploitation in estuaries, rivers, dredging works in ports, and seabed (GTL 2014 b). This issue has been discussed over the last two decades; the ENGIZC already proposed an integrated management of coastal mineral resources, thus, it is important to examine why this has not been applied.

The GTL considers that the ENGIZC constitutes a strategic reference document, and it recommends the further integration in the ENGIZC of the measure of re-establishment of sediment equilibrium and relocation measures, which should be favoured in zones at greater risk of erosion or flooding (GTL 2014 b). However, both these measures are envisaged in the ENGIZC, what is at stake is the feasibility of such measures at larger geographical scales, as proposed by the GTL (Veloso-Gomes 2014).[14]

---

[14] Importantly, the 1st POOCs already proposed planned retreat operations, as well as the POLIS Programs; however, their concretization has been successively postponed. Thus, it is important to understand why such interventions have not been carried out (e.g. social resistance, political reluctance, juridical obstacles, costs). Besides this, the removal of constructions, and the non-occupation or densification of vulnerable / risk areas, were both considered in the ENGIZC (Measures 7 and 11). Veloso-Gomes raises a key issue: what would be the geographical limits of the planned retreat proposed by the GTL (e.g. small settlements identified in the 1st POOCs around 20 years ago, new settlements identified in the new POCs; in what specific sites / areas, for instance, the first line of construction (forefront), according to height criteria, or defined on a case-by-case basis (Veloso-Gomes 2014). The GTL also calls for the intensification of inspections of illegal occupations of the littoral and the reposition of legality (GTL 2014 b), which is a measure proposed in ENGIZC (Measure 10).

The GTL analysis of the recent evolution of the mainland littoral showed that there are significant sediment deficits, therefore, sediment management should have a key role in the strategies of intervention and mitigation of erosion processes (GTL 2014 b, p.7; POC-CE 2015, p.426). In its Report, the GTL presents the strategies proposed for each cell, namely for critical parts of cells 1 and 4 (Box 3).

The GTL's proposals for Cell 1 focus mostly on 'interventions for re-setting the sediment balance' and tend to dismiss actions that are indispensable (e.g. mixed / hybrid measures); it is undoubtful that other measures (than sediment nourishment) will be necessary, namely complementary measures such as the maintenance of existing defence structures (Veloso-Gomes 2014).[15] See also Note 309 and Note 310.

BOX 3: the GTL recommended strategy of re-establishment of the sediment balance for the coast between Minho and Douro

According to the GTL, '*in the littoral between the rivers Minho and Douro (sub-cell 1a), there is a high sediment deficit, which translates into the retreat (regression) of most beaches, in the progressive substitution of sandy beaches by beaches of pebble, and in the existence of several situations of high risk*'; and '*although it is not possible to re-set the sediment balance that existed in the reference situation, the deposition of sediments on beaches (sand and pebble) of class 1 and class 2, which are currently dredged from port areas, might be sufficient to minimize, or even annul, the current sediment deficit. This assumption is based on the fact that, in the recent past, the annual volume of dredged sand in ports, which has been subtracted from the littoral system, was higher than the littoral drift estimated for the reference situation. For the implementation of sediment nourishments, it is necessary to assess the sediment stocks (reserves) in the northern continental shelf*' (GTL 2014 b, p.13, *in* POC-CE 2015, p.427). The GTL recommends the realisation of studies that evaluate the solid volume in the main waterlines between the mouth of Minho River and the mouth of Douro river, and to assess if these lines can supply more sediments to the littoral (GTL 2014 b, p.13, *in* POC-CE 2015, p.427).

However, the values obtained for the current sediment deficit might require revision; the idea that the current sediment deficit in this cell can be 'minimized' or 'annulled' with the deposition of sediments from dredging works in ports (alone) may be optimistic (this measure alone may not be sufficient to solve the problem) (according to Veloso-Gomes 2014).

Importantly, the GTL (2014 b) mentions that '*the first essential step to achieve the objective of a sustainable and integrated coastal management is the access to relevant information, including data, models, and results with an adequate spatial and temporal resolution. However, the currently existing data are clearly insufficient to characterize the current situation and the coastal dynamics. Therefore, it is indispensable to create and maintain a programme of observation and monitoring* (…) *of the Portuguese coastal system, of its mobility and of the oceanographic forces to which it is subjected. The need for such monitoring has been recognized for decades and there have been several initiatives to put it in practice, but with no success* (…)'; '*the observation and monitoring should be carried out systematically, under the responsibility of APA in articulation and partnership with other institutions* (…)'; and '*the monitoring should include the observation, study and interpretation of the sedimentary and geomorphological dynamics of the coastal zone, correlations between its characteristics and the oceanographic forces, and behaviour of coastal defence works*', and '*articulated with the monitoring of land uses and water uses*' (GTL 2014 b, *in* POC-CE 2015, p.424). It is pertinent to analyse the reasons why the monitoring has not been undertaken or is insufficient (e.g. financial constraints, an initial plan too ambitious, lack of consideration of the extension of the continental shelf, or monitoring is simply not assumed as something relevant) (Veloso-Gomes 2014).

[15] The GTL argues that a strategy of re-establishment of sediment balance (based on artificial sediment nourishments) has the advantages of minimizing the loss of territory, being more easily reversible, favouring the permanence of sand (with positive repercussions on beach activities), maintaining landscape values, and being more similar to the natural situation; the main advantage would be '*allowing the observation of the system response and the adjustment of the magnitude of interventions and it is reversible*' (GTL 2014 b, p.15, *in* POC-CE 2015, p.428). Nevertheless, as Veloso-Gomes highlights, the pre-existing coastal defences will likely need to be maintained, thus, the costs of such maintenance should be accounted for in the estimation of the costs of a strategy of re-establishment of the sediment cycle. The GTL could have considered mixed solutions (e.g. acceptance of the landward progression of the sea in some zones, creation of wetlands, construction of multifunctional or submerged artificial reefs, construction of artificial dunes, etc.) (Veloso-Gomes 2014).

The GTL warns that '*if the central administration is unable to assure the effective monitoring of the coastal processes and dynamic and to elaborate and update the coastal vulnerability and risk maps, then the management measures and the coastal protection measures will continue to be, by large, spare, maladjusted and ineffective. Their cost will be certainly higher than the cost of measures based on a systematic monitoring of the coast and updated vulnerability and risk maps*' (GTL 2014 b, *in* POC-CE 2015, p.426). Notwithstanding, many of the measures that the GTL calls '*spare* (piecemeal), *maladjusted and ineffective*', consisted of interventions proposed in the 1st POOCs, including interventions that were often postponed and then executed in limit-situations (Veloso-Gomes 2014).
The GTL argues that it is necessary ensure the monitoring of the national littoral, the systematic elaboration of vulnerability and risk maps at the national level, the modelling of interventions in the littoral (and associated cost-benefit and multi-criteria analyses), and an updated register of all expenses on coastal adaptation; and it warns that if these tasks are not undertaken, the management of the coastal zone, will continue to be done '*in a deficient and, often occasional, reactive and inconsequent way*', and with higher costs (GTL 2014 b).[16] On the GTL Report and comments to it, see Notes 309 and 310.

According to the GTL Report, at the national level, the priority actions that are necessary to ensure the integrated and sustainable management of the coastal zones in the short-, mid-, and long-term are:

- *Establish a 'regime agreement' and develop inter-institutional partnerships about the integrated management of the coastal zone.*
- *Assure the monitoring and information sharing.*
- *Elaborate risk maps and vulnerability maps.*
- *Identify and plan relocation (planned retreat) processes.*
- *Develop a policy of integrated management of sediments.*
- *Identify sources of sediments, define the deposition sites, and schedule the actions of sediment nourishment, including sediment transpositions.*
- *Initiate interventions of sediment nourishment with volumes of great magnitude ('shots'), such interventions must be seen as emergency works in the coastal stretches at greater risk.*
- *Maintain and reconfigure the coastal defence works in the coastal stretches at greater risk until it is possible to re-establish the sedimentary equilibrium by means of sediment nourishment interventions (including the initial 'shots').*
- *Assure more effective inspections with regard to the compliance of the spatial planning rules and regulations* (GTL 2014 b, *in* POC-CE 2018 f, p.189, and *in* POC-CE 2015, p.429).

These actions provided a strategic and official framework for the exploration of measures in the elaboration of the new POC-CE (POC-CE 2018 f, p.189). Most of the recommendations and advice were absorbed in the subsequent elaboration of the new POC-CE and POC-ACE.

- **Recent claims from APA**

In a recent interview, the APA's President and Vice-President argued that:

- '*the new POCs assume a new stance regarding the planning of the littoral by aiming to ensure a governance and management that are continual in the face of the acting coastal dynamics (which are uncertain). The Portuguese littoral demands 'permanent and persistent actions', namely of sediment recharge of beaches, re-establishment of dune systems, etc.*'

[16] With this regard, Veloso-Gomes argues that many of the actions of coastal management carried out in the recent years correspond to measures that were proposed and approved in the 1st POOCs. Although the POOCs were not always duly implemented and updated, it erroneous to classify all recent interventions of coastal management as '*deficient, occasional, reactive and inconsequent*' (Veloso-Gomes 2014).

- ‘*the 2nd generation POCs adopted ‘a new approach of integrated and adaptive management’ for the coastal zone, and propose more suited solutions (of prevention, protection, accommodation or planned retreat) according to the current situation and the expected future dynamics. In addition to their normative and regulatory character, the new POCs identify and program management actions to ensure the preservation of natural system, the safeguard of people, assets, and the necessary monitoring*’.
- ‘*In the face of intrinsic characteristics of the coastal zone, which is particularly vulnerable to the effects of SLR, the principles of prevention and precaution were assumed as central and strategic for the definition of the model of adaptive planning and management that constitutes the key feature (trademark) of all the new POCs*’.
- ‘*An integrated and continual management of the littoral also requires specialized scientific and technical knowledge and a monitoring system that are able to share information and support decision-making at the national, regional and local levels*’ (CEZCM / APRH 2020).

APA highlights that the operationalization of an adaptation strategy for the Portuguese mainland littoral should involve ‘*an iterative process of risk management that includes the definition of scenarios, the identification of risks and impacts, the definition of adaptation measures, their implementation, and the revision of the strategy (considering the impacts, costs, benefits, sustainability, equity, the evolving scientific knowledge and the public attitude towards risk)*’; and all this will require an optimization of resources (CEZCM / APRH 2020 b). Some authors have argued that, based on an in-depth analysis of the number of buildings located in coastal zones vulnerable to floods (associated to SLR), many in consolidated urban zones, it will be necessary the adopt ‘*diversified adaptation and defence strategies*’, as well as define priorities and program concrete intervention measures (CEZCM / APRH 2020 b).

APA recognizes that one of the greatest challenges faced in the planning and management of the coastal zone is related with *the deep uncertainty around the projection of climate change effects on coastal morphodynamical processes*’, which points to the need of deepening knowledge and monitoring (CEZCM / APRH 2020 d).

Regarding adaptation options, APA explains that ‘*until recently, the main response to the coastal risks of flooding, overtopping inundations, erosion, and slope instability, was essentially based on coastal protection; however, the expected intensification of such risks (associated to climate change effects, e.g. alterations in the frequency and intensity of erosive events and flood events, increase in the exposure of people, assets and natural systems to risks) called for an anticipatory attitude. Such anticipatory attitude involves a progressive adaptation to (current and future) risks, which not only includes protection (…), but also accommodation and planned retreat, in a logic of shared accountability and articulation of the various levels of planning and management*’ (*in* CEZCM / APRH 2020).

As noted by the APA, the GTL Report (GTL 2014) clearly assumed that the maintenance or re-establishment of the sediment balance, through the realisation of sediment nourishments on beaches and dunes, should be one of the main options of coastal protection for the mainland Portuguese coast, in detriment of other protection options. Besides this, there is now a consensus within the national scientific community in relation to the adequacy of this strategy to mitigate erosion (CEZCM / APRH 2020) According to APA (President and Vice-President), the protection measure of sediment nourishment has long been used in Portugal (since the 1950’s), and there has been a significant increase in its application since the 1990’s. The level of success and lifetime of such type of interventions vary, and they strongly depend on the local conditions (e.g. long-term erosive trend, level of exposure and length of the beach, rates of transversal and longitudinal sediment transport) and weather and oceanographic conditions (CEZCM / APRH 2020).[17] See more in Note 311.

- **EMAACs, and the ADAM methodology at the municipal scale**

  Most coastal municipalities already have their own Municipal Adaptation Strategies (*Estratégias Municipais de Adaptação às Alterações Climáticas - EMAACs*). The EMAACs were developed in the scope of the Project ClimAdapt. The ClimAdapt Team provided to municipal staff a methodological guide for the elaboration of a municipal adaptation strategy, which contained a methodology called ADAM (*Apoio à Decisão em Adaptação Municipal*). The ADAM methodology describes the steps for developing a municipal adaptation strategy (ClimAdaPT 2015), and it was developed based on the methodology used in the '*UKCIP Adaptation Wizard*' of the UK Climate Impacts Programme (UKCIP 2013, *in* ClimAdaPT 2015, p.4).[18] The ADAM methodology was applied to develop the EMAACs.

  The ADAM includes various steps, and it corresponds to a simplified version of the process for developing an 'adaptive plan / policy' of the *UKCIP Adaptation Wizard* (see Note 312). Although this methodology was developed for supporting the municipal level (and not the POCs), it contains several ingredients directly related to the five key-elements of an Adaptive Planning approach, as described in Part A of this Thesis.

Based on the analysis of the legal framework and several other strategic and policy documents that framed the elaboration of the POCs, it is possible to observe that there were several guidance and reference documents that advocated and encouraged the use of an *Adaptive Management approach* (and, in some cases an *Adaptive Planning and Management approach*). Many of these documents, and most information, are available at the website of the Portuguese Environment Agency (APA). Despite that, some of the above-mentioned documents were not produced with the specific aim of supporting the elaboration of POCs; and, in many cases, they were not directly provided to the Project Teams responsible for developing the new POCs. Excepting the GTL Report (which was of the main references for the POCs), the Decree-Law nº159/2012, and the ENGIZC, the other documents were not assumed as refences for the elaboration of the new POCs. Nevertheless, most of these documents provide several (general or specific) guidelines regarding an approach of Adaptive Planning and Management and its application in the field of coastal management and planning. Some documents contain specific references to aspects that are related with Adaptive Planning and Management approach or to each of the key-elements that were identified in Part A of this Research.

The new POCs claim that they have adopted an 'approach of adaptive planning and management', however, the existing guidance and knowledge specifically focused on Adaptive Planning and Management approaches has not been fully absorbed in the new POCs and their elaboration. To be assimilated by the POCs, these guidance documents and knowledge on the Adaptive Planning paradigm should have been explicitly prescribed by APA to the Project Teams charged of their development. APA was responsible for providing these documents to Project Teams, which did not occur in a clear way.

---

[17] In recent years, APA has sought to optimize the 'integrated sediment management' through the reinforcement of the inter-institutional coordination, namely with Port Authorities, by using the sediments dredged in port areas (e.g. dredging works for maintenance purposes in port channels, bars, etc.), and combine operations (dredging and deposition on the areas to be nourished) (CEZCM / APRH 2020).

[18] The *UKCIP Adaptation Wizard* is a model / tool to support robust adaptation planning and decision-making (ClimAdaPT 2015, p.4). The Wizard was based on the work of Willows and Connell (2003), already mentioned in Part A, which served as a reference to the TE2100 case.

II. PORTUGUESE CASE-STUDIES

CASE I: PROGRAMME OF THE COASTAL ZONE CAMINHA-ESPINHO (*PROGRAMA DA ORLA COSTEIRA CAMINHA-ESPINHO – POC-CE*)

1. PRESENTING THE POC-CE

The Programme of the Coastal Zone Caminha-Espinho (POC-CE) was developed under the leadership of the Portuguese Environment Agency (APA) by a consortium of project companies (Território XXI, Cotefis, Proman, and PAL). The POC-CE corresponds to the review of the prior (and first) Coastal Zone Management Plan CE (POOC-CE) approved in 1999 and altered in 2007 (POC-CE 2018, p.7). The elaboration of this POC occurred between 2015 and 2020.

The POC-CE is a coastal management programme, which lays down the main measures to manage the coastal zone and its land uses and activities, including measures to manage coastal risks. The POC-CE, as a ‘Special Programme’, aims to safeguard objectives of national interest and the conditions necessary to the permanence of systems; its main goal is ‘*to ensure the protection of the coastal zone, through the establishment of a management regime compatible with the sustainable utilization of the territory, through the definition of actions allowed, conditioned and forbidden*’ (POC-CE 2018, p.25).

1.1. AREA OF INTERVENTION OF THE POC-CE

According to the Law n.º 58/2005 (Lei n.º 58/2005, called *Lei da Água*), the area of intervention of a POC encompasses maritime coastal waters and interior waters, the respective seabed and margins, and the maritime and terrestrial protection strips (*Faixas Marítima e Terrestre de Protecção*) under the responsibility of the APA. Moreover, according to the Decree-Law n.º 159/2012 (Decreto-Lei n.º 159/2012), the area of intervention of a POC includes two main zones (POC-CE 2018, p.10) (Figure 4):

a) Maritime Protection Zone (*Zona Marítima de Protecção – ZMP*). It is the zone located between the limit of the seabed and the bathymetric of 30m (referenced to the hydrographical zero).
b) Terrestrial Protection Zone (*Zona Terrestre de Protecção – ZTP*). This zone includes the ‘Margin’ of seawaters and a strip with 500m width from the limit of the Margin landwards, which may be adjusted to a maximum width of 1000m if this is necessary to integrate relevant biophysical systems.

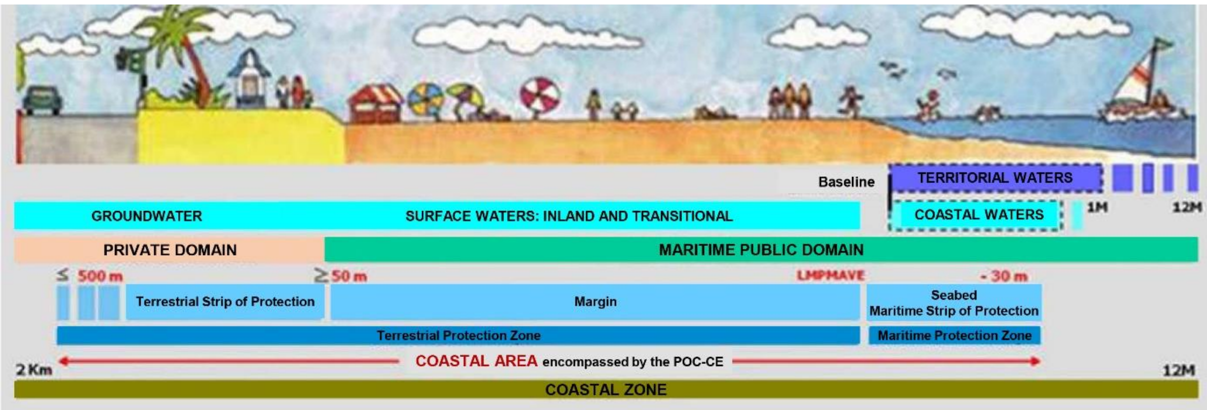


Figure 4. Territorial scope of the POC-CE. Source: POC-CE 2018, p.10, adapted from APA 2015.

The POC-CE, in specific, covers the coastal zone from Caminha (north) to Espinho (south) (Figure 5). Its area of intervention has approximately 517 km^2 (including maritime and land areas), and its coastline has nearly 122 km of length (from Minho River in Caminha, to Barra de Esmoriz in Espinho). It includes territories of the municipalities of Caminha, Viana do Castelo, Esposende, Póvoa do Varzim, Vila do Conde, Matosinhos, Porto, Vila Nova de Gaia, and Espinho (Figure 5). The land area of the POC has nearly 62,67km^2. In line with the DL n.º159/2012, the POC's area includes the areas under port jurisdiction, namely the seafront of Matosinhos and the seafront of Porto. The new POC also extends the area intervention (in relation to the POOC-CE) from the 500m width to 1000m width in the estuaries of the rivers Minho, Lima, Âncora, Neiva, Cávado, Ave, and Douro (POC-CE 2018, p.11, 45).

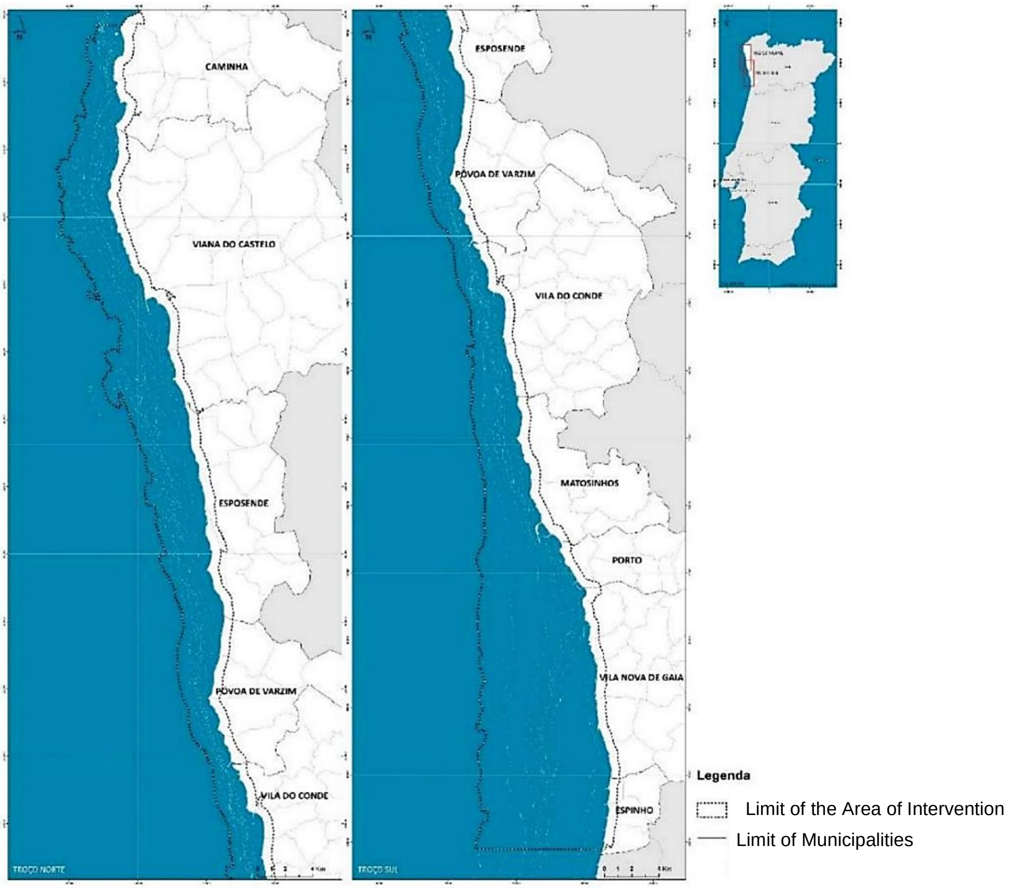


Figure 5. Area of intervention of the POC-CE. Source: POC-CE 2018, p.12.

The area of intervention of the POC-CE encompasses a diversified range of spaces, from areas with great biological and landscape value to areas with intense urban occupation, which, in some cases has occurred in the de-regulated way or is incompatible with the carrying capacity of natural systems. The area of intervention in one the coastal stretches with higher populational density in the country (POC-CE 2018 f, p.31). It also hosts two commercial ports – the Leixões Port and the Port of Viana do Castelo, and seven fishing ports (POC-CE 2018 d, p.62).[19] The two commercial ports are under the jurisdiction of the APDL (Port Administration of Leixões, Douro and Viana do Castelo); the remaining fishing ports are under the jurisdiction of DocaPesca (POC-CE 2018 f, p.251) (Figure 6). The coast also concentrates several industries, chemical plants, and fuel distribution infrastructures (POC-CE 2018 f, p.191).

19 The Leixões Port is expected to initiate, in 2021, the works for the extension of its main breakwater. This project is necessary due to security reasons, it will involve the extension of an existing breakwater southwards in 300m length and the construction of a new area for containers. The initial project did not account for the effects of SLR in the dimensioning and design of the breakwater. Despite that, and strong sustainability issues that have been raised, the work is expected to begin in 2021, with the approval of APA and Matosinhos Municipality. To sustain the investment, the Port Authority should have integrated adaptation measures in the design / project. According to APA, in the future this type of projects must explicitly consider the risks associated to climate change (APA 2021 d) (see Note 313).

1.1.1. EXISTING COASTAL PROTECTION / DEFENCE STRUCTURES

The coastal stretch CE includes low-lying sandy beaches, and in some zones, low-lying rocky beaches. Some beaches are now covered with pebble (e.g. Pedra Alta and Cepães) (POC-CE 2018, p.13). This stretch is very susceptible to, and often affected by, sea action, waves, storms, coastal floods, and erosion (POC-CE 2018 d, p.59). Figure 6 shows the main existing coastal protection works.

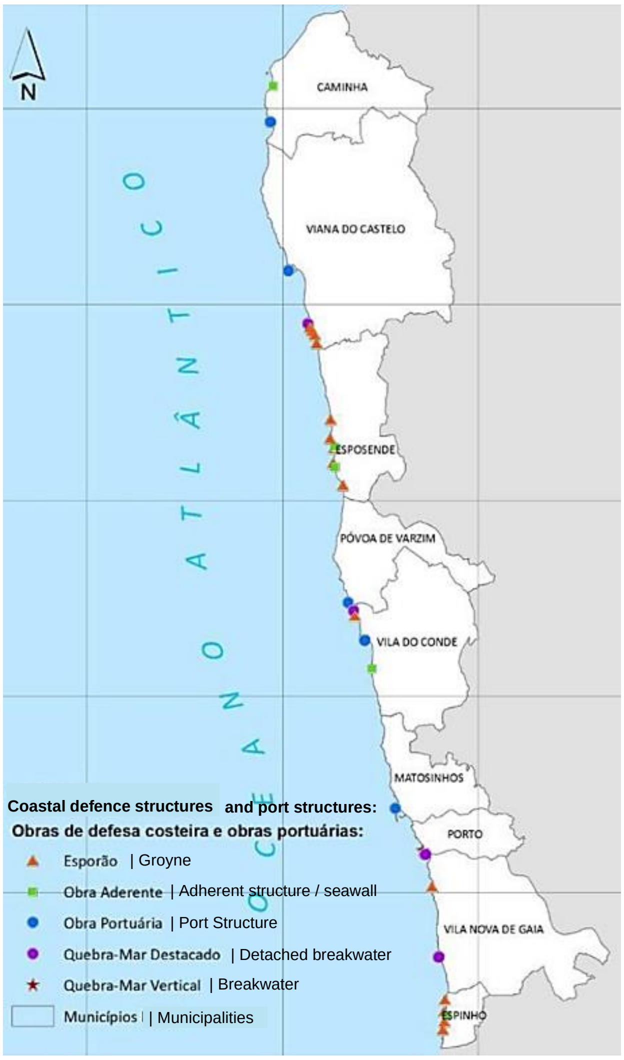


Figure 6 (left). Main coastal defence works and port works. Source: POC-CE 2018 f, p.179.
Figure 6 (right). Port infrastructures in the area of intervention of the POC-CE. Source: POC-CE 2018 f, p.252.

In general terms, the existing coastal defence works have contributed to the maintenance of the shoreline along urban forefronts, but in some critical zones, there are erosion and flood events of cyclical nature, which are particularly evident in situations of highly energetic wave climate. In other areas, there is a significant retreat (regression) of the shoreline, and the interventions carried out in the past (e.g. construction and maintenance of defences, dune rehabilitation) have not been effective in their control. Thus, interventions of repair and maintenance of groynes and longitudinal adherent defences constitute a means of protecting the shoreline that is necessary but also limited. The POC mentions that if such structures did not exist, the situation would be worse, however, they may aggravate erosion at their south side but induce to accretion at north. Such structures seem to be more effective in situations of low and medium wave energy. In cases of strong storms, the efficacy of these structures is lower, and they may not prevent localized erosion events, flood, and sea overtopping inundations (POC-CE 2018 f, p.179).

1.1.2. Drivers of increasing risks of coastal erosion, floods, and sea overtopping inundations

In the coastal zone CE, the main problems are related with: the coastal risks of erosion, flooding, and sea overtopping – and their expected aggravation associated with climate change and ongoing strong urban pressures and touristic pressures upon natural areas (POC-CE 2018, p.30).

Most stretches of the area of intervention correspond to low-lying sandy areas dominated by beach-dune systems, which are occasionally interrupted by sandy barriers, river mouths, port areas, or rock formations. Several stretches present an evolutive trend of erosion, which reflects in the loss of territory and retreat (regression and reduction) of frontal dune systems (POC-CE 2018 b, p.6). The area of intervention is characterized by a fragile and dynamic balance, despite the existence of natural and landscape resources that sustain multiple ecological processes and human activities. In this area, there are strong erosion dynamics and a great vulnerability to flooding and overtopping events, namely in intensively occupied areas. This situation tends to aggravate with the exacerbation of coastal risks associated with climate change effects, namely with SLR, changes in wave patterns, and in storm patterns (potential increase in the frequency and intensity of storms, and with alterations in route of storms / waves (POC-CE 2018, p.36).

The pressure for constructing on this coastal zone is patent in the artificialized territories that occupy nearly half of the area of intervention, namely in the cities of Matosinhos and Gaia. The urban occupation reflects in a predominantly continuous urban fabric (POC-CE 2018 d, p.64; 2018 f, p.205).

The North coast presents serious problems of erosion in several stretches. Moreover, several localized floods and overtopping inundations have occurred, causing damages on infrastructures and facilities that support beaches and surrounding areas. The existing defence works have, in general, contributed to the maintenance of the shoreline in urban forefronts, but in some critical areas and in situations of strong highly energetic sea storms, their effectiveness is lower (POC-CE 2018 f, p.191).

In the coastal zone CE, the first works for constructing hard defence structures were carried in Espinho in 1902 (in 1911, two transversal groynes were finished, the first built in the country). Since then, several interventions of coastal protection were made, mostly with the aim of protecting human settlements, and often, without considering the necessary preservation of beaches and natural zones, which contributed to a pattern of 'artificialization of the coastline' (POC-CE 2018, p.48, 50) (Box 4).

There has been an '*increasing sediment deficit*', but also *'an intense, and often deregulated, urban growth, observed since the 1970's*' (GTL 2014, *in* POC-CE 2018, p.48). Major coastal storms have often been followed by the adoption of strategies to rapidly solve the problems. However, and despite the efficacy of many hard protection structures built, some did not contribute to fix sediments and were costly. In some cases, the storms occurred in the recent years (e.g. 2002, 2009 and 2014) were followed by the adoption of reactive solutions (POC-CE 2018, p.48).

BOX 4: the area of the POC-CE

While there is a strong mobility of the shoreline (natural variability), there has also been an ongoing reconfiguration and increasing artificialization of the shoreline. The erosive trend has become quite evident in some urbanized zones. In some cases, the existing coastal defence works have contributed to increase the erosion problems in other zones, namely at the south of transversal structures like groynes (POC-CE 2018 f, p.192). There are now several occupied areas at risk due to the retreat (regression) of the shoreline. Furthermore, coastal floods and overtopping inundations are frequent in the Winter, during strong sea storms and highly energetic wave patterns and due to the erosion of sandy areas. Such floods often result in damages in infrastructures and facilities that support beach activities and the surrounding areas. (POC-CE 2018 f, p.192).

In the future, it is expected that there will be alterations in the sediment balance, and an increase in the frequency and intensity of localized coastal floods, associated to climate change effects, particularly SLR. Furthermore, there has been a marked reduction of the sediment supply due to the past construction of dams, numerous dredging works, and sediment extractions made in the Hydric Domain (POC-CE 2018 f, p.192).

Anthropic action / human and urban pressures

The POC-CE's area of intervention is one of the coastal stretches of the mainland Portuguese coast with the highest population density. In some areas, the human occupation has occurred in a disordered way, accompanied by multiple problems, such as excessive construction, disrespect for sensitive areas and risk zones, environmental degradation and landscape de-characterization, low awareness of coastal evolution processes, degradation of water quality in river basins, etc. The lack of monitoring of the coastal dynamics is also a chronical issue, which has contributed to a late or deficient detection of problems (POC-CE 2018, p.13). Despite this, the area of intervention shows great natural richness and landscape diversity, including several classified areas (Natura 2000 sites, Áreas Protegidas, etc.).

Many of the problems in this coastal stretch are related with coastal dynamic processes, namely erosion. Erosion processes have been witnessed since the 1950's, however, at that time, there was still a well-preserved dune chain that conferred resilience. Since 1980, there has been an increasing occupation of the coastal zone, with the proliferation of urban fabric and urban sprawl (emergence of new urban areas). The urban pressures on coastal zones and the increasing demand for fruition or holidays have led to an imbalance in several natural systems. Moreover, the construction of fixed structures in a highly dynamic environment has contributed to the partial or total degradation of many dune systems (also degraded by the humans). These anthropogenic factors, in conjunction with the other processes observed since the 1950's, have contributed to a tendency to force the regression (retreat) of the coastline. The deficit of sediment supply to coastal spaces was strongly induced by the construction of dams in rivers across this coastal stretch since the 1950's (POC-CE 2018, p.16).

The erosive processes, which have become quite evident in some urbanized coastal stretches, have often led the decision of constructing multiple coastal defence works with hard engineering solutions. The POC-CE mentions that, while some defence works have locally solved problems, others contributed to increase erosion in other sites, namely in the south side of groynes (POC-CE 2018, p.16).

The projections of the future evolution for the North coastal zone point to an increasing human occupation of the coastal zone, a tendency for the regression of the shoreline, and for an aggravation of the risk of coastal erosion associated to climatic factors, which will increase the need to protect coastal urbanized zones from sea actions (POC-CE 2018 f, p.229, 231). For more on this, see Note 314.

Climate change-related drivers

In addition to the existing sediment deficit in this coastal zone, the effects of climate change are expected to exacerbate coastal risks (POC-CE 2018, p.24; 2015, p.436). The GTL mentions that '*in the mid- and long-term (2050 and 2100, respectively), SLR will become an important aggravating factor of the (risk of) coastal flooding, overtopping inundation, and erosion*', and that '*although there is uncertainty about what will be the rise of the sea level until the end of the century, it is quite probable that it is higher than 0,5m, and it might reach 1m (…). There is still a considerable deficit of knowledge about these impacts and about the costs associated*' (GTL 2014, *in* POC-CE 2018, p.24; 2015, p.436; 2018 f, p.190).[20]

According to recent studies, the main effects of climate change in the mainland coast will be SLR, changes in wave and storm patterns, and changes in temperature and rainfall. These changes will generate impacts on the coastal zone, namely in the sediment balance (e.g. an increase in the existing erosive trend, and erosion in stretches currently are stable), and an increase in the frequency and intensity

[20] On the other hand, the Technical Report '*Enquadramento metodológico para a demarcação das faixas de salvaguarda à erosão costeira (nível I e II*) (APA 2015) defines that the POC-CE should adopt the values of SLR of +0,35m e + 1,50m for the time-horizons of 2050 and 2100, respectively. Therefore, the POC-CE Team decided to use these values in the coastal zone CE (POC-CE 2015, p.436). Moreover, SLR will have impacts on the propagation of waves and swells and their incidence of the coast, e.g. through the percentual increase of wave heights.

of coastal floods (POC-CE 2018 b, p.6). SLR is also expected to contribute to the regression of the coastline (shoreline); and it is expected an intensification of the coastal risks of erosion, flooding and sea overtopping inundations (POC-CE 2018, p.13, 19).

The combination of the above-mentioned factors contributes to the steep vulnerability of the coastal stretch CE (POC-CE 2018, p.24).

Analysis of the past tendencies of mobility of the shoreline

From the 1980's onwards, there has been a strong reconfiguration and mobility of the shoreline in the coastal stretch CE. Despite the lack of vectorized lines representing the shoreline position over the last years, the POC Team sought to analyse the mobility of the shorelines available and found that there are important stretches in erosion (POC-CE 2018, p.17) (see more in Note 315).

Analysis of the Sediment Balance in the 'reference situation' and 'current situation'

The GTL analysed the sediment balance of the littoral of the POC-CE, in a 'reference situation' and the 'current situation' (POC-CE 2018, p.19; 2015, p.432)[21] (see also Note 303):

- Sub-cell 1a), in the current situation: there was a reduction (in relation to the reference situation) of the sediment supply and a generalized retreat (regression) of the sandy beaches, which has been intensifying. The erosion of beaches has become the main active source of sediments the partially compensates the generated deficit. The existent high sediment deficit is related to the construction of dams, numerous dredging works, extractions of sediments in the Public Water Domain (GTL 2014, *in* POC-CE 2018, p.21; POC-CE 2015, p.433).
- Sub-cell 1b), in the current situation: the sediment deficit is now extremely high, namely because of the significative reduction of the volume supplied by the Douro river. The current sediment deficit is compensated by the strong erosion of the littoral in the south of Espinho, namely between Maceda and Torrão do Lameiro (GTL 2014, *in* POC-CE 2018, p.23; POC-CE 2015, p.435).

Overall, according to the GTL Summary, '*in the littoral between the rivers Minho and Douro (sub-cell 1a), there is a high sediment deficit, which translates into the retreat (regression) of most beaches, in the progressive substitution of sandy beaches by beaches of pebble, and in the existence of several situations of high risk. This deficit is related with the construction of dams, which has significantly reduced the sandy solid volume debited by rivers, as well as with numerous dredging operations and sediment extractions made in the Hydric Domain*' (GTL 2014 b, p.13, *in* POC-CE 2015, p.427).

In view of the geomorphological characteristics, evolutive tendencies, and current uses in this coastal stretch, the POC considers that '*it is fundamental to incorporate concrete adaptation measures that safeguard and mitigate the impacts generated by coastal dynamics and the mobility of the coastal strip*' (POC-CE 2018 b, p.6). The urban occupation of coastal zone CE, in conjunction with the retreat (regression) of the shoreline, and the exposure to extreme events, demand an exigent planning of adaptation strategies (POC-CE 2018 d, p.64).

---

[21] The 'model of sediment balance' for the comprehension of the coastal zone presented by the GTL (2014) divides the coast in 'sediment cells'. Cell 1 extends from the mouth of Minho rivers to Nazaré, and it is divided in 3 sub-cells: 1a) from Minho River to Douro River; 1b) from Douro River to Mondego Cape; and 1c) from Mondego Cape to Nazaré. The littoral CE includes the sub-cell 1a) and part of the sub-cell 1b). The 'reference situation' corresponds to the situation prior to the existence of strong anthropic disturbance in the sediment balance, prior to the construction of dams in rivers and breakwaters in seaports, sand extraction in rivers and coast, etc.; i.e. the situation that might have existed in the 19th century. The 'current situation' represents the last two decades, where the sediment balance has been altered by anthropic actions in the littoral and river basins; initially there was a strong reduction in the sediment supply, followed by the construction of several hard-engineered coastal defence works, namely groynes and seawalls (POC-CE 2018, p.19; 2015, p.431-432).

Sediment deficit in the CE stretch

The coastal zone of the POC-CE presents several critical situations in terms of need for protection, due to aggravated erosion. The erosive process and loss of sediments observed in several beaches and dunes is the result of the sediment deficit existent in several stretches (the erosive capacity is higher that the volume that enters in the system), which is also related with the occurrence of coastal floods and sea overtopping inundations (POC-CE 2018e, p.45). The problems of erosion and coastal flooding are directly related with the sediment deficit that exists in the stretch CE. According to the POC-CE, this sediment deficit is generated by two main causes: the high sediment transport (drift) along the littoral associated to the strong wave pattern; and the reduction of the sediment supply to the littoral due to human actions on river basins and coastal zone (POC-CE 2018e, p.51). While several parts of the stretch CE are already vulnerable to erosion, and several sectors have witnessed to an inland regression of shoreline in the last decades, this tendency is not generalized and does not occur at the same pace, and its causes are not easy to calculate (POC-CE 2018 f, p.316).

Occurrence of coastal erosion, coastal floods, and sea overtopping inundations

Over the last years, erosion events on beaches or dunes and coastal floods and overtopping inundations, have been registered, with associated damages, e.g.: damages on built assets and infrastructures (pedestrian paths, beach-support facilities, urban furniture, dune systems, vegetation), sediment deposition along seafront roads, partial destruction of coastal adherent defences (seawalls), inundations in beach facilities, damages on agricultural areas, obstruction (silting) at the mouth of waterlines (POC-CE 2018f, p.39, 178). Figure 7 depicts some damages caused by the storms of 2014 Winter.

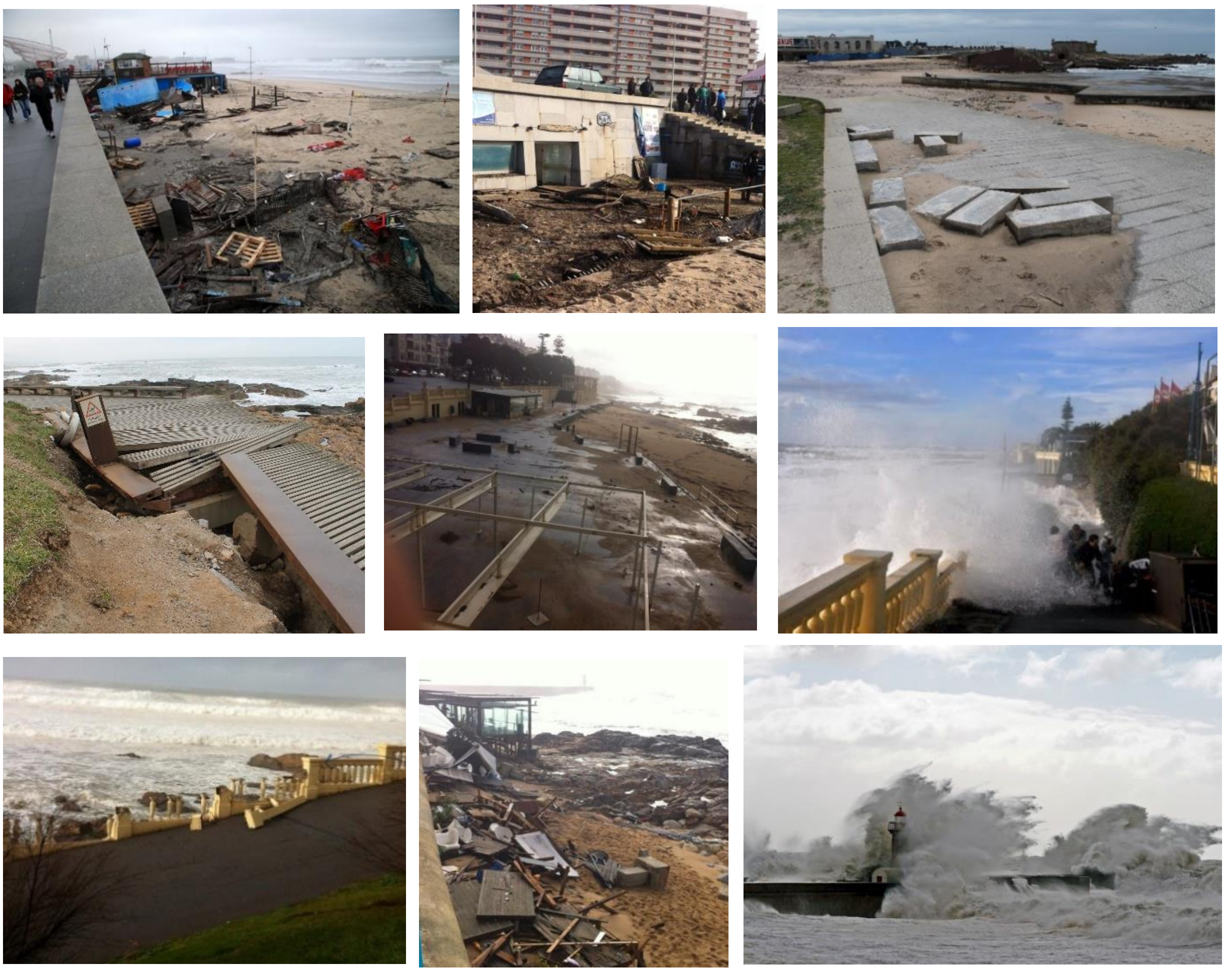


Figure 7. **First row**: damages caused by the 2014 Winter storms in the Beach of Matosinhos and Praia Internacional (Porto). **Second and third rows:** sea overtopping events and damages caused in the beaches of Foz (Porto), namely in Praia do Molhe, Praia da Luz, Praia dos Ingleses, Praia do Carneiro. Sources: internet or photos taken by the author.

1.2. Principles upon which the elaboration of the POC-CE was based

The POC-CE, namely its strategy of planning and management of the coastal zone, was developed based on several guiding documents, namely the Decree-Law nº 159/2012 (which sets principles to be considered in the elaboration of any POC), the *National Strategy of Integrated Management of the Coastal Zone* (ENGIZC 2009) and the GTL Report (GTL 2014). Drawing on the analysis of these documents, the POC-CE Team defined four main principles on which the elaboration and operationalization of its Strategy should be founded (POC-CE 2018, p.30):

a) Ecosystemic approach, *which takes into consideration the complexity and dynamics of marine and terrestrial ecosystems as fundamental elements for the safeguard of the coastal zone, and which creates a new culture of transversal, intersectoral and interdisciplinary coastal management*.
b) Adaptive management, *based on the effective and systematic monitoring of the coastal zone, and which strengthens the agility and adaptability in the management of coastal risks*.
c) Integrated management, i.e. a *multidisciplinary, intersectoral and transversal management that ensures the coordination of diverse actors with responsibilities on the coastal zone and public and the compatibilization of public and private interests, and reinforces the adaptability of decisions*.
d) Territorial cooperation and institutional articulation *at central, regional and local level, and involving all key actors in the planning, management and development of the coastal zone*.

As the POC-CE explains, integrated coastal management seeks to balance socioeconomic development with the conservation of natural resources and values of each territory, in a territorial context increasingly marked by the exacerbation of coastal risks associated with climate change. This integrated management approach aims at reaching a consensus about the Strategy of Planning and Management to allow that all interests, actors, and problems are duly pondered and articulated (POC-CE 2018, p.30).

The ecosystemic approach aims to ensure that all (positive and negative) interactions among the various factors of the coastal ecosystem are considered in the definition of POC's proposals. The POC seeks to promote, in its Territorial Model, the contention of processes of artificialization of coastal zones and the preservation of the ecological functions of natural areas (dune systems, forestry areas and coastal waters.

The POC-CE has sought to adopt '*a model of adaptive management that allows dealing with the challenge of the prevention and reduction of coastal risks*. This 'model of adaptive management' involves ensuring that the options taken in terms of planning of land uses and activities do not aggravate the vulnerability to coastal risks in the future (given the current situation is already quite complex), and, on the other hand, ensuring that the adaptation strategies and measures that are adopted (to adapt to such risks) do not preclude future strategies. The POC sought to internalize this 'model' in its Strategy. For the POC, '*the principle of prevention and precaution was crucial in the definition of a model of adaptive planning and management*' (this principle is set in DL n.º159/2012) (*in* POC-CE 2018, p.31).

Finally, the POC-CE aims to foster a multi-level coastal governance that engages all actors with responsibilities in the management of the coastal zone, and the adoption of mechanisms of participation, shared accountability, and operationality, in the management and follow-up (POC-CE 2018, p.32).

In sum, the new POC-CE aims to '*launch a new form of territorial management (...), which is substantiated and materialized through an ecosystemic approach (in the face of the dynamics and complexity of coastal ecosystems), and concretized in mechanisms of adaptive management, duly complemented by an effective and systematic monitoring of the coastal zone, all this framed in a model of integrated, multidisciplinary, intersectoral and transversal management*' (POC-CE 2018, p.32). The POC takes these principles as structuring of its Strategy and Management model (POC-CE 2018, p.52). These principles are related with the principles defined by the DL n.º159/2012 (see Note 316).

1.3. Strategic Model of the POC-CE: Vision, General Objectives, and Specific Objectives

The Strategic Model of the POC-CE includes a *Vision for the future*, *General Objectives* and *Specific Objectives*. The POC-CE formulated a '*Vision for the future of the coastal zone*' (POC-CE 2018, p.33).[22]

The Strategic Model sets five general objectives, which are subdivided into specific objectives. On their whole, these objectives have guided and are embedded in the POC's content, namely in the *Territorial Model* (which identifies the various areas that deserve different types of protection or safeguard), the *Directives* (norms / regulations that define the regimes of protection and safeguard for different areas), and the *Program of Actions* (which lists the actions to be implemented in the next 10 years) (POC-CE 2018, p.33, 37). The *Vision*, *General Objectives* and *Specific Objectives* are shown in Figure 8.

Vision	*A coastal zone that is resilient, developed and sustainable, sustained by a model of integrated and adaptive management that ensures the compatibilization between the defence of the coastline and the safeguard of people and assets, as well as the preservation of natural, landscape and cultural heritage, and that promotes the economic valorisation and harnessing of territorial resources*				
General Objectives	**General Objective 1 (OG1):** Prevention and reduction of coastal risks and of the vulnerability to climate change	**General Objective 2 (OG2):** Protection and conservation of coastal biophysical systems and landscape	**General Objective 3 (OG3):** Economic valorisation of coastal resources	**General Objective 4 (OG4):** Valorisation and qualification of maritime beaches	**General Objective 5 (OG5):** Monitoring and evaluation of coastal dynamics
Specific Objectives	**OE 1.1**. Maintenance of the integrity of the coastline, in the context of a broader strategy of adaptation to (current and future) coastal risks **OE 1.2**. Adoption of a strategy of integrated management of sediments that ensures the preservation of *borrow sites* and the harnessing of the sediments dredged from river mouths and access channels in ports, with the aim of resetting /the sediment balance in the coastal stretches affected by erosion **OE 1.3.** Definition of a model of land use and occupation of the coastal zone that restrains the territorial exposure to coastal risks in the mid- and long-term **OE 1.4**. Adaptation of the forms of urban occupation of the coastal zone, namely through planned retreat interventions in built-up / urban areas where there is a high level of exposure of people and / or assets to coastal erosion, coastal floods or overtopping inundations **OE 1.5.** Ensuring the public fruition of Public Maritime Domain in safety	**OE 2.1**. Protection of the dune ecosystems, by preserving the natural heritage and geodiversity of the coastal zone **OE 2.2**. Preservation and valorisation of the marine, estuarine and terrestrial ecosystems and habitats **OE 2.3.** Definition of a model of use and occupation of the coastal zone that assumes the ecological function of this territory as priority **OE 2.4**. Preservation of the coastal hydric resources with the aim of assuring a good state of water bodies **OE 2.5.** Protection and valorisation of the character and identity of the coastal landscapes	**OE 3.1**. Ensuring the conditions for the development of port activities **OE 3.2**. Promotion of the sustainability of the fishing activity **OE 3.3.** Promotion of the touristic resources of the coastal zone, namely the natural heritage, cultural heritage, sports and recreational activities linked to the sea **OE 3.4**. Urbanistic qualification of seafronts in a perspective of strengthening the conditions for the utilization of coastal settlements **OE 3.5**. Promotion of a sustainable harnessing of the marine resources, namely the exploitation of fossil fuels, renewable energy production, aquaculture, extraction of geological resources, and exploitation of halieutic resources	**OE 4.1**. Preservation of the beaches and dune systems and other natural spaces associated **OE 4.2**. Re-setting the legality and conformation of the use and occupation of the beaches with the Plans of Intervention on Beaches **OE 4.3.** Promotion of a model of adaptive management of the beaches, and ensuring safety conditions for their utilization and for the viability of economic activities associated **OE 4.4**. Qualification of the maritime beaches, by reconciling the conditions of urban fruition with the prevention of coastal risks **OE 4.5.** Improvement of the access conditions for users and of structures and facilities that support to beach activities	**OE 5.1**. Implementation of a system of regular and systematic monitoring focused on the sedimentary dynamics of the coastal zone, the evolution of the shoreline, and the performance of coastal protection structures **OE 5.2**. Strengthening the institutional coordination between entities with competencies in the management of the coastal zone **OE 5.3.** Promotion of a coastal planning and management system that assumes the central role of municipal or intermunicipal spatial plans in the concretization of local strategies of adaptation to coastal risks **OE 5.4**. Improvement of the technical capacity and knowledge development in the field of coastal management and adaptation to coastal risks **OE 5.5.** Awareness-raising of coastal communities, visitors and general public, about the importance of coastal ecosystems and about coastal risks associated to climate change

Figure 8. Strategic Model of the POC-CE which established the *Vision*, *General Objectives* and *Specific Objectives*. The specific objectives that are particularly relevant for this research are framed in red. Source: POC-CE 2018, p.35. See Note 317.

[22] The POC Team formulated a '*Vision for the future of the coastal zone*', based on the Study of Characterization and Diagnostic developed in the first phase of the elaboration of the POC, and on guidelines and directives enshrined in planning instruments and policy documents related to coastal spatial planning and management, among them the PNPOT, PROT-Norte, ENGIZC and GTL Report (GTL 2014). This Vision also considered the general principles and the objectives for any POC that are enshrined in the Decree-Law n.º159/2012, and it emphasizes the concepts of ecosystemic approach, integrated and adaptive management, and territorial cooperation (POC-CE 2018, p.32).

Regarding the specific objectives within the **OG 1**: The POC-CE aims to ensure the preservation of the integrity of the coastal zone (OE 1.1), which will require the implementation of local adaptation strategies in the coastal segments where there is greater vulnerability to the risks of erosion and/or flooding or higher exposure of built assets to these risks. In this sense, the POC-CE delimits, in its Territorial Model, the so-called Critical Areas (*Áreas Críticas*). In each Critical Area, the POC defines an 'adaptation strategy' among the three types of interventions – protection, accommodation, and/or planned retreat (relocation) – and these types of intervention may be used individually or combined. (POC-CE 2018, p.36). In addition to the definition of strategies of adaptation to coastal risks for the Critical Areas, the POC proposes the adoption of a strategy of integrated management of sediments at the regional scale with the aim of '*containing the erosion processes in the coastal segments with greater sediment deficits'*, which requires safeguarding possible 'borrow sites' (OE 1.2). Moreover, the POC proposes the adoption a (spatial) planning discipline that restricts human occupation in the coastal areas that present significant levels of risk (hazard) in the mid- and long-term (OE 1.3) (POC-CE 2018, p.36).

Given that the territory already presents great vulnerability to coastal erosion and flood events, in both urban, agricultural and natural areas, the POC-CE's Proposal aims to minimize (reduce) such risks through: a greater control on the exposure of the most relevant territorial elements, and the adoption of localized adaptation strategies (protection, accommodation, or planned retreat). In addition, the POC-CE prioritizes, namely in its Program of Actions, a strategy of integrated sediment management that aims to recover the sedimentary profile of the shoreline (POC-CE 2018, p.31).

Regarding the other General Objectives (OG), it is important to highlight the following:

- **OG 2**: The POC-CE aims to promote to mitigate the main threats that affect coastal biophysical systems, namely urban pressures, increasing touristic and recreational activities, loss of habitats associated to ecosystem's disfunctions, and exacerbation of coastal erosion. To this end, the POC-CE sought to propose a more restrictive and demanding regime for the protection of natural resources and values (in its Directives and Territorial Model) (POC-CE 2018, p.38).
- **OG 3**: The main challenge regarding OG3 is to ensure the articulation and compatibilization of socioeconomic interests with the safeguard of natural values and the prevention of coastal risks. In this respect, the future development project for the Leixões Port is a critical issue. The development of port infrastructures often constitutes a quite relevant form of pressure upon natural values, which is directly related with alterations on sediment flows, and which may contribute to aggravate coastal risks. The POC-CE seeks to ensure the conditions required for the development of port activities, including maritime and land accessibilities, and, at the same time, incorporate works of maintenance and development of ports into the global strategy of sediment management (POC-CE 2018, p.39).
- **OG 4**: The POC seeks to strengthen the valorisation and qualification of maritime beaches, through a (re)planning of beach activities and uses that is aware of constraints arising from coastal risks and increasing demand for peri-urban, seminatural and natural beaches. The POC promotes a model of adaptive management of beaches that assures safety conditions, the viability of economic activities and the compatibilization of public fruition with the prevention of coastal risks (POC-CE 2018, p.42).
- **OG 5**: The POC-CE defines a monitoring program, including mechanisms for continuous monitoring and evaluation of coastal dynamics. The POC also aims to foster a culture of institutional articulation and collaboration regarding the collection of information and knowledge production about coastal dynamics, and on the concretization of measures of adaptation to coastal risks. For example, implementation of an effective strategy of sediment management will require improved institutional articulation among entities responsible for the management of coastal risks, port authorities, and municipalities. The transference of the POC's proposals to the lower spatial plans is an example of how an integrated and shared management must be achieved (POC-CE 2018, p.43-44).

2. THE APPROACH OF '*ADAPTIVE PLANNING AND MANAGEMENT*' PROPOSED BY THE POC-CE

The POC-CE claims that it has adopted '*a model of adaptive management*' to address the need of reducing and preventing coastal risks. This section presents the 'approach / model of adaptive planning and management' advocated by the POC-CE, and it describes how the Programme defines the concept of 'adaptive planning and management'.

As mentioned, the POC-CE Team defined four principles on which the elaboration and operationalization of its Strategy (of Planning and Management of the Coastal Zone) should be founded, among them: *adaptive management* and *integrated management* (POC-CE 2018, p.30).[23] This *adaptive management* should be '*based on the effective and systematic monitoring of the coastal zone*', and it should '*strengthen the agility and adaptability in the management of coastal risks*' (POC-CE 2018, p.30). Moreover, the 'integrated management' should '*reinforce the adaptability of decisions*'.

The POC-CE has sought to adopt '*a model of adaptive management that allows dealing with the challenge of the prevention and reduction of coastal risks*' (POC-CE 2018, p.31). This *model of adaptive management* should be 'internalized' in the POC's Strategy: *'on the one hand, it is necessary to ensure that the options taken in terms of planning of land uses and activities do not aggravate the vulnerability to coastal risks in the future (considering that the current situation is already quite complex), and on the other hand, ensure that the strategies and measures of adaptation to such risks, which will be adopted, do not preclude future strategies*' (POC-CE 2018, p.31).

The POC-CE itself underlines that '*a model of adaptive planning and management' constitutes, in a certain way, the trademark / key feature of the POC*', and that '*the principles of prevention and precaution were absolutely central in the definition of such model*' (these principles are also enshrined in the DL n.º159/2012) (*in* POC-CE 2018, p.31). Importantly, the DL n.º 159/2012 already mentioned that the POCs should have a more strategic character and promote '*the sustainable development of the coastal zone through a prospective, dynamic and adaptive approach*' (POC-CE 2018, p.34). In line with the recent legal reform, the POC sought to establish '*a territorial model that is strategic, innovative, flexible and adaptive*' (POC-CE 2018, p.45).[24]

Moreover, according to the GTL Report (which is other reference document for the POC), '*the most adequate strategy for the Portuguese mainland coastal zone will progressively be adaptation, a broader concept that not only includes protection, but also other type of responses such as planned retreat (relocation) and accommodation* (…)', the POC-CE sought to assume this strategy and refers that it should be based on an '*adaptive management of the territory*' (GTL 2014, p.2, *in* POC-CE 2018, p.24).

The 'Report of Evaluation of the Implementation of the first POOC-CE' also recommended that '*the new POC should be more strategic, adaptive, more operational, clearer about the definition of the regime of safeguard of natural resources, and more effective in terms of monitoring and execution*' (POC-CE 2015 b, p.209). In the face of ongoing climate changes, the new POC should '*ensure that the proposed regimes of safeguard and regimes of management are aligned with a general model of flexible and progressive adaptive management*' (POC-CE 2015 b, p.54) (see Note 318).

Moreover, the POC-CE also mentions that, '*in the face of the coastal dynamics and the need to tailor and streamline practical solutions, it is proposed* (…) *a management process of the POC that is adaptive in time and in space, in order to progressively adjust the Strategy (…)*' (POC-CE 2018, p.52).

[23] The POC-CE Team defined four principles on which its Strategy of Planning and Management of the Coastal Zone should be founded: ecosystemic approach; adaptive management; integrated management; and territorial and institutional articulation (see Section 1.2).
[24] The POC argues such strategic character should have a direct correspondence in the Territorial Model and Directives (POC-CE 2018, p.34).

The POC-CE Report refers that, an effective implementation of the POC-CE requires the definition of '*a management model that allows a continual adaptation of the POC in function of the coastal dynamics and risks for people and assets (to which the area of intervention is intensely and unpredictably subjected)*', which, in turn, implies '*a system of information and continuous monitoring of the evolution of the coastal stretch and of the implementation of the Program of Actions, which sustains and informs the periodical evaluation of the POC*' (POC-CE 2018, p.96). The approach of '*adaptive management*' of the POC must be based on the articulation of these two aspects.

More specifically, the '*adaptive management model*' of the POC is based in the following guidelines:

- '*In the face of the coastal dynamics, the imponderability and unpredictability of the climate factors that induce to phenomena of coastal erosion, coastal floods and sea overtopping inundations* (…), *and the consequent risks for people and assets, the process of management of the POC-CE must be adaptive in time and in space, in order to progressively adjust the 'strategy of safeguard and protection of natural resources and of land use and occupation*' (POC-CE 2018, p.96).
- The process of adaptive management must be supported by the monitoring system of the POC (POC-CE 2018, p.96).
- The implementation of a process of adaptive management implies that the Norms concerning the enforcement of '*strategic principles of planning*' (i.e. the strategies of adaptation proposed), and the concrete actions defined in the Program of Actions, may be suspended or altered, if this contributes to better defend and safeguard people, built assets, and / or natural resources and values (POC-CE 2018, p.96).

According to the POC's Strategic Environmental Assessment (SEA) (POC-CE 2018 f), '*the POC proposes an adaptive management, as a means of adjusting (tailoring) the uses and occupations of the territory to the threats and vulnerabilities to which the coastal zone is subjected. Such adaptive management focuses on the areas of greater environmental sensitivity and higher susceptibility to extreme events, which are identified in the POC (in its Territorial Model)* (…)', namely the Critical Areas, the areas subjected to *Plans of Intervention on Beaches*, and other areas where the occurrence of extreme events may put people, assets, or natural values, at risk (POC-CE 2018 f, p.237, 198).

The POC's adaptive management approach should translate into a process of implementation (of the Programme) that is flexible and adapted to the conditions observed in each site at each moment, and, in this way, ensure the adequacy and suitability of the strategy of safeguard of people, assets and natural resources (POC-CE 2018 f, p.284). Overall, the POC aims at establishing an '*integrated and adaptive planning, organization and management of the coastal zone*' (POC-CE 2018 f, p.116, 123, 275, 282, 334).

3. Process of development of the POC-CE: stages of development

The several phases of the process of development of the POC-CE are described in Figure 9.

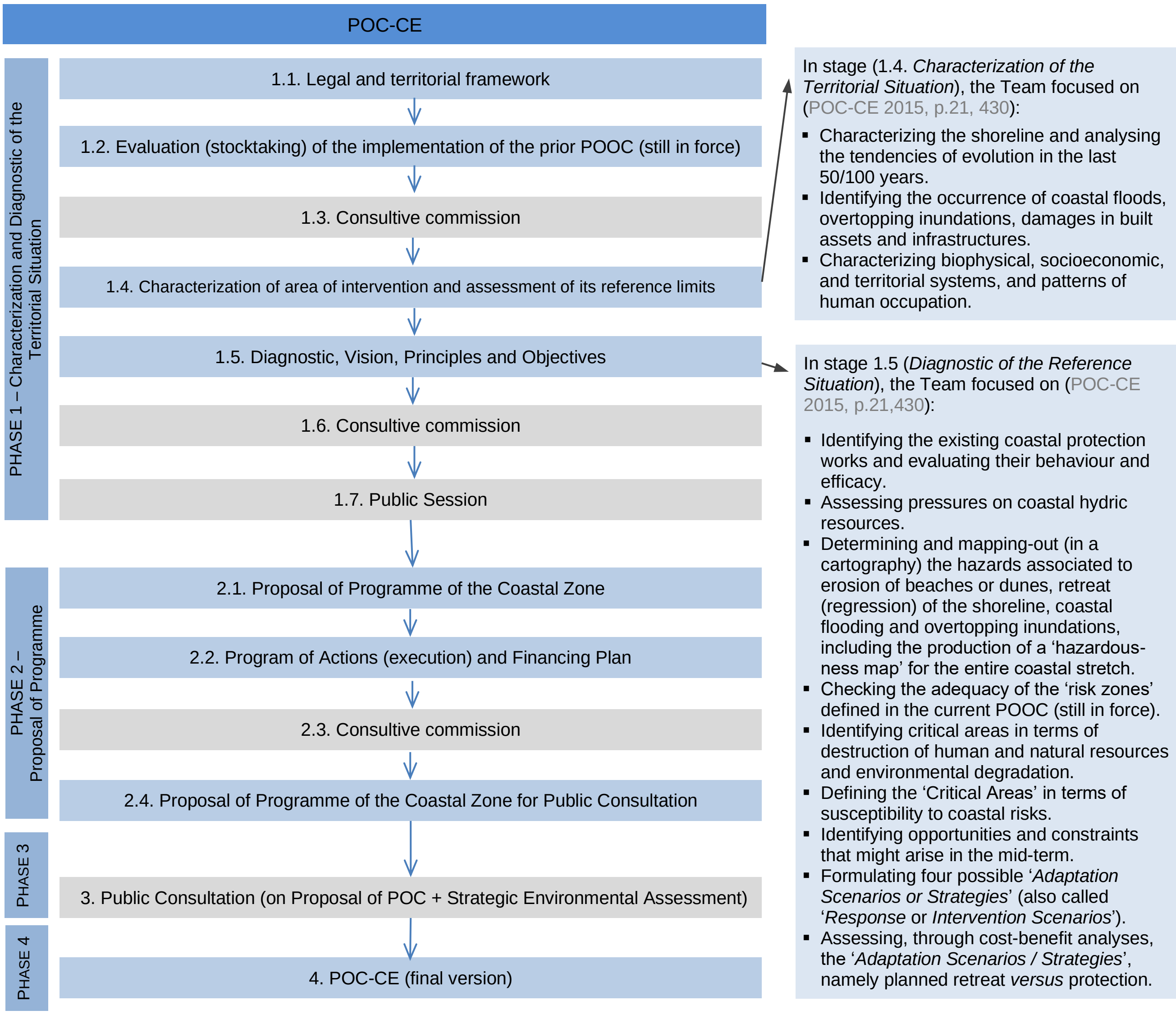


Figure 9. Main steps of the process of elaboration of the POC-CE. Source: adapted from the POC-CE 2018 f, p.24.

The POC-CE was approved in August 2021 (RCM nº111/2021). Importantly, APA ensured public participation during the elaboration of the Programme, through the realisation of several work meetings (in October, November, and December of 2017), concertation sessions (during May 2018), and 8 public clarification sessions (in December 2018). There was also a period of public discussion (between November 2018 and December 2018), during which the APA made the POC documents available for public consultation on an online platform (which also served to receive comments for subsequent appreciation). The main comments, suggestions and contributions, and the respective answers given by the Project Team, are reported in the '*Report of the Ponderation of the Public Discussion*' (POC-CE 2020).[25]

[25] During the elaboration of the POC-CE, namely in the phase of Characterization and Diagnostic, the Team produced several documents: Analysis and Discussion of the preliminary Public Consultation; Statement on the Implementation of the prior POOC-CE; Characterization and Diagnostic of the Territorial Situation; Characterization and Diagnostic of Reference Situation of Coastal Beaches (POC-CE 2018, p.9).

3.1. Conceptualization of Coastal Adaptation Strategies

The POC-CE refers that the process of adaptation to coastal risks is delivered through three main '*strategic principles of planning*', i.e. strategies of adaptation (protection, accommodation, or planned retreat) (POC-CE 2018, p.46). In the POC-CE, the main strategies of adaptation (*strategic principles of planning*) are understood and conceptualized according to the definitions provided in the GTL Report (POC-CE 2018, p.47, based on GTL 2014, p.50). The main strategies of adaptation (*principles of planning*) are described as follows (Figure 10, Figure 11, and Box 5):

a) Protection – *Reduction of risks associated to the impacts* (effects) *of climate change, mainly those related to SLR*'. Protection consists of maintaining (holding) or advancing the line (shoreline), through measures like artificial sediment nourishment, dune reconstruction, construction of artificial dunes (and associated dune ecosystems), construction of hard defence structures such as groynes, detached breakwaters, longitudinal adherent structures (e.g. revetments, seawalls).

b) Accommodation – *Increase of people's capacity to deal with the impacts of climate change and respective risks*. It involves solutions such as changing the human activities in the littoral, flexibly adapting infrastructures (in order to reduce the risk of flooding).

c) Planned Retreat – *Removal / withdrawal of people and built assets, in order to reduce the risk of disruptive events associated to climate change and limit their potential effects. This solution is recommended for zones where there is a great risk of erosion, flooding or overtopping inundations, and it should be adopted in extreme situations*' (GTL 2014, p.50, *in* POC-CE 2018, p.48).

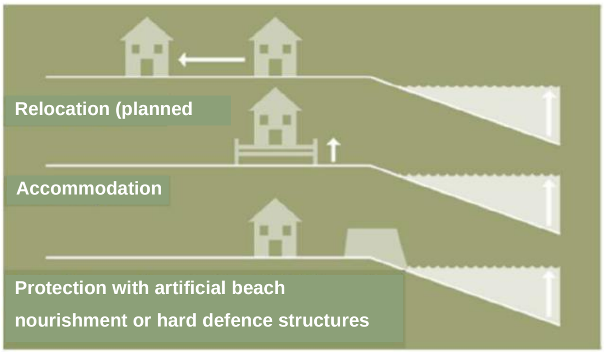


Figure 10. *Strategic principles of adaptation* in coastal zones. Source: GTL 2014, p.50, *in* POC-CE 2018, p.48.

According the POC, accommodation involves changing human activities in the littoral, or flexibly adapting infrastructures (to reduce flood risk). The POC mentions that accommodation measures can be hard (e.g. construction on piles, adaptation of drainage systems, or construction of emergency shelters) or soft (e.g. adoption of new building codes, introduction of flood- or salt-tolerant crops, creation of warning systems and evacuation procedures, or risk-based insurance). The adoption of resilient solutions for built assets, through innovative urban design solutions, the creation of seasonal uses, the rehabilitation of structures to be more resilient to water forces, the planning of public spaces as multifunctional spaces, are also examples of accommodation measures (*in* POC-CE 2018, p.50). Protection measures can be, for example, construction of defence works (geotubes, detached breakwaters, revetments with rocks, concrete blocks, or irregular structures, etc.), rehabilitation of existing defence works, sediment nourishments on beaches, strengthening / re-setting dune chains, implantation of palisades on dunes. Such types of interventions are identified in the Program of Actions (in the Strategic Axes 1 and 2) (POC-CE 2018 f, p.170).

The POC has defined the strategy of adaptation (*strategic principle of planning*) that must be applied in each Critical Area; this process of allocation of strategies took into consideration the vulnerability to coastal risks and the dimension and importance of the territorial elements exposed (POC-CE 2018, p.46).

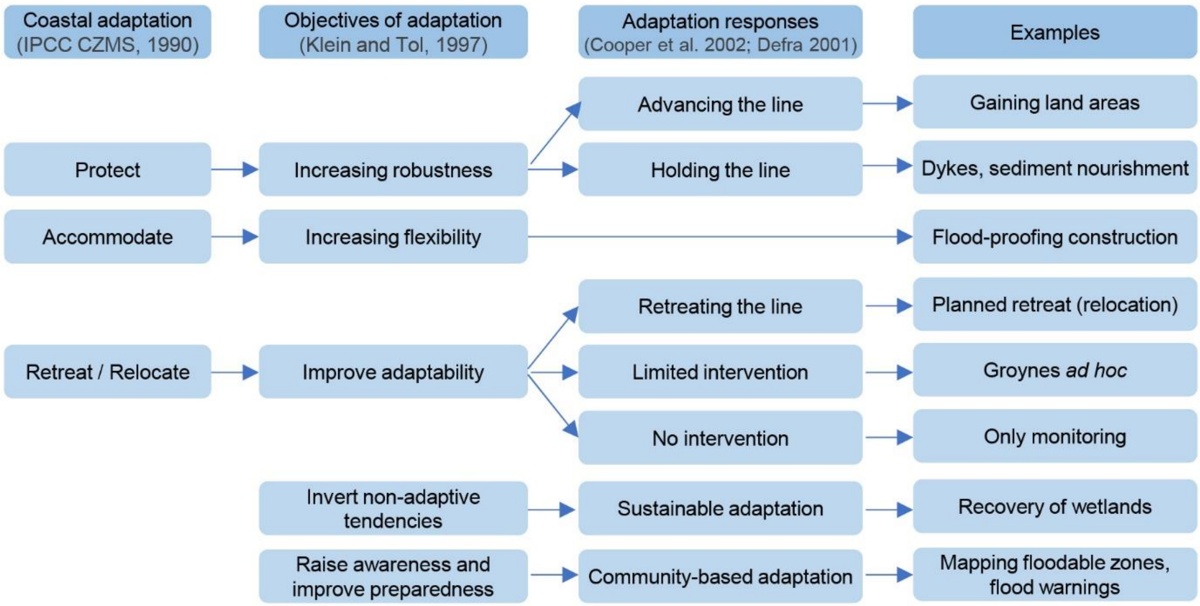


Figure 11. Examples of practices of planned adaptation in coastal zones. Source: POC-CE 2018, p.55, extracted from GTL (2014). See original version in Note 319.

BOX 5: Main adaptation options for coastal zones, as defined in the POC-CE (drawing on the GTL Report)

According to the GTL (2014), the main adaptation options for coastal zones, are:

- Protection, which aims at '*reducing the risk associated to the impacts of climate change, especially those resulting from sea-level rise*'.
- Accommodation, which aims at '*increasing the capacity of populations to cope with such impacts and respective risks*'.
- Retreat, which aims at '*reducing the risk of disruptive events caused by climate change by limiting their potential effects*' (GTL 2014, p.50, *in* POC-CE 2018 f, p.66, 188; 2015, p.424, 438)

These strategies of management of risks associated to climate change are also applicable to the risk of coastal erosion (POC-CE 2018 f, p.66, 188; 2015, p.424, 438).

'*The strategy of protection consists of maintaining (holding) or even advancing the shoreline by means of, for example, sediment nourishments (sand and pebble), reconstruction of dune systems, construction of artificial dunes and respective ecosystems, construction of hard structures such as groynes, breakwaters, detached breakwaters, and longitudinal adherent structures. Accommodation favours the alteration of human activities in the littoral and a flexible adaptation of the infrastructures to reduce the risk of flooding. Finally, planned retreat or relocation, in what regards human systems and human occupation in the littoral, is an extreme strategy which is usually only applied when the other strategies become unviable. In what regards natural systems, retreat is a strategy of migration of the coastal ecosystems further inland to make them less vulnerable to erosion and to sea-level rise.*' (GTL 2014, p.50, *in* POC-CE 2015, p.438 and POC-CE 2018 f, p.66).

The strategy of planned retreat '*implies the relocation of uses and occupations further inland, and, in practice, it is usually applied when the other strategies become unviable, namely in economic terms*' (GTL 2014 b, p.3, *in* POC-CE 2015, p.425).

These strategies are schematized in Figure 10.

The POC mentions that, regardless of the adaptation strategy chosen, the interventions can be classified as 'hard' or 'soft' (POC-CE 2018 f, p.67, 188; 2015, p.424, 438). There are different type-interventions associated to each strategy:

- The strategy of protection involves efforts to continue to use the zones subjected to hazards, risks and vulnerability in relation to sea actions. Within this strategy, there are hard interventions such as coastal defences (longitudinal / adherent structures), groynes, breakwaters, dykes, as well as soft interventions such as sediment nourishment, construction of dunes, recovery or creation of wetlands, etc. (POC-CE 2018 f, p.67; 2015, p.438).
- The strategy of planned retreat involves efforts to abandon zones subjected to hazards, risks and vulnerability in relation to sea actions. Within this strategy, there are hard interventions such as the relocation of threaten buildings, as well as soft interventions such as restrictions on land use or the definition of buffer zones. According to the GTL (GTL 2014), the strategy of planned retreat consists of the programmed removal of constructions from coastal zones at high risk of flooding, overtopping inundation and / or erosion (POC-CE 2018 f, p.67; 2015, p.439).
- The strategy of accommodation involves an effort to continue to live in zones subjected to greater hazards and risks associated to sea actions, but with alterations to habits or by adapting constructions. Within this strategy, there are hard interventions such as the construction on piles / stilts, or the adaptation of drainage systems, as well as soft interventions such as the adaptation of agricultural crops, warning systems and insurance systems (POC-CE 2018 f, p.67; 2015, p.439).

3.2. Development of four 'Adaptation Scenarios / Strategies' for the 'Critical Areas'

The POC Team developed four different possible '*Adaptation Scenarios or Strategies*', also called *Intervention Scenarios* or *Response Scenarios* (which consist of four possible adaptation strategies, not plausible future scenarios), for the critical areas (POC-CE 2018, p.73; 2018 f, p.69; 2015, p.439-440):

- 'Adaptation Scenario 0 – Reactive Strategy of Emergency Protection'. It consists of keeping the policy (philosophy) of hard defence works and / or localized interventions, mostly based on emergency interventions, with a short-term perspective.
- 'Adaptation Scenario 1 – Strategy of Planned Retreat / Relocation'. This strategy involves the programmed removal (withdrawal) of built assets from coastal zones at high risk of flooding, overtopping inundations, and / or erosion, which implies a long-term perspective. The GTL Report (2014) already recommended that (in the 2nd generation of POCs) the option of planned retreat should be favoured in stretches at high risk in relation of the options of protection and accommodation.
- 'Adaptation Scenario 2 – Strategy of Protection / Planned Maintenance'. It involves the maintenance of the existing defence structures in the mid-term, including their reinforcement or upgrade/adaptation, and the strengthening of dune systems whenever possible. It aims to defend the built environment by reducing the frequency of floods and overtopping inundations and limiting potential damages on built assets and infrastructures. This Strategy accepts a certain reduction of the dimensions of beaches and an eventual loss of recreational and landscape values.
- 'Adaptation Scenario 3 – Strategy of Mixed Protection / Planned Anticipation'. It involves the use of mixed solutions, in a long-term perspective. It requires integrated interventions of re-establishment of the sediment cycle by means of artificial sediment nourishments complemented by smaller protection interventions to protect the shoreline, which might imply innovative protection or accommodation solutions tested in pilot-cases, and/or a possible combination of diverse solutions (mix of integrated or complementary interventions) (POC-CE 2018, p.73; 2018 f, p.69; 2015, p.439).

Each Adaptation Scenario / Strategy contains several interventions (measures). The types of interventions considered in each of these Adaptation Scenarios or Strategies, and which were then used for the assessment of costs and benefits of such Strategies (in the Critical Areas), are shown in Table A (POC-CE 2018, p.73; 2018 f, p.69; 2015, p.441).

The interventions considered in each Adaptation Scenario / Strategy are (see numbers in Table A):

- Adaptation Scenario / Strategy 0 considers the interventions 1, 2 and 4, and mostly on 4.
- Adaptation Scenario / Strategy 1 is based on intervention 13 but may be complemented with any other interventions.
- Adaptation Scenario / Strategy 2 involves the interventions 1, 2, 3, 4, 5, 6, 11, and 12. It is mostly based on interventions 1, 2, 5 and 6, and the others are complementary.
- Adaptation Scenario / Strategy 3 is based on interventions 1, 2 and 3, it also considers 7, 8, 9 and 10, and may contain a combination of any other interventions except 13 (POC-CE 2018, p.74; 2018 f, p.69; 2015, p.441).

Figure 12 shows the type-interventions considered in each 'Adaptation Scenario / Strategy', and it explicitly mentions that there may be an eventual combination of interventions within each Strategy. Even the Critical Areas for which the POC proposes planned retreat were subjected to a cost-benefit analysis (in the Phase of Characterization and Diagnostic), in which the Team considered the four different 'Adaptation Scenarios / Strategies' above-mentioned (POC-CE 2018, p.73).

TYPE OF INTERVENTION	PERIODICITY / VALUE
1. Artificial beach nourishment	10 years / variable
2. Reinforcement of dune chain	5 years / variable
3. Re-establishment of sediment transport / Transposition of sand	5 years / variable
4. Rehabilitation of coastal protection structures and public fruition structures damaged by storms	5 years / variable
5. Periodical maintenance of existing coastal defence structures	10 years / variable
6. Reconfiguration / demolition of existing coastal defence structures	25 years / variable
7. Construction of new adherent defence structures (seawalls)	One-off (occasional) / variable
8. Construction of new groynes	One-off (occasional) / variable
9. Construction of detached breakwaters	One-off (occasional) / variable
10. Construction of submerged defence structures in pilot areas	One-off (occasional) / variable
11. Stabilization of cliffs	One-off (occasional) / variable
12. Landscape and environmental valorisation / recovery of degraded areas	One-off (occasional) / variable
13. Planned Retreat (removal of constructions at risk)	One-off (occasional) / variable

Table A. Types of interventions considered in the Adaptation Scenarios / Strategies envisaged for Critical Areas, namely for the assessment of the costs and benefits. Source: POC-CE 2018, p.4; 2018 f, p.69; 2015, p.441.

CENÁRIOS DE INTERVENÇÃO					
Cenário 3-Estratégia de Proteção Mista / Antecipação Planeada	Cenário 2-Estratégia de Proteção / Manutenção Planeada	Cenário 1-Estratégia de Relocalização / Recuo Planeado	Cenário 0-Reativo de Emergência / Proteção de Emergência	CENARIZAÇÃO DAS INTERVENÇÕES-TIPO DO MOOC (PARA EFEITOS DA ANÁLISE CUSTO-BENEFÍCIO DAS SITUAÇÕES CRÍTICAS)	INTERVENÇÕES-TIPO DE PROTEÇÃO / ANTECIPAÇÃO / ACOMODAÇÃO (com eventual combinação de intervenções num mesmo cenário de atuação)
X	X	x	X	1. Alimentação artificial de praias	
X	X	x	X	2. Reforço do cordão dunar	
X	X	x	·	3. Reposição do trânsito sedimentar / Transposição de areias	
X	X	x	X	4. Reabilitação de danos em estruturas de proteção costeira e de fruição pública devidos a tempestades	
X	X	x	·	5. Manutenção periódica das estruturas de defesa existentes	
X	X	x	·	6. Reconfiguração/demolição de estruturas de defesa existentes	
X	·	x	·	7. Construção de novas defesas aderentes	
X	·	x	·	8. Construção de novos esporões	
X	·	x	·	9. Construção de quebra-mares destacados	
X	·	x	·	10. Construção em área piloto de obras de defesa submersas	
X	X	x	·	11. Estabilização de arribas	
X	X	x	·	12. Valorização paisagística e ambiental / Recuperação de áreas degradadas	
x	·	X	·	13. Relocalização planeada de construções em risco	

ADAPTATION STRATEGIES, also called 'INTERVENTION SCENARIOS'					
Scenario 3 - Strategy of Mixed Protection / Planned Anticipation	Scenario 2 - Strategy of Protection / Planned Maintenance	Scenario 1 - Strategy of Relocation / Planned Retreat	Scenario 0 - Reactive Strategy of Emergency Protection	'SCENARIZATION' (PLANNING OF SCENARIOS) WITH THE TYPE-INTERVENTIONS (TO BE USED AS INPUT IN THE COST-BENEFIT ANALYSIS IN THE CRITICAL SITUATIONS)	TYPE-INTERVENTIONS OF PROTECTION, ANTECIPATION, ACCOMMODATION, AND PLANNED RETREAT (there may be an eventual combination of interventions within a given Intervention Scenario)
X	X	x	X	1. Artificial beach nourishment	
X	X	x	X	2. Reinforcement of dune chain	
X	X	x	·	3. Re-establishment of the sediment transport / sand transposition	
X	X	x	X	4. Rehabilitation of coastal protection structures and public fruition structures damaged by storms	
X	X	x	·	5. Periodical maintenance of the existing defence structures	
X	X	x	·	6. Reconstruction / demolition of existing defence structures	
X	·	x	·	7. Construction of new adherent defences (seawalls)	
X	·	x	·	8. Construction of new groynes	
X	·	x	·	9. Construction of new detached breakwaters	
X	·	x	·	10. Construction of submerged defence works in pilot areas	
X	X	x	·	11. Stabilization of cliffs	
X	X	x	·	12. Landscape and environmental valorisation / Recovery of degraded areas	
x	·	X	·	13. Planned retreat (relocation of constructions at risk)	

Figure 12 (left in Portuguese, and right in English). The 'Adaptation Strategies', also called 'Intervention Scenarios' for the critical areas, and their respective type-interventions (i.e. types of measures within the three main typologies of adaptation measures). Source: POC-CE 2015, p.442; 2018 f, p.71.

3.2.1. How the four 'Adaptation Scenarios / Strategies' were devised (*Scenario Planning*)

During the phase of Characterization and Diagnostic of the elaboration of the POC, the POC Team generated future scenarios of evolution of the coastal zone so-called 'environmental scenarios', and it also formulated possible scenarios of adaptation so-called 'Adaptation Scenarios or Strategies' (*Intervention Scenarios*, or *Response Scenarios*). While the environmental scenarios served to anticipate or predict how coastal dynamics and climate change will evolve, the Adaptation Scenarios served to discuss the actions / interventions that could be applied (POC-CE 2018 f, p.65; 2015, p.437).[26]

In the POC-CE, the formulation of the 'Adaptation Scenarios / Strategies' was implicitly associated to the selection of a temporal scale, i.e. a time-horizon. The POC has considered three *temporal horizons*: short-, mid-, and long-term (POC-CE 2018 f, p.66; 2015, p.437).

Definition of the Adaptation Scenarios or Strategies, and their type-interventions

First, the Team developed the four possible 'Adaptation Scenarios / Strategies' for the critical situations, and, then assessed them through a cost-benefit analysis (POC-CE 2015, p.424). The four 'Adaptation Scenarios / Strategies' were developed by crossing the time-horizons considered with the main types of coastal adaptation strategies and measures considered (POC-CE 2018 f, p.68; 2015, p.440). As mentioned, the POC considered 3 *temporal horizons*: short-, mid- and long-term: the short-term is mostly focused on emergency interventions / responses; the mid-term prioritizes the defence of the built heritage, through the reduction of the frequency of coastal floods and overtopping inundations and by limiting potential damages; and the long-term aims at safeguarding future generations of greater problems than the current ones, namely in areas at high risk of flooding and / or erosion (POC-CE 2018 f, p.188; 2015, p.423).

Therefore, the definition of the 'Adaptation Scenarios / Strategies' was influenced by time-horizon that was considered, which shaped the type of response that the POC could use (POC-CE 2018 f, p.188; 2015, p.423). In addition, the development of the four 'Adaptation Scenarios / Strategies' was based on the conclusions of the GTL Report (GTL 2014, *in* POC-CE 2018f, p.188; 2015, p.424), especially the definitions of *protection*, *accommodation*, and *planned retreat* of the GTL (Box 5). Subsequently, the four 'Adaptation Scenarios / Strategies', with their type-interventions, were comparatively assessed through cost-benefit analyses carried for the critical situations (POC-CE 2018 f, p.68; 2015, p.440).

3.2.2. Comparative assessment of the 'Adaptation Scenarios / Strategies' in each Critical Area

The POC-CE Team carried out a comparative assessment of the four 'Adaptation Scenarios / Strategies', through cost-benefit analyses, for each of the Critical Areas (POC-CE 2018 f, p.190). Overall, the Team aimed to comparatively assess strategies of planned retreat *versus* strategies of protection, in critical areas (POC-CE 2015, p.430). To this end, the Team carried out a comparative assessment of the four 'Adaptation Scenarios / Strategies'.

The Team proposed a methodology of cost-benefit analysis and a type-case for its application, which were discussed with and validated by APA (POC-CE 2015, p.430).[27] The study-case selected by the

[26] The Strategic Environmental Assessment (POC-CE 2018 f) mentions that 'the formulation of scenarios allowed (during the Strategic Environmental Assessment) analysing and assessing options that consist of strategic paths / ways to meet the objectives', and that 'the assessment of these options allowed selecting a strategic direction and, consequently, the decision-making' (POC-CE 2018 f, p.65). Although the SEA defines 'options' as strategic paths to meet the objectives', they do not consist of the 'adaptation pathways' defined in this Thesis.

[27] The POC-CE recognizes the value of cost-benefit analysis and multi-criteria analysis, and of the integration of both methodologies. However, due to the lack of references and examples of such integrated methodology, the Team decided to adopt a methodology of cost-benefit analysis but introduced some refinements regarding the variables, the ponderation of benefits, and the consideration of possible delays of 2 years in the completion of interventions (POC-CE 2015, p.445). For more on the methodology used, see Note 320.

Team to test and apply the methodology of cost-benefit analysis was the case of Pedrinhas-Cedovém (POC-CE 2015, p.437). The methodology was then tested in this case.

In this stage, several tasks were undertaken:

a) generation of scenarios / *scenarization* (one environmental scenario, and four Adaptation Scenarios).
b) selection of a Critical Area for applying the methodology.
c) consideration of several hypotheses about the evolution of the shoreline and sediment balance, and about the performance of existing coastal defence works.
d) development of proposals of intervention within the scope of the different Adaptation Scenarios / Strategies, for the study-case (POC-CE 2015, p.430) (see more in Note 320).

The proposed methodology of cost-benefit analysis involved the generation of two types of scenarios: (1) scenarios of evolution of the coastal zone called '*environmental scenarios*, and (2) the scenarios of adaptation called 'Adaptation / Intervention Scenarios or Strategies' (POC-CE 2015, p.437).

The *Report of Characterization and Diagnostic Phase* (POC-CE 2015) describes some of the tasks undertaken: 1) brief characterization of the study-case; 2) identification of interventions programmed in the 1st POOC-CE for this area; 2) analysis of existing structures and proposed interventions (in pre-existing studies); 3) exploration of possible alternative interventions; 4) delimitation of strips for safeguarding from coastal erosion for 2050 and 2100, including the assessment of the erosion rate at this coastal stretch, 5) assessment of costs and benefits of the four Adaptation Scenarios / Strategies.

In this way, the Team assessed the costs and benefits of each 'Adaptation Scenario / Strategy', and compared them (POC-CE 2015, p.437) (Figure 13).

COST-BENEFIT ANALYSIS FOR THE CRITICAL AREAS (TYPE-CASE) – TIME-HORIZON 2015-2100

Site: TYPE-CASE: PEDRINHAS-CEDOVÉM, Municipality of Esposende. P2.4 Ofir / Pedrinhas and P2.5 Pedrinhas / Cedovém / Apúlia

ANALYSIS OF COST-BENEFITS PER INTERVENTION SCENARIO BENEFITS, COSTS, RATIOS, AND OTHER INDICATORS

INDICATORS	VALUE OF BENEFITS	VALUE OF COSTS	VALUE = BENEFITS - COSTS	RATIO B/C = BENEFITS / COSTS	ECONOMIC dimension (0-10), weight (50%):	SOCIAL DIMENSION (score 0-10), weight (30%)						ENVIRONMENTAL DIMENSION (0-10), weight (20%)					FINAL SCORING
						Safety of populations (30%)	Safety of built assets (30%)	Public behaviour & perception (20%)	Working places (job creation) (10%)	Other items (10%)	Scoring (0-10)	Coastal dynamic (50%)	Visual impact landscape (40%)	Fauna and flora values (5%)	Impacts during interventions (5%)	Scoring (0-10)	
Scenario 0 - Reactive Strategy of Emergency Protection	5 266 590 €	1 661 622 €	3 604 968 €	3,17	8,00	5	5	5	5	5	5,0	5	5	5	7	5,1	6,52
Scenario 1 - Strategy of Relocation / Planned Retreat	1 039 084 €	9 093 382 €	-8 054 298 €	0,11	2,64	10	10	2	5	5	7,4	10	10	10	5	9,75	5,49
Scenario 2 - Strategy of Protection / Planned Maintenance	5 788 505 €	2 985 167 €	2 803 338 €	1,94	5,84	7	7	7	5	5	6,6	7	7	7	5	6,9	6,28
Scenario 3 - Strategy of Mixed Protection / Planned Anticipation	7 591 482 €	8 540 114 €	-948 632 €	0,89	4,00	8	8	8	5	5	7,4	8	8	8	5	7,85	5,79

Discount rate:	3,0%
Discount factor:	1,03
Current year:	2015
Year of initiation of intervention:	2020
Time-horizon:	2100

Figure 13. Estimated costs and benefits of the four 'Adaptation Strategies / Intervention Scenarios' considered, for the study-case of Pedrinhas-Cedovém. Source: POC-CE 2015, p.637.

4. Content of the POC-CE

According to the Decree-Law n.º80/2015 and the Decree-Law n.º159/2012, the POC-CE is composed of the following elements (POC-CE 2018, p.9):

a) Directives (*Directivas*).
b) Territorial Model (*Modelo Territorial*), i.e. the spatial representation of the Directives.

Complementarily, the POC-CE contains the following documents (POC-CE 2018, p.9):

i) Report of the Programme (*Relatório do Programa*)
ii) Program of Actions with the Financing Plan (*Programa de Execução e Plano de Financiamento*)
iii) Environmental Report and non-technical summary (*Relatório Ambiental e Resumo Não Técnico*)
iv) Qualitative and quantitative indicators to support the evaluation of the Programme.

4.1. Territorial Model

The Territorial Model pursuits the national objectives for the management of the coastal zone namely the protection of public interests and the protection of the resources of this area. The Territorial Model defines the regimes for the safeguard of natural resources and values and the regimes of management for ensuring a sustainable development of the coast (POC-CE 2018, p.53).

The area of intervention of the POC-CE is divided into two zones:

a) **Maritime Protection Zone** (*Zona Marítima de Protecção – ZMP*). It consists of the maritime area where the natural resources and values, and the current and potential uses and activities, require the establishment of regimes of protection that ensure the quality of water resources, the preservation of marine ecosystems, and allow the concretization of the strategy of sediment management. The regime of protection and management of this zone aims at ensuring the improvement of coastal and inland water bodies, the preservation of marine areas and volumes of greater biological productivity, the preservation of marine areas with relevance for the protection of nature and biodiversity, the safeguard of geological resources necessary to re-balance the sediment deficit. The ZMP corresponds to the area between the limit of the seabed and the bathymetric of 30m (POC-CE 2018, p.53-54).
b) **Terrestrial Protection Zone** (*Zona Terrestre de Protecção – ZTP*). It consists of the inland zone of the area of intervention (between the seabed limit and the inland limit of this area). In this zone, the existing resources and activities, and the current and potential threats, require the establishment of regimes of protection that ensure the safeguard of natural resources and values, the safety of people and assets, the compatibilization of socioeconomic development with a sustainable use of the territory. The ZTP contains coastal biophysical systems indispensable for the physiographic and ecological balance of the territory, namely areas with functions of protection of, or contention of pressures on, local systems. The planning and management of the ZTP must ensure the protection of the biophysical integrity of coastal spaces, the conservation of environmental and landscape values, the valorisation of existing resources in the coastal zone, the creation of conditions for maintaining, developing or expanding economic activities, a safe public fruition of the Maritime Public Domain, and the flexibilization and adaptability of the management measures (POC-CE 2018, p.53, 59, 60).

The ZMP and ZTP encompass different components (POC-CE 2018, p.53):

i) **Fundamental Components**, which aim to ensure the safeguard of natural resources and values, safeguard from coastal risks, and safeguard and management of the hydric domain. The Fundamental Components are subject of *Specific Norms* that set actions forbidden, conditioned and allowed.
ii) **Complementary Components**, which identify relevant biophysical, social, and economic resources, and which are the subject of *General Norms* that set directives for the planning and management.

Within the **Fundamental Components**, there are the following components (Figure 14):

- **Coastal Protection Strips** (*Faixas de Protecção Costeira*), which establish the regimes of safeguard/ protection of natural resources and values. There are two levels of importance – the Coastal Protection Strip (*Faixa de Protecção Costeira*) and the Complementary Protection Strip (*Faixa de Protecção Complementar*). Both strips (main and complementary) are identified in the ZMP, and in the ZTP (POC-CE 2018, p.53-54). The Coastal Protection Strip in the ZMP corresponds to the maritime area between the limit of the seabed and the bathymetric 16m. It is characterized by significant transversal and longitudinal transport of solid materials and by significant morphological variability in the sea bottom in short timescales. The Complementary Protection Strip in the ZMP is the adjacent area from the bathymetric 16m up to the bathymetric 30m (POC-CE 2018, p.56-57). The Coastal Protection Strip in the ZTP corresponds to the first inland strip that interacts with the sea, which encompasses representative elements of the coastal biophysical systems, namely the beach-dune systems, associated vegetation, dune systems (some artificialized), natural habitats, and the last sections of coastal waterlines. This strip is essential for keeping the balance of the coastal system and for the preservation of the coastline. The main biotypes presented in this Strip are dunes, estuaries, rocky littoral, and woodlands. The Complementary Protection Strip in the ZTP is a 'buffer zone' that is predominantly natural or partially artificialized, which is contiguous to the Coastal Protection Strip or frames (buffers) the *Predominantly Artificialized Areas* (POC-CE 2018, p.60-62).
- **Strips for Safeguarding from Coastal Risks**, namely the Strips for Safeguarding from Coastal Erosion (*Faixas de Salvaguarda à Erosão Costeira*) and the Strips for Safeguarding from Coastal Floods and Overtopping Inundations (*Faixas de Salvaguarda ao Galgamento e Inundação Costeira*). These strips seek to ensure the safeguard of people and assets from coastal risks.
- **Critical Areas** (*Áreas Críticas*), which consist of areas which, in terms of coastal risks, present greater susceptibility to destruction or damage of built assets and infrastructures, and / or natural resources. The Critical Areas may include urban spaces, productive activities, and / or natural spaces. For each Critical Area, the POC defines an adaptation strategy to taken (among *protection*, *accommodation*, or *planned retreat*).
- **Strategic Areas for Sediment Management** (*Áreas Estratégicas para a Gestão Sedimentar*), which consist of submersed sediment deposits with potential to become 'borrow sites' to allow sediment nourishments into adjacent beaches and dune zones. These areas are located within the Maritime Protection Zone (ZMP), between the bathymetric of 16m and 30m (POC-CE 2018, p.53, 58).
- **Margin** (*Margem*). It was delimitated according to Law (*Lei da Titularidade dos Recursos Hídricos e na Lei da Água*) and it seeks to ensure the safeguard and management of the Hydric Domain (POC-CE 2018, p.53-54). It corresponds to the strip of land contiguous to the limit of the seabed, and its width is established in law (*Portaria nº204/2016, de 25 de julho*). The Margin is essential to ensure the protection and safeguard of water bodies and the preservation of physical and biological dynamic processes on the land-water interface (POC-CE 2018, p.75).
- **Maritime Beaches** (*Praias Marítimas*), which may encompass areas in the ZMP and in the ZTP (POC-CE 2018, p.53-54). Beaches are classified in six typologies: urban, peri-urban, seminatural, natural, with restricted use, with forbidden use. The Territorial Model identifies the location and classification of the beaches. The regime of protection for the beaches is expressed in the *Management Norms*, which aim to regulate the uses and activities in the beaches, and in the Plans of Intervention on Beaches (*Planos de Intervenção nas Praias, PIPs*) (POC-CE 2018, p.79).

Within the Complementary Components, there are the following components (POC-CE 2018, p.53-54):

- *Areas with Special Interest for the Conservation of Nature and Biodiversity*.
- *Superficial Water Resources*.
- *Waves with Special Value for Water-Sports*.
- *Predominantly Artificialized Areas*, i.e. urban fabric. Given the current and future vulnerability to coastal risks of some of these areas, urban qualification and the management of urban seafronts must be aligned with the prevention and reduction of coastal risks. The POC defines General Norms to restrain urban expansion along the coast, which must be integrated into municipal plans
- *Port Areas*. Areas under port jurisdiction (commercial and fishing ports), namely the Leixões Port, under the jurisdiction of APDL (*Administração Portuária dos Portos do Douro, Leixões e Viana do Castelo, S.A*). In port areas, the management and planning are under the responsibility of the port authority but must attain to the POC's guidelines) (POC-CE 2018, p.92).
- *Fishing Centres* (POC-CE 2018, p.90) (on the Territorial Model, see Note 321).

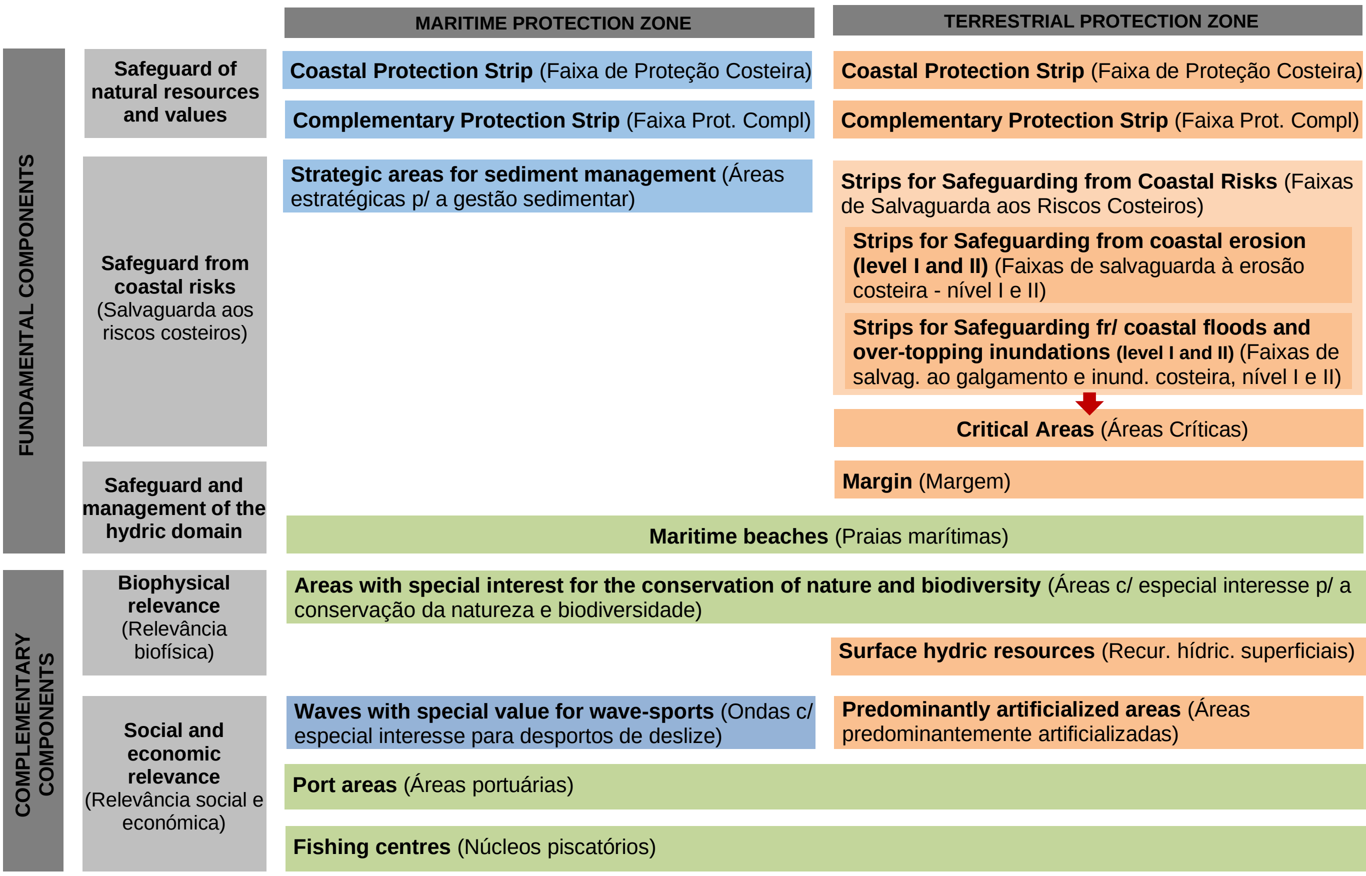


Figure 14. Structure of the Territorial Model of the POC-CE. Source: POC-CE 2018, p.55.

In line with the General Objective 1 (*Prevention and reduction of coastal risks and vulnerability to climate change*), the POC defines, in the Territorial Model, the *Strips for Safeguarding from Coastal Erosion* (for 2050 and 2100) and the *Strips for Safeguarding from Coastal Floods and Overtopping Inundations* (for 2050 and 2100) (POC-CE 2018, p.46, 63). These Strips consist of the spatial representation of '*regimes of safeguard that aim to contain the exposure of people and assets to the risks of coastal erosion, flooding, and overtopping inundations*', which must '*ensure the territorial protection from current vulnerabilities, and ensure that the forms of land use and occupation are compatibilized with the probable evolution of the climate and the consequent aggravation of the vulnerability to coastal risks*' (POC-CE 2018, p.63). Overall, these strips serve to set specific regimes for ensuring safety and safeguard from coastal risks (POC-CE 2018, p.46). These Strips have a preventive character and aim to safeguard land area from hazards expected to occur in a plausible future scenario with two time-horizons (2050 and 2100) (POC-CE 2018 f, p.192). In the Directives, the POC defines the actions allowed, forbidden, and promoted, in these Strips (ibid, p.195, 235). According to the POC, the definition of these Strips took into consideration the physical characteristics of coastal zones, the level of vulnerability of diverse sites, and the temporal horizon of exposure (POC-CE 2018, p.64) (Note 322). The Strips for 2050 served as the basis for delineating the Critical Areas (priority areas for adaptation) (ibid, p.46).

In the Territorial Model, the POC also defines (delimits) the Critical Areas, which are areas of greater susceptibility to damages and destruction of built assets, infrastructures, or natural values, which must be safeguarded. The planning of Critical Areas was based on the definition of the *strategic principle of planning* (or *strategic principle of adaptation*), i.e. the strategy of adaptation that must be applied (protection, accommodation, planned retreat) (POC-CE 2018, p.52, 64; 2018 f, p.197). The delimitation of the Critical Areas, and the definition of their *principle of planning*, substantiate the POC's strategy of prevention and reduction of coastal risks for urban zones with greater exposure.

In addition, the POC defines *Strategic Areas for Sediment Management* with the aim of promoting a greater sedimentary equilibrium, and, ultimately, inverting the marked retreat of the shoreline that has occurred in some stretches of the area of intervention (POC-CE 2018 f, p.198). Furthermore, the POC proposes actions of protection and recovery of the natural systems (namely dune systems, estuarine systems and river systems) that complement and strengthen the prior strategies, by making the territory more resilient to the effects of climate change (POC-CE 2018 f, p.198).[28]

These are the main ways through which the POC seeks to ensure the reduction and prevention of coastal risks and associated climate change effects (POC-CE 2018 f, p.198).

4.1.1. Strips for Safeguarding from Coastal Erosion

In the face of geomorphological characteristics, evolutive tendencies, and land uses, of the coastal zone CE, the POC Team considered that it was essential to incorporate measures explicitly aimed at safeguarding from, and mitigating, the impacts resultant from shoreline mobility and coastal dynamics. As a planning and management measure (also an adaptation measure), the POC has delineated the '*Strips for Safeguarding from Coastal Erosion*' for 2050 and 2100 in low-lying sandy littoral. According to the POC, these Strips have a preventive character: they impose restrictions on the use and occupation of soil, and aim at '*protecting (safeguarding) the land-territory from the occurrence of different scenarios of hazardousness in the future*'. Their definition involved '*the extrapolation (for 2050 and 2100) of evolutive tendencies observed in recent past*' (POC-CE 2018 b, p.6-7; 2015, p.397; 2018 f, p.181).

The POC-CE describes the 'Strip for Safeguarding from Coastal Erosion' as the '*land area where it is likely to occur erosion and where the coastline will possibly migrate landwards*' (POC-CE 2018, p.64).

The 'Strips for Safeguarding from Coastal Erosion' were defined and delineated (by the POC-CE Team) based on an addition (sum) of three components: 1) the projected retreat (regression) of the shoreline based on historical erosion rates (shoreline migration rates) observed in the last decades; 2) the projected erosion induced by extreme storms; and 3) the projected erosion induced by expected SLR (POC-CE 2018, p.64). This Strip was delineated for two time-horizons[29]: 2050 (Level I), and 2100 (Level II) (POC-CE 2018, p.64). In simple terms, these Strips correspond to areas that the POC Team has projected to be potentially affected by coastal erosion and shoreline retreat (regression) until 2050 and 2100.

[28] To ensure the protection of natural resources and values, the POC-CE establishes, in its Directives, different regimes for protecting different areas located in the Terrestrial Protection Zone (*Zona Terrestre de Proteção, ZTP*) or Maritime Protection Zone (*Zona Marítima de Proteção, ZMP*). Such Directives are included in General Norms, Specific Norms and Management Norms (POC-CE 2018, p.45).

[29] In the POC-CE, these time-horizons are erroneously called 'temporal scenarios'. In fact, the POC-CE only considered a single scenario with two time-horizons. Despite that, the POC refers to them as different temporal scenarios, each with a respective level of susceptibility. This is a wrong interpretation of the term 'scenarios', which in fact, has hindered the exploration of other plausible future scenarios.

Methodology for defining the *Strips for Safeguarding from Coastal Erosion*

To calculate and delineate the *Strips for Safeguarding from Coastal Erosion*, the Team has considered and analysed three main processes: i) the long-term erosion (for 2050 and 2100), ii) the erosion induced by extreme storms, iii) the erosion induced by SLR (POC-CE 2018 b, p.3). The Team examined the effects of long-term erosion for each profile and the effects of the other processes in a generalized way (POC-CE 2018 b, p.9; 2015, p.397). Despite the differences between various stretches of the coast CE, e.g. different geomorphological and physiographic characteristics, evolutionary trends, and levels of intervention (existence of defences), the Team analysed the coastal zone as a whole.

The components considered by the Team as influencing the projected future retreat of the shoreline are:

- *Shoreline Evolution Rate* (*TELC $_{50\ /\ 100}$*). It corresponds to the linear extrapolation, for the time-horizons of 2050 and 2100, of the annual erosion rate calculated for each profile. In fact, this component should be called 'projection of the evolution of the shoreline for 2050 and 2100', as it is not a rate, but a prediction / projection of the position of the shoreline, which was calculated based on the assumption that the existing annual migration rates are going to continue in the coming years. For the projection for 2050 and 2100, the Team used the average annual rate of migration of the shoreline, obtained from the analysis of available lines (past shorelines). The Team compared different historical shorelines correspondent to different years for which there were aerial photographs and calculated the retreat (regression) rate for each profile (based on the mobility of the past shorelines extracted from photos) (POC-CE 2018 b, p.9-10; 2015, p.397).[30]
- *Erosion induced by Storms* (*$R_{MÁX}$*). It consists of the maximum expectable retreat of the shoreline due to an extreme storm (POC-CE 2018 b, p.17).
- *Erosion induced by SLR* (*R_{NMM} 50/100*) (POC-CE 2018 b, p.18) (see more in Note 323).

Component I - Shoreline Evolution Rate (*TELC $_{50\ /\ 100}$*): As mentioned, the TELC 50/100 results from the linear extrapolation, for 2050 and for 2100, of the annual erosion rate calculated for each profile (POC-CE 2018 b, p.10). These lines (bidimensional representations of shoreline in different past years) were extracted from aerial photos of the years 1958, 1965, 1973, 1983, 1987, 1994, 1995, 2006, 2012 (some covered the whole coastline, while others covered parts of it).[31] The evolutionary tendencies of the shoreline were studied through the analysis of the mobility of the shoreline (lines extracted from the aerial photos of different dates) using the *Digital Shoreline Analysis System* (DSAS) developed by the US Geological Survey (POC-CE 2018 b, p.12).

Component II - Erosion induced by Storms' (*$R_{MÁX}$*): It consists of the maximum retreat expectable of the shoreline due to an extreme storm (POC-CE 2018 b, p.17) (the maximum expectable retreat of the beach profile). To calculate the maximum expectable retreat of the shoreline caused by an extreme storm, the Team used the formula of Dean et al. (2008):

[30] The 'Shoreline Evolution Rate' (*TELC 50 / 100*) corresponds to the linear extrapolation, for the time-horizons of 2050 and 2100, of the annual erosion rate calculated for each profile (POC-CE 2018 f, p.181). The annual erosion rate that was considered in each profile is presented in the maps of the POC-CE (2015) (see *Peça Desenhada n.º19 – Faixas de projeção da evolução da linha de costa a 50 e a 100 anos*).

[31] The Team considers that the extraction of 'lines' (from aerial photos) as bidimensional representations of the migration of the shoreline is a useful methodology but recognizes that it does not allow the calculation of sediment balances (which is a tri-dimensional calculation). Thus, there may be areas where, the Team did not observe significant retreat of the shoreline, but there is a great loss of sediments. Moreover, though this methodology aggregates the sum of all factors that influence the migration, it does not distinguish the intensity of each factor (POC-CE 2018 b, p.10). In addition, the extraction / vectorization of shorelines may contain numerous sources of error, e.g. the operator's interpretation of photos, handmade delineation of the line, its accuracy, spatial resolution and quality of the photo, georeferencing and angle of the photo. To deal with these uncertainties, the Team assumed a value of error or uncertainty associated to the delineation of all shorelines of 4 meters.

$$R_{MÁX} = (SM + 0.068\ H_b)\frac{W_b}{B + d_b}$$

$R_{MÁX}$ – the maximum expectable retreat of the shoreline (in meters)
SM – storm surge (in meters)
H_b – the height of wave breaking in meters
d_b – the depth in the wave breaking (in meters relative to medium sea level) = 1,28 H_b
W_b – the width of the active profile (in meters)
B – the average ground-level (altimetric height) of the eroded area (in meters relative to medium sea level)

Component III - Erosion induced by climate change-induced SLR (*R_{NMM} 50/100*): This component was obtained through the application of the Bruun Rule (Bruun 1962), which is a model that calculates the readjustment of the transversal profile of the coast to the rise of the average water level (base-level), and which assumes that a fraction of the lost volumetry of the beach results from the alteration of the sediment pattern imposed by SLR (POC-CE 2018 b, p.18). In the face of the rise of the sea level, the beach profile tends to respond by promoting the feeding of sediments on the near platform. The retreat is given by the following formula:

$$R_{NMM} = \Delta_{NMM}\frac{W_c}{B + d_c}$$

Δ_{NMM} – secular variation of the medium (average) sea level (in meters)
W_c – width of the active profile (up to the closure depth) (in meters)
d_c – depth of closure (in meters in relation to the medium sea level)
B – average height (ground level) of the eroded regions (in meters in relation to the medium sea level).

The values of SLR adopted for the calculation of the R_{NMM} for 2050 and 2100, were, in accordance with the indications of APA, + 0,35m and + 1,50m, respectively. The Team argues that the +1,5m scenario of SLR for 2100 is aligned with the recommendations of scientific community, and considers it a more precautionary scenario, given the uncertainty around the projection of SLR (POC-CE 2018 b, p.19).

Calculation of the width of the *Strips for Safeguarding from Coastal Erosion*

The final width of the Strips for Safeguarding from Coastal Erosion (FSEC) for 2050 (Level I) and 2100 (Level II) corresponds to the sum (addition) of the three components previously described, as follows:

$FSEC_{Level\ 1\ (2050)} = TELC_{50} + R_{MÁX} + R_{NMM\ 50}$

$FSEC_{Level\ 2\ (2100)} = TELC_{100} + R_{MÁX} + R_{NMM\ 100}$

In the coastal stretches where no trends of retreat in the past were identified, the FSEC results from the sum of the retreat induced by the SLR and retreat induced by extreme storms (POC-CE 2018 b, p.19).

The values obtained for the ***TELC** $_{50/100}$* were represented (mapped) in layouts (POC-CE 2018 b, p.23).

Regarding the ***$R_{MÁX}$***, the POC-CE Team considered a value of 30m for 2050, and of 35m for 2100, '*in a way that accounts for the possible aggravation of the storm patterns*' (POC-CE 2018 b, p.23).

Regarding the ***R_{NMM}***, the POC-CE Team calculated a value of 10m for 2050, and of 40m for 2100, in '*a perspective that is not excessively extreme (since the projections of SLR, and other factors, have always deep uncertainties associated to them)*'.

Then, the Team added (summed) the values of the *$R_{MÁX}$* and of the *R_{NMM}*, to the values of the *TELC* (POC-CE 2018 b, p.23).

In sum, according to the methodology used by the POC-CE, the final width of the Strips for Safeguarding from Coastal Erosion for given year (*$FSEC_{year\ n}$*) corresponds to the protected shoreline retreat for a *year n* (in meters), and it results from the sum of the three components described, as follows:

$FSEC_{year\ n}$ = Retreat $_{(for\ a\ year\ n)}$

Retreat $_{(for\ a\ year\ n)}$ = $TELC_{year\ n}$ + $R_{MÁX}$ + $R_{NMM\ year\ n}$

$TELC_{year\ n}$ is the projection of the future retreat based on historical retreat.
$R_{MÁX}$ is retreat induced by extreme storm.
$R_{NMM\ year\ n}$ is retreat induced by SLR.

Thus, the POC-CE Team calculated the width of the Strips as follows:

Retreat $_{(for\ 2050)}$ = $TELC_{2050}$ + 30m + 10m = $TELC_{2050}$ + 40m

Retreat $_{(for\ 2100)}$ = $TELC_{2100}$ + 35m + 40m = $TELC_{2100}$ + 75m

The Figure 15 and Figure16 show the Strips for Safeguarding from Coastal Erosion in relevant stretches.

Figure 15 (left and right). Strips for Safeguarding from Coastal Erosion for 2050 and 2100 in the area of Matosinhos and Porto, respectively. Source: Peça Desenhada n.º 20 - Faixas de salvaguarda à erosão costeira, *in* POC-CE 2015).

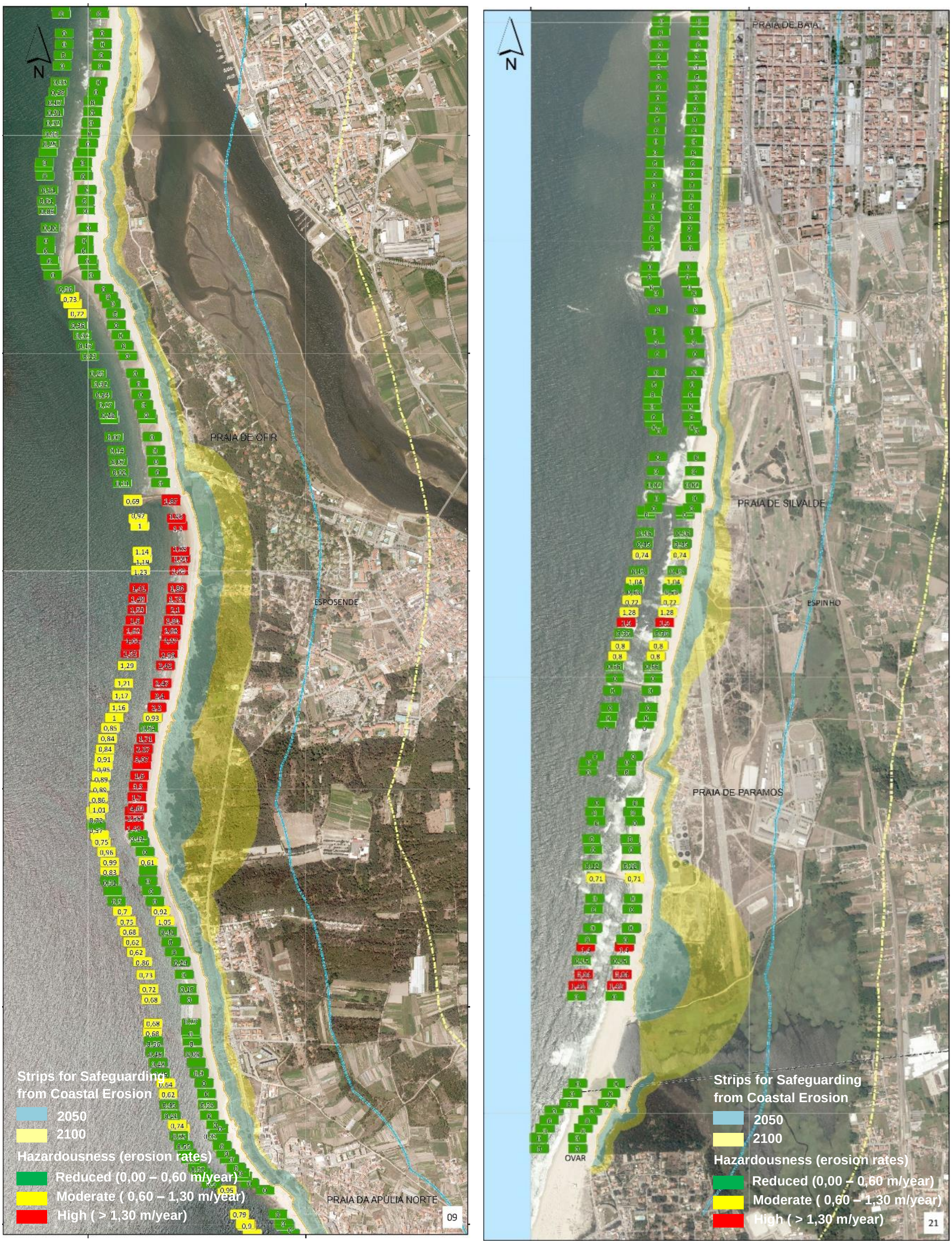


Figure 16. The Strips for Safeguarding from Coastal Erosion for 2050 and 2100 in the area of Ofir and Pedrinhas / Cedovém (left), and in the area of Espinho and Paramos (right). Source: Peça Desenhada n.º 20 - Faixas de salvaguarda à erosão costeira, *in* POC-CE 2015).

4.1.2. Strips for Safeguarding from Coastal Floods and Sea Overtopping Inundations

The POC-CE defines the 'Strips for Safeguarding from Coastal Floods and Sea Overtopping Inundations' as the land area where there is probability of occurrence of coastal flooding or overtopping events (from the sea). According to the POC, in the delineation of these Strips, the Team took into account '*the expected scenarios of SLR, and the occurrence of extreme weather events like storm surges*' (POC-CE 2018, p.65). This Strip was also delineated for two time-horizons[32]: 2050 (level I) and 2100 (level II). In simple terms, these Strips correspond the areas that may be potentially affected by coastal flooding or overtopping events in 2050 (Level I) and in 2100 (Level II) (POC-CE 2018, p.65).

Methodology for defining the *Strips for Safeguarding from Coastal Floods and Sea Overtopping Inundations*

The POC-CE defines coastal flooding and coastal overtopping inundation as the condition of submersion by seawater, permanently or episodically (during a certain period), of areas that are usually not submersed. According to the methodology applied by the POC-CE, the maximum height achieved by the seawater surface depends, in each coastal profile and at each moment, of the sum of three vertical components (POC-CE 2018 b, p.25):

- The sea level, which is determined by the astronomical tide (**MA**).
- The storm surge (or wind setup), i.e. the phenomena of rising water (**SM**).
- The run-up, which includes the wave set-up (**S**) and the extension of the waves (**E**) (POC-CE 2018 b, p.25).[33]

Thus, in accordance with the methodology used in the POC-CE, the height of the maximum flood (**ZH**) is given by the following formulation (POC-CE 2018 b, p.25):

$$\mathbf{ZH = (MA + SM) + (S + E)}$$

The POC-CE Team decided to use the methodology developed by Viegas and Sancho (2005). Viegas and Sancho (2005) developed a simplified probabilistic method for the determination of extreme sea levels (flood heights), which is applicable to the North coast of Portugal, provided that there is data about the meteorological tide and wave climate (POC-CE 2018 b, p.28).

In the application of this methodology to the stretch CE, the POC Team made an extrapolation of the W direction, for the return period of 20 years and 35 years (2050) and 85 years (2100), and it also included the projections of SLR (0,35m for 2050 and 1,50m for 2100). The Team obtained the following average flood heights, for 2050 and 2100: 7,60m (ZH – hydrographical zero) and 9,09m (ZH), respectively (POC-CE 2018 b, p.28-29). Other wave directions may potentially induce to higher levels of inundation.

Then, the flood heights obtained were applied to an altimetric model of the coastal zone (LIDAR), which allowed the identification of zones vulnerable to flooding (that may be directly or indirectly flooded, contiguous or not to the shoreline or which may be affected by the breaching of the shoreline). This information was then crossed with the location of flood and overtopping events occurred in 2014 (resultant from extreme events) (POC-CE 2018 b, p.29). See more about this methodology in Note 324.

[32] In the POC-CE, these time-horizons are erroneously called 'temporal scenarios'. The POC only considered a single scenario with two time-horizons. Despite that, the POC refers to them as different temporal scenarios, each with a respective level of susceptibility.

[33] According to the POC, the storm surge (SM) can be obtained by the difference between the real levels of the risen waters (observed in tide gauges / marigraphs) and the levels solely caused by the tide (POC-CE 2018 b, p.26). There are several methodologies available for the determination of the run-up (S+E) (POC-CE 2018 b, p.27).

Figure 17 and Figure 18 show the Strips for Safeguarding from Coastal Floods and Overtopping Inundations, in some relevant stretches.

Figure 17 (left and right). Strips for Safeguarding from Coastal Flooding and Overtopping Inundations for 2050 and 2100 in the area of Matosinhos and Porto, respectively. Source: Peça Desenhada n.º 21 - Faixas de salvaguarda ao galgamento oceânico e inundação costeira, *in* POC-CE 2015).

Figure 18. The Strips for Safeguarding from Coastal Flooding and Overtopping Inundations for 2050 and 2100 in the area of Ofir and Pedrinhas / Cedovém (left), and in the area of Espinho and Paramos (right). Source: Peça Desenhada n.º 21 - Faixas de salvaguarda ao galgamento oceânico e inundação costeira, *in* POC-CE 2015).

Figure 19 shows part of the Territorial Model in the area of Matosinhos and Porto.

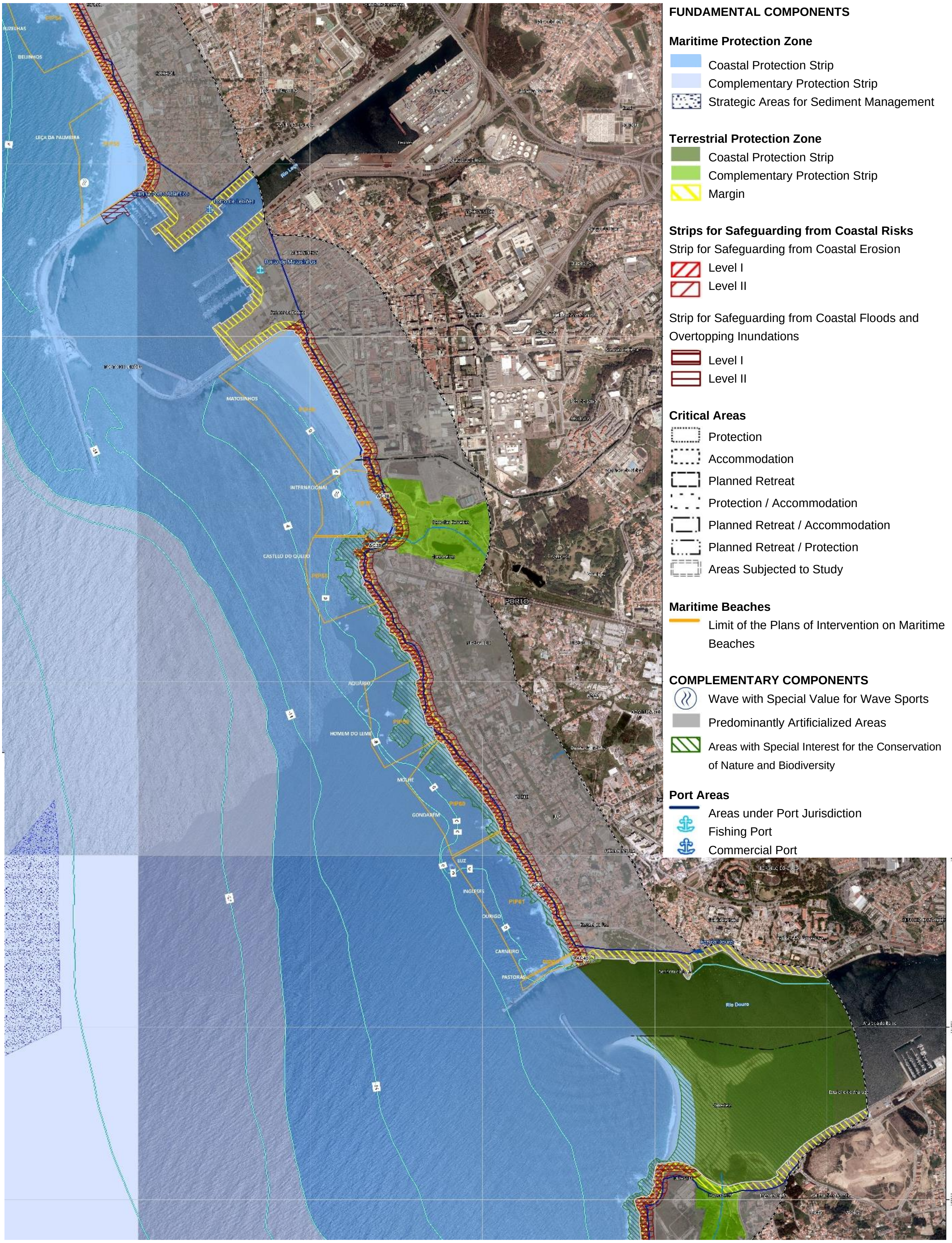


Figure 19. The Territorial Model of the POC-CE in the area of Matosinhos and Porto. Source: POC-CE 2018 (MT 11 and MT12).

4.1.3. CRITICAL AREAS

The Critical Areas are areas where the susceptibility to coastal risks, and the relative importance of the exposed elements, require the implementation of strategies of adaptation to coastal risks as priority interventions.[34] The strategies of adaptation for the Critical Areas, also called '*strategic principles of planning*' or '*strategic principles of adaptation*' – i.e. protection, accommodation, or planned retreat – and their conceptualization, are linked to the definitions of the GTL Report (POC-CE 2018, p.64).[35]

The POC Team defined the Critical Areas by overlapping of the risk of coastal erosion with the effect of coastal floods and overtopping inundations for the time-horizon of 2050 (POC-CE 2018, p.66).[36] The Critical Areas may encompass urban zones, productive activities, and/or natural zones (Note 325). The Critical Areas will be particularly relevant for the operationalization of the strategy of prevention and reduction of coastal risks proposed by the POC-CE (POC-CE 2018, p.66).[37]

4.1.3.1. *Strategies of Adaptation / Strategic Principles of Planning* proposed for each Critical Area

According to the POC, the Critical Areas are areas where, given their susceptibility to coastal risks and their occupation, priority adaptation interventions must be carried. Such interventions must be framed within specific adaptation strategies – i.e. they must be based on, and guided by, the '*principles of planning*' (strategies of adaptation) that, in each case, represent the best trade-off between the costs and benefits of interventions (in terms of safeguard of people, built assets, and natural values) (POC-CE 2018, p.67, 64). The POC-CE has considered three main '*principles of planning*', i.e. three main strategies of adaptation, which stem from the GTL (POC-CE 2018, p.67, based on GTL 2014):

- Protection – defence interventions in urban, productive, or natural areas, which may be undertaken in the Critical Areas identified or in the adjacent Maritime Protection Zone (ZMP), with the aim of 'holding' or advancing the line (the shoreline).
- Accommodation – management measures for urban areas which aim to change or adapt the type of occupation and human activities and make the existing infrastructures more 'flexible'.
- Planned Retreat – interventions of retreat (withdrawal / setback) of built-up zones in relation to the shoreline, by relocating land uses and infrastructures and ensuring the re-naturalization of such areas.

The POC identifies 46 Critical Areas in the Territorial Model. For each Critical Area, the POC defines the *strategic principle of planning* (also called *strategic principle of adaptation*), i.e. the strategy of adaptation, that must be implemented, and its priority (high / medium / low) (POC-CE 2018, p.68) (Figure 20 and Figure 21). Thus, in a given Critical Area, the POC may establish a strategy of: 'protection', 'accommodation', 'planned retreat', 'protection and accommodation', 'planned retreat and protection', 'planned retreat and accommodation', or 'area subjected to study' (POC-CE 2018 d, p.52). The Critical Areas for which the POC proposes planned retreat must be incorporated in municipal plans, and their implementation must be articulated with APA, and, whenever justifiable, it should be considered the possibility of transferring construction rights to adequate zones (POC-CE 2018, p.72).

---

[34] The POC-CE defines the Critical Areas as areas that are within the Strip(s) for Safeguarding from Coastal Risks and where there are situations of high hazardousness in the short- and mid-term, which justify the adoption of specific strategies of adaptation to coastal risks (POC-CE 2018, p.72). These areas present greater susceptibility to damage / destruction of coastal resources and values (either natural or anthropic) (ibid, p.66).
[35] The strategies of adaptation to be prosecuted in the Critical Areas were oriented by the *principles of planning* divulged by the GTL Report – protection, accommodation, and planned retreat (*in* POC-CE 2018, p.64). The term 'principles of planning' is often used in the POC, as well as the term 'principles of adaptation' or 'strategies of adaptation'. Both terms refer to the three main types of coastal adaptation strategies.
[36] The methodology used for the definition of the Critical Areas involved the analysis (and crossing maps) of the Strips for Safeguarding from Coastal Risks for 2050, Cartography of Land Use and Occupation, the GTL Report, etc. (*in* POC-CE 2018, p.72).
[37] The Critical Areas do not have a specific regime specifying actions allowed, conditioned and forbidden. If the Critical Areas overlap with the Terrestrial Protection Zone, then the regimes of protection of natural values must be applied; and if they overlap with Strips for Safeguarding from Coastal Risks, then the regimes of safeguard from coastal risks must be applied. In the Critical Areas, the POC's way of operationalizing its adaptation strategy is through the definition of *principles of planning/adaptation*, instead of the definition of a protective regime (ibid, p.67).

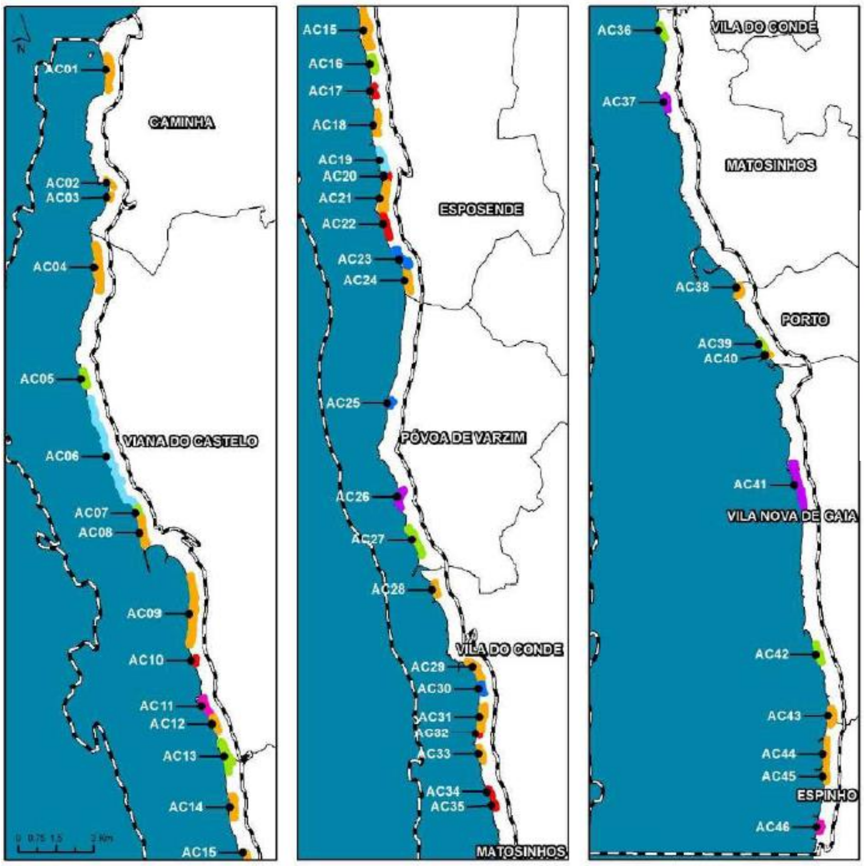


Figure 20. Critical Areas and the respective strategy of (*principle of planning*) proposed by the POC-CE. Source: POC-CE 2018, p.71; 2018 f, p.81.

Principle of Planning or Adaptation

- Protection
- Accommodation
- Planned Retreat
- Protection / Accommodation
- Planned Retreat / Accommo.
- Planned Retreat / Protection
- Areas subjected to study

Identification of the Critical Area	Principle of Planning or Adaptation	Priority
AC01-Praia de Moledo	Protection	High
AC02- Vila Praia de Âncora	Protection	Intermediate
AC03-Dunas do Caldeirão	Protection	Intermediate
AC04-Praia da Ínsua	Protection	Low
AC05-Praia do Carreço	Protection / Accommodation	Low
AC06-Areosa	Area Subjected to a Study	Intermediate
AC07-Praia Norte	Protection / Accommodation	Low
AC08-Porto de Viana do Castelo	Protection	Intermediate
AC09-Rodanho / Areosa	Protection	High
AC10-Praia da Amorosa	Planned Retreat	Intermediate
AC11-Pedra Alta	Planned Retreat / Protection	Intermediate
AC12-Litoral da Pedra Alta	Protection	Low
AC13-Foz do Neiva	Protection / Accommodation	High
AC14-Belinho	Protection	Intermediate
AC15-Praia de Rio de Moínhos	Protection	High
AC16-Praia de Cepães	Protection / Accommodation	Intermediate
AC17-Praia de Suave Mar	Planned Retreat	Intermediate
AC18-Restinga de Ofir	Protection	Intermediate
AC19-Praia de Ofir Norte	Area Subjected to a Study	High
AC20-Praia de Ofir Sul	Planned Retreat	High
AC21-Bonança	Protection	High
AC22-Pedrinhas / Cedovém	Planned Retreat	High
AC23-Apúlia	Accommodation	Intermediate
AC24-Praia da Ramalha	Protection	Low
AC25-Aguçadoura	Accommodation	Intermediate
AC26-Aver o Mar	Planned Retreat / Accommodation	Intermediate
AC27-Praia da Póvoa do Varzim	Protection / Accommodation	High
AC28-Caxinas Norte	Protection	Low
AC29-Praia da Azurara	Protection	Intermediate
AC30-Árvore	Accommodation	Low
AC31-Praia do Mindelo Norte	Protection	Intermediate
AC32-Praia do Mindelo	Planned Retreat	Intermediate
AC33-Praia do Pinhal dos Eléctricos	Protection	Intermediate
AC34-Praia da Congreira	Planned Retreat	Intermediate
AC35-Praia do Pucinho	Planned Retreat	Intermediate
AC36-Angeiras	Protection / Accommodation	Intermediate
AC37-Praia do Marreco	Planned Retreat / Accommodation	Intermediate
AC38-Praia Internacional	Protection	Intermediate
AC39-Praia dos Ingleses	Protection / Accommodation	Low
AC40-Praia do Carneiro	Protection	High
AC41-Litoral da Madalena	Planned Retreat / Accommodation	Intermediate
AC42-Praia da Granja	Protection / Accommodation	High
AC43-Litoral São Félix da Marinha	Protection	Low
AC44-Praia da Baía	Protection	Intermediate
AC45-Praia de Silvalde Sul	Protection	High
AC46-Praia de Paramos	Planned Retreat / Protection	High

Figure 21. List of the Critical Areas and the respective strategy of (*principle of planning*) proposed by the POC-CE. Source: POC-CE 2018, p.71; 2018 f, p.81.

The POC-CE defines 46 Critical Areas – which consist of areas of greater susceptibility to the destruction of coastal (natural and anthropic) resources and values, where it is necessary to carry specific strategies of adaptation guided by the three '*strategic principles of planning*' (protection, accommodation, and / or planned retreat) (POC-CE 2018 f, p.316).

The Critical Areas for which the POC proposes 'planned retreat' were subjected to cost-benefit analyses (*in* POC-CE 2018, p.73).

In the cost-benefit analyses, the POC Team considered the four possible '*Adaptation Scenarios or Strategies*' (POC-CE 2018, p.73) (described in Section 3.2).

Through the cost-benefit analysis, the Team carried out a comparative assessment of different strategies (mainly of strategies of protection *versus* a strategy of planned retreat) (POC-CE 2018 f, p.190).

4.1.3.2. Examples of some Critical Areas

For each Critical Area, the POC-CE defines the ‘*strategic principle of planning / adaptation*’, i.e. strategy of adaptation, that must be applied (protection, accommodation, planned retreat, or two strategies combined, or area subjected to study). It also defines one or two interventions within the strategy(ies) chosen (e.g. ‘the POC proposes a strategy of protection based on interventions of sand nourishment and rehabilitation of existing hard defences’) (Figures 22 to 27).

Figure 22 (top left). The **Critical Area 38 – Praia Internacional**, is partially artificialized and partially located above a rocky platform. The Strip for Safeguarding from Coastal Erosion for 2050 includes almost the entire area located at the west of the roadway ‘Via do Castelo do Queijo’ and the roundabout ‘Praça Gonçalves Zarco’. For this Critical Area, the POC proposes **a strategy of Protection**, based on the following specific interventions: beach nourishments, construction of a detached breakwater and construction of a rainfall submarine out-flow pipeline (POC-CE 2018 c, p.41).

Figure 23 (top right). For the **Critical Area 39 – Praia dos Ingleses**, the POC proposes a strategy of Protection / Accommodation of low priority, including, as specific measures, the redesign / remodelling of the sandy areas of the beaches along the seafront.

Figure 24 (bottom right). For the **Critical Area 40 – Praia do Carneiro**, the POC proposes a strategy of Protection of high priority, based on the following interventions: remodelling / redesign of the sandy areas of the beaches, sand removal in the beach Praia das Pastoras, construction of a detached breakwater in front of the beaches Praia do Carneiro e Praia das Pastoras, rehabilitation of the breakwater ‘Molhe do Touro’ (POC-CE 2018 c, p.44).

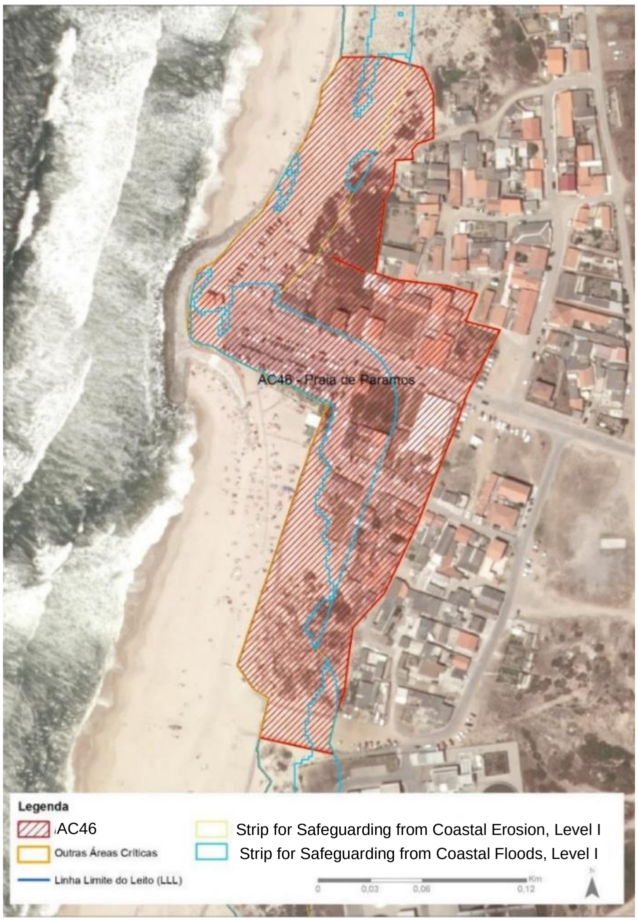


Figure 25. The Critical Area 19 (Praia de Ofir Norte). The towers *Torres de Ofir* are within this Area. The POC proposes an urgent Study in order to develop an adaptation strategy that reconciles the safety of people and built assets, which is clearly threatened, with the shoreline defence (POC-CE 2018 c, p.23).

Figure 26. Critical Area 22 (Pedrinhas-Cedovém). It is proposed a strategy of Planned Retreat with high priority, which require the removal of the at-risk buildings and illegal constructions in the Public Maritime Domain, and dune regeneration. It will be necessary to ensure the relocation of the important economic activities located on this area (POC-CE 2018 c, p.26).

Figure 27. Critical Area 46 – Praia de Paramos. This area was already identified in the 1st POOC as a UOPG for relocation. The POC proposes a strategy of Planned Retreat and Protection, of high priority, including the removal of buildings at-risk and / or illegal (in the Public Maritime Domain), and the recovery of the dune chain through geomorphological reinforcement and re-naturalization (POC-CE 2018 c, p.50).

According to the Directives, in the Critical Areas, the policy of coastal climate adaptation translates into the *strategic principles of adaptation* (*principles of planning*), and their respective measures and specific interventions (per *principle of adaptation*) (POC-CE 2018 d, p.52-54):

a) Protection – defence interventions in the *Terrestrial Protection Zone* (ZTP) and adjacent *Maritime Protection Zon*e (ZMP), with the aim of maintaining (holding) or advancing the shoreline, namely:
   i. Construction of detached protection works, whose design must be defined in detailed studies (e.g. geotubes, revetments, artificial blocks or irregular structures).
   ii. Rehabilitation of existing defence works.
   iii. Actions of artificial sediment nourishment for replenishment of beaches.
   iv. Actions of artificial sediment nourishment for reinforcing and / or re-establishing the dune chain.
   v. Implantation of palisades in dune areas (POC-CE 2018 d, p.53; 2018 f, p.197, 235).

b) Accommodation – measures of management of urban / occupied zones, with the aim of changing or adapting the type of occupation and human activities on the coastal zone and 'flexibilizing' the existing infrastructures, namely:
   i. Increasing the permeability of soil, through adaptation of pavements and increment of green areas.
   ii. Strengthening natural and artificial drainage conditions.
   iii. Urbanistic decompression.
   iv. Progressive accommodation of existing constructions to the risk of coastal flooding.
   v. Progressive substitution of the uses / functions of built assets (by replacing residential use for other non-permanent uses) (POC-CE 2018 d, p.54; 2018 f, p.197, 236).

b) Planned Retreat – interventions aimed at retreating (stepping back / withdrawing / removing) built assets and occupied zones in relation to shoreline, by relocating uses and infrastructures and ensuring the re-naturalization of such areas, which must attain to the following:
   i. Be duly framed in the intermunicipal and municipal spatial plans and their execution must be ensured in articulation with APA.
   ii. Consider the possibility of transferring constructability (construction rights) to more adequate zones, which must be pondered and developed in the scope of intermunicipal and municipal spatial plans and their execution instruments (POC-CE 2018 d, p.54; 2018 f, p.197).

The actions of protection proposed by the POC are listed in the Program of Actions, in the Strategic Axis 1 (Prevention and Reduction of Coastal Risks and Vulnerability to Climate Change), within the typologies of '*Sediment nourishment*', '*Construction of new coastal defences*', '*Rehabilitation of existing coastal defences'*, and '*Interventions in dune systems*' (POC-CE 2018 f, p.235).

The actions of accommodation proposed by the POC are listed in the Program of Actions, in the Strategic Axis 3 (Economic Valorisation of Coastal Resources), within the typologies of '*Urbanistic qualification of seafronts*' and '*Improvement of the circulation and parking conditions*' (POC-CE 2018 f, p.235, 238).

The actions of planned retreat proposed by the POC are listed in the Program of Actions, in the Strategic Axis 1 (Prevention and Reduction of Coastal Risks and Vulnerability to Climate Change), within the typologies of '*Intervention in dune systems*' and '*Removal of Constructions*'; in the Strategic Axis 2 (Protection and Conservation of Coastal Biophysical Systems and Landscape), within the typology '*Recovery and restoration of the dune system*'; and in Strategic Axis 4 (Valorisation and Qualification of Beaches), within the typologies of '*Interventions of Qualification of Beaches - Demolitions*' and '*Interventions of Qualification of Beaches – Re-naturalization*' (POC-CE 2018f, p.237).

4.1.4. Overview of generic strategies proposed

Given the historical background of interventions of coastal protection, and given the currently expected projections of climate change that indicate a likely aggravation of coastal risks due to SLR and alterations in storm patterns and wave patterns, the POC-CE proposes a new paradigm of adaptation to coastal risks, which is essentially based on two complementary actions / measures:

i) reduction of coastal erosion by means of artificial sand / sediment nourishments, and,
ii) alteration of the forms of occupation of the coastal areas with greater susceptibility by means of accommodation strategies and / or retreat (relocation) strategies (in POC-CE 2018, p.50).

The POC recommends the option of planned retreat in cases of higher risk (in comparison to the other two strategies). Following planned retreat, it is necessary to ensure the management of the evolution of the coastline and land occupation must be adapted to the natural dynamic of the coast (in line with GTL advice). The POC mentions that planned retreat requires '*prospective studies (of planned retreat) in sites at great risk of erosion, flooding and overtopping, supported by cost-benefit analyses and multi-criteria analyses that account for the mid- and long-term*' (POC-CE 2018, p.51, based on GTL 2014).[38]

The prosecution of the adaptation policy envisaged by the POC, which is based on three strands of action (protection, accommodation, planned retreat), will be relevant in the built-up areas located within the Strips for Safeguarding from Coastal Risks, mainly in the Critical Areas (POC-CE 2018 d, p.64).[39]

<u>Sediment Management:</u> the analysis of the recent evolution of the area of intervention carried by the POC showed the existence of a negative sediment balance that contributes to coastal erosion and to retreat of the shoreline, thus, for the POC-CE, the management of sediments must have a crucial role in the strategies of minimization of coastal erosion. The concretization of a protection strategy based on the re-establishment of the sediment balance must be supported by a policy of integrated sediment management involving all entities with responsibility in this field (POC-CE 2018 d, p.55).[40]

Importantly, the priority actions set by the GTL (GTL 2014 b, p.21) as necessary to ensure the integrated and sustainable management of coastal zones at national level provided a strategic and official frame for the exploration of measures in the POC-CE (POC-CE 2018 f, p.189). Notwithstanding, the POC considers it is wise to implement other measures (not explicated in the GTL Report), namely:

- S<u>edimentary reinforcements / strengthening</u> in time-intervals of 2 / 3 years, based on the continuous monitoring of the evolution of the shoreline (not emergency interventions but anticipatory interventions). The volume of nourished sediment must compensate the estimated or assessed losses.
- A 'strategy of <u>adaptation' for the pre-existing coastal defences</u>. It is necessary to ensure the adaptation of the currently existing coastal defence works whenever this is justifiable or in view to minimize their negative impacts, for example, through the modification of their characteristics (dimensions, height, weight, materials, typology of their blocks, roughness, permeability, etc.). Such strategy must be based on studies, tests and monitoring that support the decision-making about the most favourable solution for each site (which should minimize its negative impacts and boost the purposes for which such defence was built or repaired) (POC-CE 2018 f, p.189; 2015, p.429).
- A <u>possible strategy of 'advancing the line'</u>, through the construction of hard / soft submerged structures that dissipate wave energy coupled with sediment nourishments (POC-CE 2018 f, p.190; 2015, p.429).

---

[38] Planned retreat was considered in the 1st POOC, in the *Operative Units of Planning and Management* (UOPGs): areas in which the POOC identified built assets to be removed. An example was the demolition of 26 buildings in São Bartolomeu do Mar (POC-CE 2018, p.50).

[39] In the Predominantly Artificialized Areas, the municipal plans must find the solutions most suited for each area within the strategy of adaptation proposed, and ensure the convergence of funding mechanisms and spatial plans at local, regional and national level (ibid, p.65).

[40] The need of guaranteeing conditions for the operation of the two commercial ports (Leixões and Viana do Castelo) in the estuaries of rivers opens opportunities for ensuring an active role of these spaces in the sediment management for the coastal zone CE (POC-CE 2018 d, p.62).

4.2. Directives: normative content of the POC-CE

In its Directives, the POC-CE establishes the regime (norms) of protection of natural resources and values, and the regime (norms) of management to ensure a sustainable utilization of the territory, namely through the definition of actions allowed, conditioned and forbidden (POC-CE 2018 d, p.49). The Directives consist of norms concerning different spaces of the coastal zone (which are identified in the Territorial Model) and diverse activities that occur or may occur in such spaces. Such norms aim to sustain and guide the management of activities and uses of coastal resources, ensure the protection and valorisation of resources, and ensure the prevention of risks and safeguard of people and assets, in line with the principles established (POC-CE 2018 d, p.49). The Directives are grouped in three main types:

- General Norms (*Normas Gerais – NG*). These norms consist of guidelines directed to public entities, which must fulfil them within their scope of action and planning. The General Norms aim at safeguarding national objectives with territorial incidence.
- Specific Norms (*Normas Específicas – NE*). These norms establish the actions allowed, conditioned and forbidden. In this way, the NE deliver the proposed regimes of safeguard. The content of the NE must be directly transposed to the (lower) spatial planning instruments, namely Municipal Director Plans, whenever the NEs refer to the occupation, use and transformation of land / soil. The NEs defined for the Maritime Zone of Protection (ZMP) must be compatibilized with the disposals of the spatial planning instruments concerning the Maritime Space. The NEs have a specific spatial incidence which is defined in the Territorial Model, as such, the limits of the different areas considered – namely the Margin, Strips for Safeguarding from Coastal Risks (Level I and II), Coastal Protection Strip and Complementary Protection Strip (located in the Terrestrial Protection Zone – ZTP) – must be transposed to the intermunicipal and municipal spatial plans (POC-CE 2018 d, p.49). The Specific Norms concern the Coastal Protection Strip and Complementary Protection Strip, the Strips for Safeguarding from Coastal Erosion, the Strips for Safeguarding from Coastal Floods and Overtopping Inundations, and the Margin. The Specific Norms apply cumulatively, and the most restrictive ones prevail (POC-CE 2018 d, p.76).
- Management Norms (*Normas de Gestão – NGe*). These norms consist of principles and criteria for the use and management of the beaches with a bathing vocation and surrounding areas. These are aimed at the valorisation and qualification of beaches and water resources. These norms must be applied immediately by public and private entities (POC-CE 2018 d, p.50).

The General Norms are directed to public entities responsible for spatial planning and management of the coastal zone, namely municipalities, and should be met in the elaboration, revision, or alteration, of municipal spatial plans. The Specific Norms that concern the occupation, use or transformation of land must be transposed in lower spatial plans, soon after the approval of POC-CE (POC-CE 2018, p.45).

Given the vulnerability of area of intervention to climate change, the POC-CE assumed the principles of prevention and precaution as central for spatial planning and management. The POC refers that '*the General Norms (NG) follow the guidance of the GTL Report (GTL 2014), by delivering an adaptation policy that encompasses* (strategies of) *protection, accommodation, and planned retreat / relocation. The combination of these three strategies emerges as the most adequate solution as it allows greater sustainability of the options in social, economic, and environmental terms*' (POC-CE 2018 d, p.51).

Some of the Norms concerning the Objective 1 (prevention and reduction of coastal risks and vulnerability to climate change) are shown in Note 326.

4.3. Program of Actions

The Program of Actions of the POC-CE is structured in five 'strategic axes of intervention' that correspond to the General Objectives (set in the Strategic Model) (POC-CE 2018 e, p.11). The 5 strategic axes are sub-divided into 33 typologies of intervention. The interventions envisaged in each Axis that concern the reduction of coastal risks are presented next, in dark. See also Note 327.

STRATEGIC AXIS 1
Prevention and reduction of coastal risks and vulnerability to climate change

STRATEGIC AXIS 2
Protection and Conservation of Coastal Biophysical Systems and Landscape

STRATEGIC AXIS 3
Economic Valorisation of Coastal Resources

STRATEGIC AXIS 4
Valorisation and Qualification of Maritime Beaches

STRATEGIC AXIS 5
Monitoring and Evaluation of Coastal Dynamics

To fulfil the Strategic Axis 1 (Prevention and reduction of coastal risks and of the vulnerability to climate change), the Team established the following typologies of intervention:

1.1. Artificial sand / sediment nourishment.
1.2. Dredging works.
1.3. Construction of coastal defence structures.
1.4. Rehabilitation of (existing) coastal defence structures.
1.5. Interventions in the dune system.
1.6. Removal of constructions.

To fulfil the Strategic Axis 2 (Protection and conservation of coastal biophysical systems and landscape), the Team established the following typologies of intervention:

2.1. Actions for improvement of the quality of coastal waters.
2.2. Preservation of the coastal ecosystems.
2.3. Protection of the coastal habitats (it mainly consists of the elimination of invasive species).
2.4. Protection and valorisation of the geological heritage.
2.5. Recovery and restoration of the dune system.
2.6. Requalification of the estuaries and coastal waterlines.
2.7. Valorisation of coastal landscapes.

To fulfil the Strategic Axis 3 (Economic valorisation of coastal resources), the Team set the following typologies of intervention:

3.1. Improvement of the conditions of circulation and parking.
3.2. Qualification of nautical sports' infrastructures and facilities.
3.3. Qualification of the commercial ports.
3.4. Qualification of the fishing ports.
3.5. Urbanistic qualification of the seafronts.
3.6. Qualification of the local fishing infrastructures and facilities.
3.7. Strengthening of the touristic attractiveness.
3.8. Valorisation of the cultural heritage.

To fulfil the Strategic Axis 4 (Valorisation & qualification of maritime beaches), the Team set the following typologies of intervention:

4.1. Demolition of constructions and waterproof paved zones existent in the sandy beach or in the Margin.
4.2. Re-naturalization aimed at recovering the dunes and degraded vegetation.
4.3. Maintenance of the car parks aimed at a valorisation of the environmental and landscape values.
4.4. Requalification of the car parks aimed at allocating to beaches adequate parking areas.
4.5. Creation of new car parks suited to the specific characteristics of dunes.
4.6. Maintenance of pedestrian accesses aimed at improving the pedestrian accessibility to beaches.
4.7. Creation of new pedestrian accesses suited to the specific characteristics of the beaches.

To fulfil the Strategic Axis 5 (Monitoring & evaluation of coastal dynamics), the Team set the following typologies of intervention:

5.1. Monitoring.
5.2. Studies.
5.3. Studies / Monitoring / Awareness-raising.
5.4. Monitoring / Surveying.
5.5. Monitoring / Awareness-raising (POC-CE 2018 e, p.11-13; 2018 f, p.87-89).

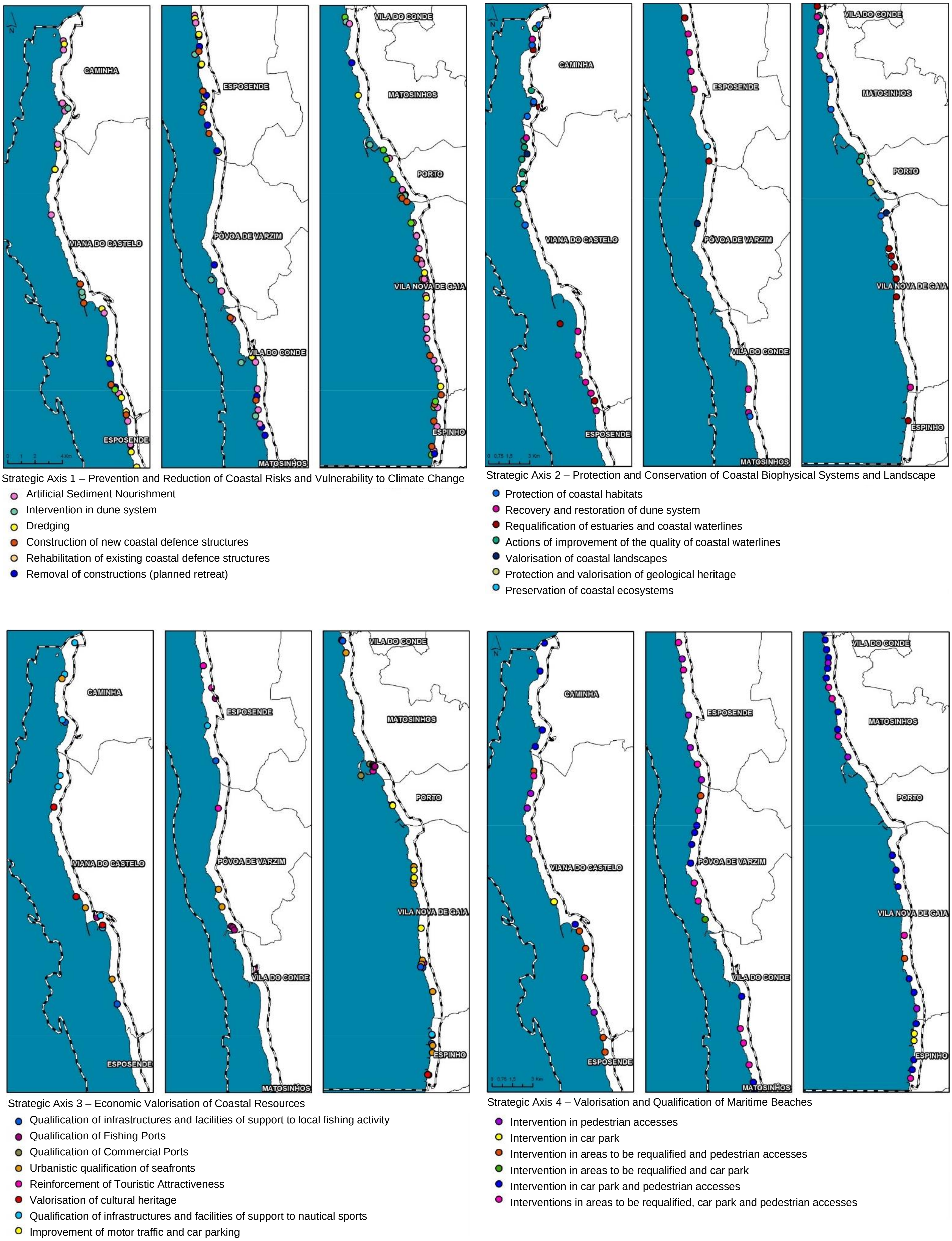


Figure 28. Location of the interventions programmed in the Program of Actions, per Strategic Axis. Source: POC-CE 2018 e, p.38-41.

4.4. Monitoring and Evaluation

According to the POC-CE, the observation of the behaviour of the coast over time is fundamental to quantify the changes occurred and support the planning and management of natural systems of great dynamism and vulnerability, and to anticipate measures of adaptation to such changes that minimize risks and detrimental effects on natural and socioeconomic systems (POC-CE 2018e, p.118). The POC highlights that a continual monitoring is '*the only way to obtain, in space and in time, data that allows the comprehension of the changes underway and the generation of future evolutive scenarios, and, thus, it provides tools to support decision-making*' (POC-CE 2018, p.43; 2018e, p.118; 2018 f, p.317).

The POC recognizes that '*it is necessary to increment a process of adaptive management, based on a monitoring system that strengthens the agility and adaptability in the management of risks*', which requires '*an effective, systematic and operational monitoring of the coastal zone*' (POC-CE 2018e, p.120; 2018, p.30). Moreover, an effective implementation of the Programme will require '*a management model that allows a continual adaptation of the POC in function of the coastal dynamics and risks for people and assets*', which, in turn, implies the definition of '*a system of information and continual monitoring of the evolution of the coastal zone and of the implementation of the Program of Actions, which sustains and informs the periodical evaluation of the POC*' (POC-CE 2018, p.96). The POC's *model of adaptive management* must be based on the articulation of these two aspects. Above all, the process of adaptive management must be supported by the monitoring system (ibid).

To monitor the process of implementation of the POC and its articulation with other spatial plans, APA will have to create a monitoring and information system in the coastal zone CE (POC-CE 2018, p.97).

In the POC, monitoring is understood as the 'observation, in space and in time, of the ongoing changes in coastal zones', and it involves 'the collection of the biggest number of data that allow the registering of the hydrodynamic and geo-morphological evolution that is occurring' and the regular interpretation of the collected data (POC-CE 2018e, p.118). This procedure should: identify, quantify and understand the drivers of coastal dynamics; determine the duration of the acting processes; determine the geographical extension of the influence of certain processes; identify sources and patterns of mobilization of sediments; identify impacts, behaviour and evolving characteristics of coastal defences; establish relations between morphological dynamics and climatic and weather factors; predict evolutive trends; grasp ecological dynamics; elaborate instruments to support spatial planning and management; assess positive and negative effects of planning and management actions.[41] In the Program of Actions, the POC lists some of the main aspects that must be monitored (POC-CE 2018e, p.119):

- Position of the beaches, dune systems and cliffs, including the calculation of the annual variation rates and the spatial and temporal characterization of erosion / accretion processes.
- Distribution of sediments, sources, transport, and balance of volumes, in spatial and temporal terms.
- Variations in the medium sea level, wave patterns, sea currents, tides, and wind speed.
- Geo-morphological changes, and dynamics of associated ecosystems.
- Variations in the levels and quality of subterraneous and superficial waters.
- Evolution of the occupied areas, and other urban, social, and economic indicators.

[41] The monitoring actions are listed in the Program of Actions in the Strategic Axis 5 (Monitoring and Evaluation of Coastal Dynamics). It contains a list of the main tasks to ensure a continual monitoring of the coastal zone: aerial photos, tide and wave surveys, visual inspections, registering of floods, survey of the shoreline (mapping), transversal topographic profiles of beaches, analysis of sediment coverage of beach-dune systems, bathymetrical surveys, topographic surveys, studies of the hydro- and morpho-dynamics of river mouths and coastal zones, etc. Monitoring should be steered by its own body created by APA-Norte (POC-CE 2018e, p.127). The monitoring process should result in a database that supports decision-making and the improvement of models of coastal evolution (POC-CE 2018e, p.118). For more on the monitoring and evaluation system, see Note 328.

4.4.1. The POC-CE's process of management (adaptive management)

The POC refers that '*the process of management of the POC must be adaptive in time and in space, in order to progressively adjust the strategy of safeguard and protection of natural values and of land use and occupation of the territory*' (POC-CE 2018, p.96). The process of adaptive management must be steered by its own steering body created and headed by APA-Norte.

Moreover, the *adaptive management* (process) must prioritize the Critical Areas as priority areas in terms of need for adaptation, and according to their exposure and vulnerability to coastal risks, as well as the areas subjected to *Plans of Intervention on Beaches*, and other additional areas that may be identified where coastal risks threaten people, assets, or natural values (POC-CE 2018, p.96).[42]

The POC explains that '*the implementation of a process of adaptive management implies that the 'Management Norms' and the 'Specific Norms' concerning the enforcement of the 'strategic principles of planning'* (i.e. the strategic principles of adaptation)*, and the concrete intervention actions established in the Program of Actions, may be suspended and altered, if this is required to better defend people and assets and better safeguard natural resources and values*' (POC-CE 2018, p.96).

Regarding the areas subjected to studies on adaptation, the POC mentions that they require '*specialized studies led by the steering body in articulation with the respective municipalities (...), which should illustrate the causes of existing problems and justify the measures to be implemented. (...) the steering body must deliberate the beginning of the process, delimit its respective area of intervention and the objectives of the study. Once the study containing the proposed interventions is elaborated and approved, such interventions must the transposed to the local spatial plans*' (POC-CE 2018, p.97).

Furthermore, the POC highlights that the 'model of coastal governance' must be more adaptive and integrated (see Note 329). APA-Norte is responsible for the follow-up and implementation of the POC. The entities responsible for implementing actions are identified in the Program of Actions. The POC recommends that the implementation of the Programme should be based on a shared and de-centralized management, which involves a greater accountability of local actors (municipal and intermunicipal authorities). It is necessary to ensure the compatibilization of intermunicipal and municipal spatial plans with the POC's proposals (such plans must comply with and implement the guidelines and directives of the POC, especially the strategies of adaptation for the Critical Areas) (POC-CE 2018, p.98-99).

4.4.2. The Monitoring and Evaluation System of the POC-CE

APA-Norte is the entity responsible for managing the POC-CE: it must steer its implementation (namely the licensing and execution of the planned actions, especially coastal protection works); implement the monitoring system (that monitors the coastal zone and the POC itself); and follow-up the implementation of the POC by other parties and ensure their coordination. The 'follow-up' must be carried by APA-ARH Norte and must involve all relevant actors (from the elaboration of the POC to the implementation of the proposed actions). The 'follow-up' will be ensured through the realization of annual meetings promoted by APA-ARH Norte, which will serve to evaluate the level of execution of the actions envisaged, based on the monitoring results, and identify barriers and hindrances to their execution. APA-Norte will also be the main entity responsible for the monitoring system (POC-CE 2018, p.100).

[42] This adaptive management will focus on '*the areas of greater environmental sensitivity and higher susceptibility to extreme events, which are identified in the POC (in the Territorial Model) as Critical Areas, areas of the Plans of Intervention on Beaches, and other areas where there is a tendency to the occurrence of extreme events that put people, assets or natural values at risk*' (POC-CE 2018 f, p.237, 198).

The monitoring will be assured through a system of indicators and a process of collection, analysis and presentation of results (engaging all relevant actors). Every three years, it will be produced a monitoring report based on the monitoring results (output and result indicators) and on the information collected in the annual follow-up meeting. Such report will allow an informed evaluation of the POC's implementation and, consequently, the re-programming of actions (Program of Actions) and even the alteration of the strategic and normative content of the POC (POC-CE 2018, p.100).

In the scope of the monitoring and evaluation system, '*the Program of Actions will be evaluated and re-programmed every three years*' and this procedure must involve all entities engaged in coastal management, namely those of the Consultive Commission of the POC (POC-CE 2018, p.99). Importantly, '*the POC-CE must be reviewed whenever the respective monitoring and evaluation identify levels of realisation, and / or an evolution of the environmental, economic, social, and cultural conditions, that may demand modifications to its content*' (POC-CE 2018, p.100).

The monitoring system will allow the identification of changes in the socioeconomic context that may eventually constrain the execution of the actions (by several entities), and which may require the adjustment of the programming. The monitoring system must support the regular evaluation of the POC, and it must identify problems or constraints that hinder the implementation of the actions planned in the Program of Actions and the main results and impacts of the implementation of the POC (in its programming, strategic, and normative dimensions) (POC-CE 2018, p.101).[43]

The monitoring system will use two types of indicators (POC-CE 2018, p.101):

- Output indicators, which will monitor the implementation of the Program of Actions. These indicators track the implementation of the POC at the operational level and allow the identification of constraints and problems that preclude the implementation of the planned actions.
- Outcome (result) indicators, which will monitor the achievement of the strategic objectives of the POC (materialized in the Territorial Model and Directives). They allow an evaluation of direct and immediate effects of the POC, in environmental, socioeconomic, territorial, and institutional, terms.

The output and outcome indicators must be monitored and updated annually. The output indicators and the outcome indicators (and their respective measurement units, updating periodicity, target, and entities responsible for collecting information), are indicated in Table B and Table C, respectively.

The monitoring and evaluation system will involve the following procedures (POC-CE 2018, p.102):

a) Collection and systematization of information to establish a baseline that will serve as a reference in the analysis of the evolution of the outcome indicators.
b) Communication to APA-Norte of the level of concretization of the actions planned in the Program of Actions, every year, by entities responsible for the implementation of actions (output indicators).
c) Collection and systematization of information for updating, every year, the outcome indicators.
d) Annual follow-up meeting to evaluate the implementation of the POC and its Program of Actions, identify of constraints hindering the actions planned, discuss the evolution of outcome indicators.
e) Elaboration, every three years, of a monitoring report that is presented and discussed in the annual follow-up meeting, with a view to allow the eventual alteration of the POC.

[43] Besides this, the POC-CE also proposes actions related with the study of the littoral, namely scientific research and monitoring of hydrological and sedimentary processes, and habitats. Such studies are intended to contribute to an *adaptive management* based on scientific and technical knowledge. In the Program of Actions, particularly in the Strategic Axis 5, the POC Team proposes actions of monitoring, study, awareness-raising, surveying, and combinations of these (POC-CE 2018 f, p.198). See Note 328.

Strategic Axis / Output indicator	Units	Periodicity	Target	Entity responsible
Strategic Axis 1 (Prevention and reduction of coastal risks and vulnerability to climate change				
Interventions of artificial sand nourishment	nº; €	annual	35	APA
Dredging interventions	nº; €	annual	10	APA
Interventions of construction of coastal defence works	nº; €	annual	13	APA
Interventions of rehabilitation and maintenance of coastal defence works	nº; €	annual	15	APA
Interventions in dune system	nº; €	annual	19	APA
Interventions of removal of constructions	nº; €	annual	12	APA
Strategic Axis 2 (Protection and conservation of coastal biophysical systems and landscape				
Actions of improvement of the quality of coastal waters	nº; €	annual	13	APA
Interventions of preservation of coastal ecosystems	nº; €	annual	3	CM
Interventions of preservation of coastal habitats	nº; €	annual	9	CM
Interventions of protection and valorisation of geological heritage	nº; €	annual	2	CM
Interventions of recovery and restoration of the dune system			10	APA
Interventions of recovery and restoration of estuaries and coastal waterlines	nº; €	annual	12	APA
Interventions of valorisation of coastal landscapes	nº; €	annual	10	CM
Strategic Axis 3 (Economic valorisation of coastal resources)				
Interventions of improvement of circulation and car parking	nº; €	annual	2	CM
Interventions of qualification of infrastructures and facilities of support to nautical sports	nº; €	annual	5	CM
Interventions of qualification of commercial ports	nº; €	annual	2	APDL / DOCAPESCA
Interventions of qualification of fishing ports	nº; €	annual	10	APDL / DOCAPESCA
Interventions of qualification of urban seafronts	nº; €	annual	14	CM
Interventions of qualification of infrastructures and facilities of support of local fishing activity	nº; €	annual	7	DOCAPESCA
Actions of reinforcement of the touristic attractiveness	nº; €	annual	4	CM
Actions of valorisation of the cultural heritage	nº; €	annual	13	CM
Strategic Axis 4 (Valorisation and qualification of maritime beaches)				
Interventions of qualification of beaches (demolition)	nº; €	annual	24	APA
Interventions of qualification of beaches (re-naturalisation)	nº; €	annual	21	APA
Interventions of qualification of beaches (maintenance of car parks)	nº; €	annual	48	APA / CM
Interventions of qualification of beaches (requalification of car parks)	nº; €	annual	14	APA / CM
Interventions of qualification of beaches (creation of car park)	nº; €	annual	17	APA / CM
Interventions of qualification of beaches (maintenance of pedestrian accesses)	nº; €	annual	64	APA / CM
Interventions of qualification of beaches (creation of pedestrian accesses)	nº; €	annual	4	APA / CM
Strategic Axis 5 (Monitoring and evaluation of coastal dynamics)				
Actions of monitoring	nº; €	annual	17	APA / CM
Actions of monitoring and surveying	nº; €	annual	8	APA / CM
Actions of monitoring and awareness-raising	nº; €	annual	4	APA / CM
Action of evaluation	nº; €	annual	10	APA
Monitoring studies and awareness raising	nº; €	annual	9	APA

Table B. Output indicators of the POC-CE. Source: translated from POC-CE 2018, p.103.

Strategic Axis / Outcome indicator	Units	Periodicity	Entity
Strategic Axis 1 (Prevention and reduction of coastal risks and vulnerability to climate change			
Overtopping inundations (flood events)	nº; %	annual	APA
Lost territory in function of the evolution of the shoreline	ha	annual	APA
Annual rate of retreat (regression) of the shoreline	m; %	annual	APA
Width and height of the dyne chain	m; m	annual	APA
Width and volume of the (unsubmerged) beach	m;	annual	APA
Morphology, volumetry, and height of the submerged beach up to the depth of 10m (or 20m)	m^2;	annual	APA
Variation of the number and cost of emergency interventions of coastal defence undertaken	nº; €;	annual	APA
Proportion of resident population located on the risk strips (in the total of the settlement)	%	annual	APA
Proportion of residences located on the risk strips Level I (in the total of the settlement)	%	annual	CM
Variation of the costs of inundations / destruction resultant from sea overtopping floods	%	annual	CM
Variation in the number of urbanistic licences in risk strips	nº; %	annual	CM / APA
Variation of the extension of soil (land) in the Strips for Safeguarding from Coastal Erosion	ha /	biannual	APA
Variation of the extension of soil (land) in the Strips for Safeguarding from Coastal Floods and Overt. Inundations	ha /	biannual	APA
Borrow sites identified (characterization and inventory)	nº	biannual	APA
Strategic Axis 2 (Protection and conservation of coastal biophysical systems and landscape			
Evolution of number of protected terrestrial and marine species and habitats	nº; %	biannual	ICNF
Variation of the extension of the area classified with status of protection	nº; %	biannual	ICNF
Parameters of sampling in accordance with the legislation in force (assessment of quality of bathing waters)	nº	annual	APA
Parameters of sampling in accordance with the legislation in force (assessment ecological state coastal waters	nº	annual	APA
Parameters of sampling in accordance with the legislation in force (assess ecological state coastal waterlines	nº	annual	APA
Parameters of sampling in accordance with the legislation in force (assess environmental state marine environ.	nº	annual	APA
Area occupied by invasive alien vegetal species	m^2	biannual	ICNF
Recovered area per habitat	m^2	biannual	ICNF
Visitors registered in the interpretative centres or bird observation sites	nº	annual	ICNF
Strategic Axis 3 (Economic valorisation of coastal resources)			
Extension of the pedestrian area in the urban seafront of coastal settlements	km^2	annual	CM
Extension of the bicycle paths in the area of intervention	km	annual	CM
Overnight stays in hotel facilities	nº	annual	INE
Titles of private utilization of the National Maritime Space (ZMP)	nº	annual	DGRM
Beach supporting facilities with functions of support to sports	nº	annual	APA
International, national and regional competitions / contests of wave sports carried per year	nº	annual	FPS + APK
Companies with registered maritime-touristic activities	nº	annual	Turismo PT
Touristic facilities in the area of intervention	nº	annual	Turismo PT
Accommodation capacity in touristic facilities	nº	annual	Turismo PT
Accommodation capacity in local touristic housing	nº	annual	CM
Seasonality rate	%	annual	INE
Number of interdictions to bivalve harvesting due to maritime toxins	nº	annual	IPMA
Enrolled fishermen per fishing segment	nº	annual	DGRM
Evolution of the fish unloading (docks and purchasing points)	%	annual	DGRM
Strategic Axis 4 (Valorisation and qualification of maritime beaches)			
Coverage rate of the beach supporting facilities envisaged in the Plans of Intervention on Beaches	%	annual	APA
Rate of execution of the pedestrian paths planned in the Plans of Intervention on Beaches	%	annual	APA
Rate of execution of the car parks planned in the Plans of Intervention on Beaches	%	annual	APA
Rate of Execution of the actions of recovery of dunes planned in the Plans of Intervention on Beaches	%	annual	APA
Number of beaches awarded with Blue Flag	nº	annual	APA
Number of beaches awarded as accessible beach	nº	annual	APA
Number of hours / days of interdiction of utilization of coastal bathing waters	nº	annual	APA
Strategic Axis 5 (Monitoring and evaluation of coastal dynamics)			
Rate of execution of actions planned in the Municipal Plans of Adaptation to Climate Change	%	biannual	CM
Annual Variation in the number of users of web tools of integrated management	%	biannual	APA
Beaches with signalling of danged updated in the beginning of the bathing season	%	biannual	APA
Level of utilization and improvement of the cartography and complementary information	%	biannual	APA

Table C. Outcome indicators of the POC-CE. Source: translated from POC-CE 2018, p.103.

4.5. CRITICAL ANALYSIS AND COMMENTARIES ON SOME OF THE MAIN CONTENTS OF THE POC

This section discusses the methodology used for delimiting the Strips for Safeguarding from Coastal Erosion, as well as the definition of the Critical Areas and of the adaptation strategies proposed for them.

4.5.1. CRITICAL ANALYSIS OF THE METHODOLOGY USED FOR CALCULATING AND DELINEATING THE STRIPS FOR SAFEGUARDING FROM COASTAL EROSION

As mentioned, for developing the projection of the future shoreline retreat (for projecting the lines that represent the future retreat of the shoreline), the POC-CE Team considered three components:

1) The rate of retreat of the shoreline for the horizon year *n* ($TELC_{year\ n}$). To develop the projection for the horizon-years, the Team calculated the average annual rate of migration of the shoreline which was obtained from the available lines (of the shoreline) for the coastal stretch under study. This average annual rate was then multiplied by the number of years that will occur until each time-horizon is reached (30 years until 2050 and 80 years until 2100).
2) The erosion induced by a storm ($R_{MÁX}$). It corresponds to the maximum instantaneous retreat of the shoreline expectable due to the occurrence of an extreme storm. The Team used the calculation formula of Dean et al. (2008). The value of $R_{MÁX}$ obtained was 30m for 2050, and 35m for 2100.
3) The erosion induced by SLR ($R_{NMM\ year\ n}$). This was obtained through the application of the Bruun Rule (Bruun 1962).

BOX 6

Regarding the **1st component**, the projection of a trend for the *year n* based on the past observations made during the few last decades is obviously subjected to deep uncertainty, particularly due to: the short temporal extension of the past observations in many areas analysed; the quality, spatial resolution and actualness of the past observations available; the fact that the factors that, in the past, caused the retreat are multiple, have different origins and occur at different scales (temporal, meteorological and anthropogenic scales) – e.g. SLR, existence of defence structures, urban occupation on dunes, etc. – and these factors may have aggravated / reduced, which has implications in the prediction (Veloso-Gomes 2018, p.4).

Regarding the **2nd component**, the projection of the maximum retreat caused by extreme storms through the formulation of Dean et al. (2008) does not take into consideration several aspects, namely: the possible occurrence of not one but diverse extreme storms with different characteristics and their cumulative effects; the possible increases in the storminess and possible changes in storm patterns associated with climate change; the significant sediment transport due to longitudinal drift; the complex local hydrodynamics and sediment flows; the current and future presence of coastal and port defence structures. In the formulation used, the complexity of the hydrodynamic interaction between the storm and the coastal zone is only treated through 5 variables. Thus, its applicability can be questioned in the mentioned situations, which are quite common in the coastal stretch CE (Veloso-Gomes 2018, p.4).

Regarding the **3rd component,** the Bruun Rule is a predictive model which is simplified (it uses simplistic hypotheses), geometric and bidimensional (equilibrium profile), and which is used for visualizing and quantifying the translation of the exposed sandy slope caused by SLR (the adjustment of the shoreface of a sedimentary coast to SLR) (Veloso-Gomes 2018, p.6, based on Bruun (1962), and other authors). The applicability of this formulation is questionable in certain situations, e.g.: highly energetic coastal environments characterized by a great temporal and spatial variability in wave patterns, complex sandy transversal profiles, areas with coastal defence structures, urban / built-up areas (Veloso-Gomes 2018, p.6).

Moreover, while there are now several different projections of SLR, the POC-CE Team only considered a single projection. In addition, it did not consider other plausible scenarios of climate change and its effects (e.g. on wave patterns, on storm routes, frequency and intensity, etc.) (Veloso-Gomes 2018, p.7).

The methodology applied by the POC for defining the Strips for Safeguarding from Coastal Erosion presents several gaps / shortcomings.

The Team only developed a single projection (a single plausible future scenario) of the future shoreline retreat (regression) with two time-horizons (2050 and 2100), which was calculated based on the sum (addition) of three components. In the generation of this projection, the Team assumed a single scenario of future SLR (one climate parameter), and a single scenario for extreme storms (another climate parameter). The other component – the expected shoreline retreat induced by erosion – was extrapolated from past observations, and it only resulted in a single prediction (for each time-horizon). Therefore, the Team did not develop more than one projection (scenario) of the future shoreline retreat.

Moreover, the Team did not consider more than one scenario (it only assumed one for SLR, and one for storms), and it did not account for other scenarios that could have been assumed for other paraments / variables (e.g. climate change, changes in storm patterns, socioeconomic development, natural climate variability, or a combinations of both climatic and socioeconomic scenarios). In fact, the Team generated a unique projection (a single plausible future scenario) of the future shoreline retreat (regression) for each time-horizon considered (2050 and 2100). This seems to be a quite limited approach given the aim of developing an 'adaptive programme' (Veloso-Gomes 2018, p.1) (see Note 330).

In this exercise, the Team only considered a single scenario for SLR (which is only one of several effects of climate change). This scenario was considered in the 3rd component 'erosion / retreat induced by SLR'. The same can be said regarding the 2nd component ('erosion induced by extreme storm'): the Team only considered a single possible extreme storm (Veloso-Gomes 2018, p.8). Therefore, the Team did not consider other parameters for which it is important to develop different scenarios (e.g. changes storm patterns induced by climate change, socioeconomic developmental scenarios, natural climate variability, anthropic actions, influence of existing coastal defence works and port structures, etc.). The non-consideration of other scenarios for other parameters is a major lacuna (Veloso-Gomes 2018, p.8).

Another important gap concerns the generation of a single projection of the plausible future shoreline retreat (regression) as the result of a linear sum of three components – which, in fact, are non-linear and heterogenous in terms of temporal scale, hydrodynamics and hydro-morphology of the phenomena involved, as well as in terms of prediction and quantification capacities (hence they cannot be simply summed)[44] (Veloso-Gomes 2018, p.8). The Team should have generated more than one projection of the future shoreline retreat, which would likely lead to the representation of several plausible future 'shorelines' or 'uncertainty margins / bands' (encompassing different projections of the future shoreline) – which would lead to a different representation of the Strips for Safeguarding from Coastal Erosion.

The Team applied linear (simplified, bidimensional) formulations that are less valid for coastal zones marked by highly energetic wave patterns, complex morphology, significant sediment transport in the littoral drift, and highly artificialized with defence structures, port infrastructures, roadways, urban areas, built forefronts, and also in pebble beaches or rocky shores (Veloso-Gomes 2018, p.8).

According to Veloso-Gomes, the methodology used for the definition of the Strips for Safeguarding from Coastal Erosion should have been accompanied by the definition of 'uncertainty bands / margins' that expressed the uncertainty associated to the methodology itself, the models (and formulations) applied, the hypotheses assumed, and the quality of the data available (Veloso-Gomes 2018, p.1). More specifically, the projected future evolution of the shoreline for a year *n* (2050 and 2100), which was represented in a line that corresponds to the inward limit of the Strip for Safeguarding from Coastal Erosion, should have been accompanied by *uncertainty bands* (Veloso-Gomes 2018, p.1, 8).[45]

The projected future shorelines and the associated Strips for 2050 and 2100 (with their respective regimes of safeguard) will have crucial implications for spatial planning (namely for regulatory instruments, licensing procedures, heritage valuation, etc.). During the public consultation period, several actors (academic experts, decision-makers, and citizens) contested the methodology used for delineating the Strips for Safeguarding from Coastal Erosion, however, the Team explained that it would be difficult to work with several plausible scenarios and to determine possible 'uncertainty bands'.

[44] To obtain the projection of the shoreline location / position for a certain year, these components cannot be simply summed, other components would have to be considered, and the calculation would probably require a more complex formulation.

[45] The POC-CE Team delineated the *Strips for Safeguarding from Coastal Erosion* based on the projected lines of evolution / retreat of the shoreline for 2050 and 2100, and, based on this, defined the respective regimes of safeguard (Veloso-Gomes 2018, p.1, 8). The eventual generation of different projections would imply the representation of several plausible future shorelines and, consequently, *uncertainty bands*.

4.5.2. COMMENTS ON THE *CRITICAL AREAS*

This section raises relevant issues and points that deserve further attention regarding the Critical Areas.

Delimitation of the Critical Areas

The delimitation of the Critical Areas was mostly based on the projection of the future shoreline retreat (regression) for 2050 (i.e. the inland limit of the Strip for Safeguarding from Coastal Erosion for 2050), and it also considered the Strip for Safeguarding from Coastal Floods and Overtopping Inundations for 2050. However, at the scale of the Critical Areas, the limits of both Strips, are, in several cases, roughly represented, that is, when we downscale (zoom-in) up to the scale of the Critical Areas, it is possible to observe the lack of detail of their delineation. This will likely lead to conflicts in the interpretation of the limits of these Strips at the municipal level. In several cases, there are buildings that fall partially within and partially outside the Strips for Safeguarding from Coastal Risks.

Importantly, if the Team had considered other plausible future scenarios (namely other scenarios of SLR and other parameters) and had generated other projections of the future shoreline retreat (regression) for 2050, the limit of the Strip for Safeguarding from Coastal Erosion 2050 would vary (according to the scenarios considered). Consequently, the limit of the Critical Areas would also be different (for each of the scenarios considered). This has strong implications for the Critical Areas where the POC proposes a strategy of planned retreat. If the projection that was considered in the POC fails (proves to be too optimistic or pessimist), the strategy of planned retreat may be insufficient (under-investment) or represent an over-investment, respectively. As it is devised, the proposal of planned retreat will be effective until a certain level of risk (a certain value of shoreline regression), but from that value upwards, no solution was provided by the POC. Therefore, it is important to consider various scenarios/ projections, and prepare for them, which requires exploring different measures (within the same and different typologies) to cope with different levels of risk and designing different strategies (sequences of measures), and then, based on a probable scenario, chose the preferred strategy. The preferred strategy might still be planned retreat, but its spatial extension will differ depending on the scenario chosen.

Lack of detail and specificity of the proposed strategy of adaptation

For each Critical Area, the POC defines the *strategy of adaptation* (the *strategic principle of planning* or *strategic principle of adaptation*) that must be implemented (protection, accommodation, planned retreat, protection and accommodation, planned retreat and accommodation, planned retreat and protection, or area subjected to study), and, most often, it also prescribes one or two *interventions* pertaining to the *strategy* proposed, and it mentions the level of priority of the strategy proposed (high, intermediate, or low). Nevertheless, almost always, the POC does not specify which concrete interventions, how many, where, and when (or under what conditions) each intervention should be implemented, and with what specific characteristics. Indeed, in the Critical Areas, the proposed Strategy is usually vague or insufficiently described. The proposal of the strategy of adaptation for a given Critical Area is usually oversimplified: it provides little detail on the measures proposed, and it offers no alternatives beyond the intervention(s) proposed. The lack of precise information on the measures is evident in the Critical Areas where a strategy of accommodation is proposed. The POC lists specific accommodation measures in the General Norm 3 (Directives), which could be stated in such Areas. In other cases, the POC proposes a combined strategy in the following way ‘protection / accommodation’; it mentions that such cases correspond to complementary strategies but does not specify if such measures are applied at the same time and where.

Overall, it can be said that the proposal for each Critical Area offers a short description, which could have been further explored, e.g. contain different possible measures (interventions) available for different moments in time and for the same and different zones, within a certain Critical Area. For an analysis of some Critical Areas, see Note 331 (on the lack of detail of the proposed interventions, see, e.g. the Critical Area 42). The Team could have developed a map at a lower scale to further define and detail the strategy proposed in space, accompanied by a schedule of the programmed measures to provide an overview of the 'path' to be followed in the next decade (at least), in each Critical Area.

Responsibility for the planning and the detailed design of concrete adaptation measures

The POC remits to the municipal councils, the responsibility for the integration (inclusion) of the Critical Areas in their planning instruments, as well as the task of planning and detailed design of specific measures (within the *strategy* / *principle* proposed by the POC), and it allows a possible re-definition of the limits of the Critical Areas within the scope of the revision or alteration of the municipal spatial plans. By allocating these responsibilities and roles to the municipal sphere, the POC-CE is, in a certain way, 'passing the buck' to the municipalities. This problem already occurred in the prior POOC: it defined '*Operative Units of Planning and Management*' (UOPGs), in which the municipality (in coordination with APA) had to develop a spatial plan defining concrete measures of coastal risk management / adaptation. However, experience showed that many UOPGs were not addressed.

In this sense, the Team may have not fully seized the more strategic character given to new POCs to address (in a more strategic way) the planning of coastal adaptation measures (coastal risk management) in the Critical Areas and other areas. Moreover, while the POC delegates the planning and design of coastal adaptation measures to the municipal level, municipalities, in their turn, are usually not thoroughly prepared nor up to the task (they lack technical resources to undertake such planning and are often unable to ensure their coordination with wider regional strategies, such as the strategy of 'integrated sediment management' proposed by the POC).[46]

POC's conceptualization of the three main strategies of coastal climate adaptation

The strategies of adaptation and type-interventions considered in the POC correspond to the main typologies of coastal adaptation measures (see Theoretical Framework), however, their conceptualization (meanings) and the spectrum of measures given for each typology are, to a certain extent, poor. The POC enumerates few concrete examples of measures within each typology. Moreover, the POC could have provided definitions for concepts such as *risk*, *vulnerability*, *exposure*, *impacts of climate change* (which refer to 'effects of climate change'). The definition provided in the POC for each type of adaptation strategy seems to limit, or distort, the main purpose of each strategy and the real array of measures available, which could be broader than the one described, and specify whether a measure aims to reduce the probability of a hazard, or the systems' exposure, or vulnerability (impacts).

Table D sums up some of the main problems that were identified in the analysis of the Critical Areas. Box 7 discusses the strategies proposed the Critical Areas that are illustrated in Section 4.1.3.2.

---

[46] It is worth mentioning that, within the scope of this research, several coastal municipalities of the Metropolitan Area of Porto and of the Metropolitan Area of Lisbon were interviewed about their willingness to introduce and apply the method of Adaptation Pathways in municipal spatial plans, for the purpose of coastal adaptation planning. All showed interest in using the method but mentioned that they could not apply it without the explicit prescription / indication of APA or higher-level governance institution. Notwithstanding, the POC is clearly more appropriate to address coastal adaptation / risk management issues. It is the spatial plan that is more suited to incorporate the method of Aps, and where the APs' maps could best be drawn up for different coastal stretches and scales, namely due to its strategic character (the Municipal Director Plans have a more normative / regulatory character). Importantly, APA was also contacted by the author, to examine whether it was willing to apply the APs method in the POC-CE and POC-ACE, however, it did not reply (see more in Note 332).

Table D. Commentaries regarding the Critical Areas: problems identified in the analysis		
Subject	**Comments**	Some examples
Limits and delimitation of the Critical Areas Delimitation of the Strips for Safeguarding from Coastal Risks	It is possible to observe that, when downscaled to the local scale, the Strip for Safeguarding from Coastal Erosion (Level I) and the Strip for Safeguarding from Coastal Floods and Overtopping Inundations (Level I) were delineated with little accuracy, which will likely generate interpretation errors that will imputed to the local municipality. Besides this, in several cases the limit (contour) is questionable, namely the inland side. Moreover, in several cases, it may be questioned why the Critical Area did not include the beach zone. In some cases, the limit of the Strip for Safeguarding from Coastal Risks is quite detailed but does not include an uncertainty band / buffer, and it may generate doubts (which will have to be solved by the local municipality), e.g.: in some cases there are buildings partly within and partially outside a Strip, which calls into to question the accuracy of the delimitation of this Strip at lower scales). In some cases, the limit of the Strip for Safeguarding from Coastal Floods and Overtopping Inundations is questionable, it does not provide a uniform area, nor its buffers zone (uncertainty band).	01 (Praia de Modelo) 02 (Praia de Vila Praia de Âncora) 10 (Praia da Amorosa) 32 (Mindelo) 08 (Porto de Viana do Castelo)
	In other cases, it can be questioned why the Critical Area did not include some important buildings that already exist in the area adjacent to the east side / inland limit.	07 (Praia Norte) 32 (Mindelo)
	Problems of interpretation: which buildings are within and outside the limit of the Critical Areas (some buildings are partly within it).	02 (Vila Praia Âncora) 37 (Praia Marreco)
It would be logical to extend a Crit. Area towards north / south	In some cases, it may be questioned why the Critical Areas was not extended southward (e.g. Critical Area 28 - Caxinas Norte) or northward. For example, the Critical Area 08 (Porto de Viana do Castelo) could be extended southwards, up to the Critical Area 09, and even include it.	08 (Porto de Viana do Castelo) 28 - Caxinas Norte 34 – Praia da Congreira
It would be logical to unify two Critical Areas	There are cases where two Critical Areas that are contiguous, and which are close / nearby, or interact with each other or are interdependent should be united into a single Critical Area.	07 (Praia Norte) + 08 (Porto Viana Cast.) 19 (Praia Ofir Norte) + 20 (Praia Ofir Sul) 39-Praia dos Ingleses + 40-Praia do Carneiro
Proposed Strategies and / or measures / actions: lack of detail, and they may not be sufficient to tackle increasing risk of coastal erosion and / or flooding Lack of detail of proposed interventions	It can be questioned whether the strategies proposed are sufficient to tackle the problems, and why the measures were not specified with further detail (location, amount, periodicity, timing, etc.). E.g. • The strategy proposed for the Critical Area 03 – Vila Praia de Âncora is protection, and the specific measure proposed is beach nourishment with sediments coming from dredging works that must be carried out in the channel of the fishing port (for maintenance of the channel). In such case, the proposed strategy does not specify what should be the periodicity of interventions, the volumes of sand (amount), the source sites, and the deposition sites. • The strategy proposed for the Critical Area 07 – Praia Norte is 'protection and accommodation', though the following measures: maintenance and rehabilitation of coastal defence structures, compatibilized with the safeguard of a local natural heritage rock formations. The proposed strategy might not be sufficient to address the increasing flood risk. It does not specify what structures should be maintained or rehabilitated nor how the natural monument will be safeguarded. • The proposed strategy for the Critical Area 08 (Porto de Viana do Castelo) is Protection based on: interventions of protection of the shoreline involving the consolidation of the existing breakwater (northern breakwater of the Port), as well as the use of sediments obtained for dredging works (for maintenance of the port areas) for nourishments on the beach located in the south side of the river mouth. However, it is not specified whether the volumes of dredged sediments would be sufficient to tackle erosion problems in the southern beaches. It is not mentioned what type of solutions could be used to tackle different scenarios of SLR, which is particularly relevant in the Port areas and in the urban area nearby it (e.g. heightening the seawall, raising the ground level of the port platform, etc.).	02 (Praia de Vila Praia de Âncora) 07 (Praia Norte) 42 (Praia de Granja)
Issues regarding the strategy of 'planned retreat'	The inland limit of the areas proposed for retreat: if the delimitation of the Strips for Safeguarding from Coastal Erosion had considered other possible scenarios (namely SLR scenarios), the inland limit of the areas for which the POC proposes planned retreat would likely be different for each of the scenarios considered. As such, the limit of the area to be subjected to planned retreat would vary according to the scenario considered.	All Critical Areas where planned retreat is proposed, e.g.:11 (Pedra Alta) 17 (Praia Suave Mar)
	In some cases, the limits of the Critical Areas for which the POC proposes planned retreat are questionable, for instance: the limit does not include certain buildings that are located at a distance to the shoreline similar to other buildings that are proposed for removal, because in that case it would be necessary to retreat / relocate a road that extends parallel to the shoreline, and more consolidated buildings, which are more complicated to remove and relocate. This raises issues of justice. Moreover, within the strategy of Planned Retreat, the POC should have mentioned possible areas for the relocation of people and assets, whenever necessary, and	10 (Praia da Amorosa)

	measures for the future forefront that will be generated with the retreat (e.g. accommodation and urban qualification for the new seafront).	
	The POC-CE does not specify the interventions of planned retreat will be funded.	All Critical Areas where planned retreat is proposed
	The POC-CE does not mention the relocation sites for the built assets that will require relocation (see, for example, Critical Area 22 - Pedrinhas-Cedovém; 34 – Praia da Congreira)	
Areas where two strategies are proposed: e.g. planned retreat + protection	The POC does not specify what should be the timing, priority, and order of the interventions proposed. It may be not necessary to undertake many interventions of beach nourishment if the planned retreat is carried out earlier in time, but the POC provides no clues on this.	11 (Pedra Alta)
	For the Critical Area 42 (Praia da Granja), the POC proposes a strategy of Protection/ Accommodation of high priority, including beach nourishments (POC-CE 2018 c, p.46), but it does not mention which accommodation measures should be used, nor where.	42 (Praia da Granja)
Strategy of protection through beach nourishments	The POC does not specify what should be the timing of the interventions of beach nourishment proposed, nor the number, volume, periodicity, sources and deposition sites. More specifically, the POC does not mention at what time should these interventions be carried out, the volumes of sediments required in each Critical Area, the source that would be used, the specific nourishment sites, and the nourishing procedures / mechanisms (geotubes / geotextiles, by truck, by boat, etc.), and how each intervention will be funded.	11 (Pedra Alta) 28 (Caxinas Norte)
Issues about the strategy proposed	In some Critical Areas, it may be questioned whether the POC considered other possible strategies, namely planned retreat where it proposes protection, and conversely, protection where it proposes planned retreat. The development of a map of pathways containing both alternatives would be deeply useful to support decision-making in cases of greater controversy over the options proposed. This also points to potential issues of equity between the various Critical Areas, and the criteria that were used to choose a given strategy in each Area.	13 (Foz do Neiva)
Lack of exploration of possible measures (uncertainty and vagueness, and potential conflicts between C. Areas	For certain Critical Areas, the POC proposes the development of a Specific Study in order to develop an adaptation strategy that reconciles the safety of people and built assets with the shoreline defence. There is clearly a vagueness regarding these Areas, which requires further investigation. The design of possible pathways would be even more pertinent and valuable in these cases, given the complexity (ambiguity), and uncertainty that surrounds the choice of the 'best' solution(s). For example, the POC does not specify how it will ensure coherence and articulation of the strategy that will be developed for the Critical Area 19 (Praia de Ofir Norte) with the strategy of planned retreat that it proposes for the Critical Area 20 (Praia de Ofir Sul), which is contiguous.	19 (Praia de Ofir Norte) 20 (Praia de Ofir Sul)
Cases where the POC proposed a strategy of planned retreat (alone), but which will likely require additional measures	In the case of the Critical Area 20, the POC proposes planned retreat but does not mention whether the existing groyne will require any maintenance and repair works.	20 (Praia de Ofir Sul)
	The POC does not specify whether any additional measures will be needed (namely in the mid-term) in addition to the removal of constructions followed by dune regeneration, such as, regular dune reconstruction works / nourishments (to keep the dune chain in its current location and avoid further shoreline retreat). It does not mention if the existing seawall (revetment) will be removed, and whether the small groyne that exists in this area will be maintained or removed.	22 (Pedrinhas-Cedovém)
	The POC does not mention what should be done regarding the pre-existing defence structures (e.g. longitudinal adherent structures) when the intervention of planned retreat is carried.	32 (Praia do Mindelo)
Where a strategy of accommoda-tion is proposed	The POC does not mention which specific interventions should be used within the strategy of accommodation in each Critical Area. It provides a generic list of measures in the Directives.	23 (Apúlia) 25 (Aguçadoura) 30 (Árvore) 39-Praia dos Ingleses
Where a strategy of planned retreat + accommoda-tion is proposed	The POC does not mention which areas / buildings should be subjected to planned retreat and which areas / buildings should receive a strategy of accommodation, or whether these strategies will be sequenced (first retreat, then accommodation), nor what types of accommodation measures may be used.	26 (Aver-o-Mar) 37 (Praia do Marreco) 41-Litoral Madalena 42-Praia da Granja
Cases where the POC proposes two measures within the same strategy	In some cases, the POC proposes a strategy of protection based on two measures (e.g. beach nourishments + rehabilitation of existing detached breakwater). However, the POC does not specify what should be the timing, priority and order of the interventions proposed. It may be not necessary to undertake many interventions of beach nourishment if the existing detached breakwater is rehabilitated earlier in time.	28 (Caxinas Norte)
lack of articulation bet/ strategies proposed for adjacent C. Areas	The Critical Area 40 – Praia do Carneiro should be unified with the Critical Area 39 – Praia dos Ingleses. It may not be coherent to define an intervention of high priority for this Critical Area, and low priority for the Critical Area 39, they influence each other.	39-Praia dos Ingleses + 40-Praia do Carneiro 31-Mindelo Norte + 32-Mindelo
Absence of reference to projects / works that are crucial for reducing risks	For example, in the south of the Critical Area 37 – Praia do Marreco, it was initiated in 2019, the construction of a hotel which located in a lot that is partially within the Strip for Safeguarding from Coastal Erosion 2100 and the Strip for Safeguarding from Coastal Floods and Overtopping 2100. Regarding the Project of Extension of the Breakwater of the Leixões Port, whose construction is expected to start in March 2021, and which faced public opposition, there may be a potential redundancy with protection measures envisaged for the Critical Area 38 – Praia Internacional.	37 (Praia Marreco) 38 (Praia Internacional)

Table D. Commentaries regarding the Critical Areas, and problems identified in the analysis. Source: own elaboration based on the analysis of some Critical Areas.

BOX 7. Comments on the Critical Areas illustrated in p.66-67

For the **Critical Area 38 (Praia Internacional)**, the POC proposes a strategy of Protection, based on specific interventions: beach nourishments, construction of a detached breakwater, and construction of a rainfall submarine out-flow pipeline underneath the beach (POC-CE 2018 c, p.41). The POC does not mention the projected extension of the external breakwater of the Leixões Port (300m southwards), although the funds necessary to build this project are included in the POC's Program of Actions. The construction works (expected to begin in 2021) will have strong implications on this Critical Area. The project has faced strong public contestation from citizens, local associations, and even opposition from the Municipality of Porto, and other municipalities in the surrounding area. This Critical Area should include the whole beach of Matosinhos in the North, in order to understand potential interactions / interdependencies and impacts between the different parts of the beaches of Matosinhos and Praia Internacional. The construction of a detached breakwater which is proposed by the POC will likely become redundant or even contradictory to the extension of the breakwater of the port. Besides this, the maintenance and repair works associated to the building 'Edifício Transparente' (located in this Critical Area) have gradually increased, and the option of demolishing it has been on the table in recent years. This is clearly a case where the design of adaptation pathways could be useful to critically explore and discuss alternative solutions, in an integrated way.

For the **Critical Area 39 (Praia dos Ingleses)**, the POC proposes a strategy of Protection / Accommodation of low priority, including, as specific measures, the remodelling / re-design of the sandy areas of the beaches along the seafront (POC-CE 2018 c, p.43). However, the POC does not explain what specific measures within the typologies of protection and accommodation (only refers 'actions of remodelling / refurbishment of the sandy areas).

For the **Critical Area 40 (Praia do Carneiro)**, the POC proposes a strategy of Protection of high priority, based on the following interventions: remodelling / redesign of the sandy areas of the beaches, removal of sand deposited in the beach Praia das Pastoras, construction of a detached breakwater in front of the beaches Praia do Carneiro e Praia das Pastoras, rehabilitation of the breakwater 'Molhe do Touro' (POC-CE 2018 c, p.44). This Critical Area should be unified with the Critical Area 39, in a single Critical Area.

For the **Critical Area 22 (Pedrinhas-Cedovém)**, the POC proposes a strategy of Planned Retreat with high priority, which will require the removal of the at-risk buildings and illegal constructions in the Public Maritime Domain, and dune regeneration; and it will be necessary to ensure the relocation of existing economic activities (POC-CE 2018 c, p.26). Nevertheless, the POC does not indicate the possible areas for relocating of the activities and buildings that will be removed. The POC does not specify whether any additional measures will be needed (namely in the mid-term) in addition to the removal of constructions followed by dune regeneration, such as, for example, regular dune reconstruction works / nourishments (to keep the dune chain in its current location and avoid further shoreline retreat). It does not mention if the existing seawall (revetment made of rocks) will be removed, and whether the small groyne that exists in this area will be maintained or removed.

For the **Critical Area 46 (Praia de Paramos)**, the POC proposes the strategy of Planned Retreat and Protection, with high priority, including the removal of buildings at-risk and / or illegally settled in the Public Maritime Domain, and the recovery of the dune chain through geomorphological reinforcement and re-naturalization (POC-CE 2018 c, p.50). However, the POC does not specify where measures (of Planned Retreat and of Protection) should be used, or whether planned retreat will be followed by dune recovery. The Critical Area does not include the sewage treatment plant that is located on the southern side of this Area. Yet, it is expected that such Plant will be retreated in the future. The overlapping of the Strips for Safeguarding from Coastal Risks for 2100 with this Area might justify a strategy of Planned Retreat for the entire built-up area in the long-term. Therefore, it may be pertinent to use different strips, or uncertainty bands, to enrich the exploration of measures (enlarge the scope of possible alternatives).

4.5.3. Spatial planning of beaches

Regarding the spatial planning of the beaches, in the POOC-CE, the systematic application of the same general principles to all beaches of the stretch CE led to 'rigid solutions'. The Plans of Beaches in some areas have been contested due to their rigidity. Often, such Plans do not leave room for manoeuvre for alterations that might stem from the coastal dynamic itself or from the evolution of new forms of use of the beach. Given that this territory is under permanent transformation, due to both natural and anthropic drivers, the Plans of Beaches should be regulatory instruments with a high level of flexibility that allows adapting solutions, but without losing their force (POC-CE 2018 f, p.221-222, 230).

While the beaches are themselves quite dynamic, in terms of profile and extension of the sandy area, (which has implications for the concessions and location of the beach supporting facilities), there has been an excessive rigidity in the *Plans of Beaches* of the POOC. Moreover, the current Plans of Beaches do not reflect the concerns over the risk of erosion (POC-CE 2018 f, p.226-227, 231). This has led to several calls for the 'flexibilization of the management measures' for beaches (POC-CE 2018 f, p.225). The new POC-CE sought to address this issue (see Note 333).

4.5.4. CRITIQUES AND COMMENTS TO THE POC-CE RECEIVED DURING THE PUBLIC CONSULTATIONS

The main comments, suggestions and contributions received during public consultations on the POC-CE, and the respective answers given by the Project Team, are reported in the 'Report of the Ponderation of the Public Discussion' (POC-CE 2020). For an analysis of the main comments, see Note 334.
The online public platform received 308 participations, which concerned mostly the following topics: the delimitation of the Critical Areas and the definition of the adaptation strategies proposed; the beach facilities; the actions / measures of coastal protection, and the Specific Norms.

Several commentaries of public actors, scholars and decision-makers raised important issues, namely:
- How the Critical Areas were delimited, and with what criteria the Team defined the adaptation strategies for each Critical Area.
- What will be the regulatory consequences and implications of having to adopt a strategy of planning retreat at the local / municipal sphere.
- What were the criteria used to define the adaptation strategy that is proposed for a Critical Area.
- Why the POC-CE Team did not consider more than one scenario.
- Calls for the transference of competences for the management of beaches to municipal bodies.
- The methodology used for defining the Strips for Safeguarding from Coastal Erosion. The existence of several flaws and lacunas in the methodology used to define the Strips for Safeguarding from Coastal Erosion. Several actors, including scientific experts, government actors, and local citizens, question how these Strips were drawn, and indicate several shortcomings of the methodology used.
- Regarding the Specific Norms: requests about the safeguard of pre-existing rights in the Strips for Safeguarding from Coastal Erosion (pre-existing and juridically consolidated rights prior to the date when the POC comes into force) (most requests were attended).
- Regarding the Specific Norms: requests for the creation of the regime of exception, in urban consolidated zones within the Strips for Safeguarding from Coastal Erosion, to the restrictions on construction. Such request was partially attained (POC-CE 2020, p.47).
- Requests for the alteration of the limits of, and adaptation strategy proposed for, some Critical Areas.
- Contestation to the adoption of the strategy of planned retreat.
- Proposals for inclusion of new Critical Areas.
- Doubts about the compatibilization of the POC with municipal spatial plans.

Many of the commentaries received consist of critiques and raise issues about the ways (methods) used to define and allocate the 'strategy of adaptation' (*strategic principle of planning*) to the Critical Areas. As expectable, there are several comments of property owners, or interested parties contesting the proposals of planned retreat and arguing in favour of a strategy of protection.

Regarding the methodology used for defining the Strips for Safeguarding from Coastal Erosion

Regarding the methodology applied for designing the Strips for Safeguarding from Coastal Erosion, the POC Team answers that: these Strips were delimited based on the observation of the evolution occurred in the past, and their future projection based on models that include the expected evolution of factors that influence coastal dynamics, e.g. SLR, and the probability of extreme storms (POC-CE 2020, p.58).

To reply to critiques, the Team refers that the entity responsible for the POC-CE is aware of the limitations that were pointed to this methodology (during the public consultation period), however, the time and data available for the elaboration of the POC did not allow the adoption of other more complex methodologies. Despite that, the assumed projections correspond to medium values and account for factors such as SLR and the action of extreme storms. The Team argues that the methodology used was based on the best data available (namely the representation of the shoreline based on the best historical aerial photos that were possible to gather) and on the best methodological tools currently available for this kind of studies (e.g. the 'Digital Shoreline analysis System' in GIS).[47] Moreover, the POC envisages an extensive monitoring program of coastal systems which must support the revision or alteration of the POC in the long-term. Regarding this topic, the Specific Norm NE27 establishes the possibility to re-assess the Strips for Safeguarding from Coastal Risks provided that this is substantiated on detailed studies on the evolutive tendency and shoreline dynamics (which must be informed by the monitoring system) (POC-CE 2020, p.55; 520).

Regarding the Critical Areas

The delimitation of the Critical Areas was based on the projection and delimitation of the Strips for Safeguarding from Coastal Erosion and Strips for Safeguarding from Coastal Floods and Overtopping Inundations for the time-horizons of 2050 (POC-CE 2020, p.51). The POC Team replies to the comments, by explaining that '*the Critical Areas do not have immediate implementation, and they may be subjected to further studies in the future*'. Thus, the Critical Areas may be further developed or re-assessed based on specialized studies, in the scope of the processes of elaboration, alteration or revision of (municipal and intermunicipal) spatial planning instruments. It is important to highlight that the POOC-CE (in force) already proposed a strategy of 'planned retreat' for some UOPGs. The current POCs are remitting this issue to the next reviews or alterations of municipal spatial plans (POC-CE 2020, p.51), which, in practice, may be a way of postponing the problem.

Importantly, around 58% of the suggestions that were not accepted are related with the topic 'Critical Areas', however, according to the POC Team, the solution for the Critical Areas does not directly stem from the POC-CE but should be subjected to subsequent further study, namely in the scope of the processes of elaboration, alteration, or review, of spatial planning instruments, in which the programming and financing of the measures can be developed in-depth (POC-CE 2020, p.64). The ponderation of the contributions concerning the Critical Areas resulted in few alterations to the limits and adaptation strategies, and in the inclusion of two new Critical Areas (POC-CE 2020, p.66).

Some actors disagree with the delimitation of the Critical Areas, but also with the adaptation strategies proposed. The POC Team argues that the proposed adaptation strategies and interventions reflect the current (paradigm) shift in coastal management (which is institutionalized in the GTL Report) from a model of coastal protection based on interventions of artificialization of the shoreline towards a model based the integrated sediment management (POC-CE 2020, p.58). To clarify the general strategy of coastal protection envisaged in the POC, the Team refers that '*the strategic premises upon which the POC relies, namely the guidelines of the GTL Report, envision the adoption of a strategy of integrated sediment management as a central aspect of the efforts to adapt to coastal risks*'. In most cases, the POC proposes for Critical Areas, the adoption of '*passive measures*' like *artificial sediment nourishments* and *geomorphological reinforcement of dune system*. The use of hard protection solutions (e.g. adherent defence works or detached defences) is sporadic and exceptional and mostly focused on the maintenance / rehabilitation of some existing defences (POC-CE 2020, p.60). The Team explains that the POC assumed the 'integrated sediment management' as an 'option by defect' to be adopted. In some cases, the intervention of artificial beach nourishment and dune reinforcement must be complemented by active protection works (e.g. detached breakwaters) that allow that the 'passive measures' are more effective for a longer period (POC-CE 2020, p.534).

---

[47] The Team argues that some of the elements that were suggested by Veloso-Gomes in his participation are currently not sufficiently known or largely unknown and require further investigation. As such, and although it was desirable their utilization in an ideal situation, in which such type of information was available and organized, it was impossible to integrate the Program several of the data / elements suggested.

5. ANALYSIS OF THE POC-CE AGAINST THE KEY-ELEMENTS OF AN ADAPTIVE PLANNING AND MANAGEMENT APPROACH

This section analyses whether and how the five key-elements of an Adaptive Planning and Management approach were applied in the POC-CE case. For this purpose, the author searched for the ingredients essential to a '*dynamic adaptive plan*' in the POC-CE and examined how they are being used and delivered. The POC-CE's content is discussed in the light of the (against) each of the five key-elements that were identified in Part A as essential to produce an adaptive plan / strategy (see Table 12, Part A). Table E sums up the main questions addressed to analyse whether the five key-elements identified in Part A as essential in an Adaptive Planning approach are present in the selected POC.

Table E. List of questions for each step of the process of Adaptive Planning and Management (derived from reference cases)

Step		Question
1	Scenarios	Which developments / changes / parameters are considered in the scenarios used? (climatic, socioeconomic, SLR, river discharge, storm patterns, etc.)
		What type of scenarios were used and how many (predictive / projections / exploratory scenarios)
		What is the temporal scale addressed in such scenarios (projection years, time-horizons, continuous or discontinuous trends)
2	Risk / impact assessment	What are the main vulnerabilities/threats and opportunities identified (based on the analysis of scenarios)
		How are risks / impacts assessed?
		Were critical thresholds / tipping-points identified?
3-4	Strategy development	What (type of) measures were identified?
		How were strategies designed / assembled?
		What type of criteria were taken into account in the design of strategies and selection of measures (robustness, flexibility, resilience, structural / non-structural, hard / soft, low- / no-regret, win-win)
		Whether and how is the timing of measures taken into consideration?
5	Adaptive Plan (action plan)	How were the preferred strategies identified and selected?
		How were the preferred strategy(ies) are translated into a plan?
		How is the robustness and flexibility of the Plan safeguarded? What does the Action Plan look like?
6-7	Implem. and Monitoring	Were the monitoring and re-evaluation (review) of the Plan / Programme accounted for and included in the definition of the Plan / Programme itself?

Table E. List of questions addressed for each step of the process of an Adaptive Planning and Management.
Source: adapted from Jeuken et al. 2014

5.1. KEY-ELEMENT 1: WORKING WITH A WIDE RANGE OF PLAUSIBLE FUTURE SCENARIOS

As seen, to delimitate the Strips for Safeguarding from Coastal Erosion, the POC-CE Team generated a single projection of the future retreat (regression / landward migration) of the shoreline. To develop this projection (to calculate the plausible future shoreline retreat), the Team considered three components: erosion (shoreline retreat) extrapolated from past observations of the shoreline migration; 2) erosion (shoreline retreat) induced by an extreme storm; and 3) erosion (shoreline retreat) induced by SLR. Regarding the parameter SLR, the Team only considered a single plausible scenario (0,35m for 2050 and 1,50m for 2100), and regarding the parameter 'extreme storms', the Team only considered one possible extreme storm. The final projection of the future shoreline retreat results from the sum of these three components. The projected future shoreline (for 2050 and for 2100) sets the inward limit of the Strips for Safeguarding from Coastal Erosion (for 2050 and for 2100, respectively).

To delimitate Strips for Safeguarding from Coastal Floods and Overtopping Inundations, the Team applied a different methodology. Such methodology served to estimate the maximum flood height, for 2050 and 2100, which was calculated as the sum of three different components – i.e. sea level determined by the astronomical tide, the level induced by a storm surge, and the run-up (which includes the wave set-up and the extension of the waves). Then, the flood heights obtained were overlapped to an altimetric model (LIDAR), which allowed the identification of zones vulnerable to coastal flooding. In this calculation, again the Team considered a single projection of SLR (0,35m in 2050 and 1,50m in 2100).

Thus, the POC-CE Team only generated a single projection (scenario) of the plausible future shoreline retreat for each of the time-horizons considered (i.e. 2050 and 2100), and a single projection (scenario) of the plausible future floodable area for each time-horizon considered (2050 and 2100). In the generation of both projections, the Team only considered a single scenario of plausible future SLR.

Overall, the Team dismissed the need of developing more than one projection (scenario) of the plausible future shoreline retreat, and more than one projection (scenario) of the plausible future floodable area, which would be quite useful to express the uncertainty involved in these predictions.[48] The Team not only disregarded the importance of developing various projections (scenarios) to understand the spectrum of uncertainty involved (from extreme to softer scenarios) and to prepare for such plausible futures, but it also dismissed the importance of considering other relevant parameters (e.g. changes in storm patterns induced by climate change, urban / socioeconomic development scenarios).

The POC recognizes that, *'given the great uncertainty that characterizes the databases and the analytical and numerical simulation models, the definition of the Strips for Safeguarding (…) must be wise and consider the precaution principle, particularly because there may be overlapping effects of each of the acting processes*[49]' (POC-CE 2018 b, p.3). However, in practice, the Team did not develop several projections (scenarios) of the plausible future shoreline retreat and of the plausible future floodable area. Instead, it only developed a single projection/ scenario of the future shoreline retreat and a single projection / scenario of the future floodable area. Despite the current great level of urbanization of the littoral and the existing sediment deficit, which might call for more transformative measures in the long-term, the POC did not consider various plausible futures. Working with a wide variety of scenarios would have helped to explore the *long-term dynamic robustness* of the POC and its strategies.

Importantly, an eventual consideration of more scenarios (including more figures for SLR and for other parameters) would have led to the generation of several projections of the future shoreline retreat, and, thus, to several plausible future shorelines (or different strips with different widths). To address this, uncertainty bands could have been represented (adjacent to the line corresponding to an intermediate scenario). Such uncertainty bands could reflect the spectrum of uncertainty that surrounds the projection of future risk: from high-end / worst scenarios to softer scenarios. This would be a sounder way of delineating the Strips for Safeguarding from Coastal Erosion. Regarding the Strips for Safeguarding from Coastal Floods: the consideration of different scenarios (of SLR, storminess, wave climate variability, etc.) would have led to the generation of different flood heights and, thus, different flood extensions (coverage in m^2). Similarly, the representation of uncertainty bands would be useful.

The projection of the future shoreline retreat, which is expressed in a line (a line for 2050 and a line for 2100), corresponds to the inland limit of the Strip for Safeguarding from Coastal Erosion (Level I and Level II, respectively). In a similar way, the projection of the plausible future floodable area is also represented in a line that delimits the Strip for Safeguarding from Coastal Floods. These Strips for 2050 (coastal erosion and coastal flooding) were crucial for the delimitation of the Critical Areas, especially the inward limit of the Strip for Safeguarding from Coastal Erosion 2050. Therefore, both projections were used for exploring the possible spatial extension of erosion and flooding phenomena, and were quite determining for planning purposes (namely in the Critical Areas and their strategies). In the

[48] As mentioned, the definition of the Strips for Safeguarding from Coastal Erosion (as strips that represent the projected retreat / regression of the shoreline, and landward progression of the sea) is surrounded by deep uncertainties, namely the uncertainties related to: the methodology itself and the numerical and simulation models applied (and regarding each of the three components, and the formulations used to estimate their combined effect); the hypotheses considered; lack of data or quality in the available data (e.g. in areas with no registers); and finally, the non-consideration of various scenarios for a given parameter, the non-consideration of other parameters (e.g. anthropic scenarios, storminess).

[49] The POC-CE considered four main drivers of risk and change on coastal zones (acting physical processes that induce to morphological changes in sandy coasts): a) the historical long-term erosion, b) the erosion induced by an extreme storm, 3) erosion induced by SLR associated to climate change), and d) flooding and overtopping inundations (POC-CE 2018 b, p.3).

comparative assessment of the four possible 'Adaptation Scenarios / Strategies' available for Critical Areas, the Team considered the projection of the future shoreline retreat (for 2050) and prior studies, e.g. GTL Report, namely the GTL's model of sediment balance, and a study on the efficacy of pre-existing coastal defences. The POC-CE Team called to all this data '*environmental scenarios*'.

In the POC-CE, the time-horizons (2050 and 2100) associated to the Strips for Safeguarding from Coastal Risks (Level 1 and Level 2) are erroneously called *temporal scenarios*. Although the POC mentions that the Strips for Safeguarding from Coastal Erosion aim to '*safeguard the land territory from the occurrence of different scenarios of hazardousness'* (*in* POC-CE 2018 b, p.7; 2018 f, p.181; 2015, p.397), in fact, the Strips for Safeguarding from Coastal Erosion do not correspond to differentiated scenarios: the Team only developed a single projection (scenario) with two time-horizons.

BOX 8: The Team generated a single protection (with two time-horizons) – i.e. the projected line of evolution of the coastline in 2050 and 2100, and these two lines correspond to the inward limit of the Strips for Safeguarding from Coastal Erosion for 2050 and 2100, respectively. The delimitation of the Critical Areas was based on the limits of the Strips for 2050. An eventual generation of several projections (plausible future scenarios) would have led to a different delimitation of the Strips for Safeguarding from Coastal Risks and of the Critical Areas. Overall, working with several projections / scenarios would require the representation of several 'lines' or 'uncertainty bands' (each respective to a different scenario), and this, in turn, would call for a wider exploration of the range of possible measures, and demand a greater flexibility and robustness in the strategies used to cope with evolving risks over time, in different spaces contained by different bands. Note 335.

In a certain way, the POC was developed as a '*static robust plan*': the Programme only considered a single 'probable' future scenario, and it proposed measures optimized for this scenario, thus, if this projection fails (i.e. if the future unfolds in different ways than projected), the Programme (and its measures) might fail too (representing an over- or under-investment). The POC disregarded other plausible future scenarios that might occur, and, consequently, dismissed possible alternative measures that might be required to deal with different and changing levels of risk over time.

5.2. Key-element 2: identifying thresholds / tipping-points

The POC-CE Team did not identify critical thresholds / adaptation tipping-points (ATPs) – neither in terms of relevant thresholds (limits) for the existing defence systems, nor in terms of important threshold levels in certain parameters (e.g. SLR, eroded area, sediment deficit, etc.) that might render a given measure ineffective or unacceptable and demand new measures. To a certain extent, this occurred because the Team did not consider different plausible future scenarios, it only assumed a single 'most likely' scenario as a given and sought to find the 'optimal' (most cost-effective and cost-beneficial) strategy to cope with such scenario, in each area. On the other hand, the POC-CE Team did not identify tipping-points because it is still framed in a short-term view of the future, which is focused on solving problems in the near-future and which does not account for the multiplicity of plausible future conditions that might unfold and changing risks over time. For example, the Program of Actions provides a scheduling for the implementation of actions / interventions over the next 10 years, but it does not go beyond the next decade (i.e. the mid- and long-term are not addressed). In Portugal, there is still a strong emphasis on the need to produce more risk maps and vulnerability maps (in a desire to reduce uncertainty), however, even if this need is gradually met, it has been disregarded the necessary capacity to plan under uncertainty (*make good decisions with the existing information*) and the need to ensure that the plan (and its measures) can be adapted if such 'risk maps' are updated or corrected. Thus, the pertinence of analysing future risks and vulnerabilities and the need of specifying potential critical thresholds (disruptive levels in certain variables), i.e. tipping-points, has not been fully acknowledged.

Although the identification of ATPs is usually difficult, in the case of the POC-CE, critical thresholds / tipping-points could have been identified for certain variables, for example: area lost due to erosion (eroded area in m^2), sediment deficit (volume lost m3 / year), retreat (regression) of the shoreline (m / year), floodable area (extension), critical flood heights / levels, number of floods per year, etc.

5.3. Key-element 3: developing a '*robust and flexible* set of measures' to deal with uncertain future changes, by using the 'Adaptation Pathways approach'

In the Phase of Characterization and Diagnostic of the process of elaboration of the POC, the Team developed four '*Adaptation Scenarios / Strategies*' for the Critical Areas. Each of these *Adaptation Scenarios / Strategies* may contains several *type-interventions* (adaptation measures), except Strategy 1 which has a single type-intervention (planned retreat). It is explicitly mentioned that each *Adaptation Scenario / Strategy* may include a combination of various interventions. The four *Adaptation Scenarios* can be deemed four possible adaptation strategies, i.e. four alternative strategies, that were available for the diverse Critical Areas. Based on their comparative assessment, through a cost-benefit analysis, the Team would choose one *Adaptation Scenario / Strategy* (the most cost-beneficial) for each Critical Area. Hence, these four *Adaptation Scenarios / Strategies* do not constitute a '*robust and flexible set of measures to deal with uncertain future changes*' (as Key-element 3 implies). These *Scenarios / Strategies* do not fully ensure the *dynamic robustness* / *flexibility* and *adaptability* required in an 'dynamic adaptive plan / strategy' that contains a '*robust flexible* set(s) of actions'. The reasons for this are outlined next. These reasons are shown in comparison to sub-elements of Key-element 3, which are represented in boxes (grey concerns sub-elements that provide both *robustness and flexibility*, and blue concerns sub-elements that provide *flexibility*).

> The APs method: allows switching between different options in the future. It identifies possible options for switching and remaining flexible.

<u>No adaptation pathways were developed / designed</u>: The four *Adaptation Scenarios / Strategies* were not devised nor drawn up as 'adaptation pathways' (each *Strategy* does not consist of a pathway); instead of this, they consist of four possible alternatives for the near future. The POC-CE does not mention whether the diverse type-interventions (measures) envisioned within an *Adaptation Scenario / Strategy* should be implemented at the same time (as a combined strategy that is applied at start and lasts over time), or whether such interventions will be sequenced and implemented over time. Moreover, the POC-CE does not specify where each intervention should be applied within a Critical Area (its specific location), and whether the diverse interventions must be implemented in the same or different zones (as complementary measures applied at the same time).

> APs: short-term decisions are coupled with long-term options. It involves envisioning options and possibilities for switching between them, through adaptation pathways.

<u>The possibility of switching from a given measure to another, or from a Strategy to another, is not ensured</u>. The POC does explain whether it will be possible to switch from an intervention to another (within a given *Strategy*, over time), nor under what conditions. Thus, it was not truly contemplated nor safeguarded the possibility of shifting (changing) of measures over time, as conditions change, or as new information arises. Similarly, with respect to the four *Strategies* devised, it was not considered the eventual need of having to switch from a *Strategy* to another in the future.

> A pathway is a set of measures sequenced and implemented over time to manage risk. Each pathway is flexible (e.g. it is possible to move from a measure to another), and it is also possible to move from a pathway to another.

> The APs' map clearly identifies thresholds defining when (under what conditions) to switch from an action to another (greater flexibility).

<u>No examination / identification of critical thresholds / tipping-points (ATPs)</u>: The prior points can be, in part, explained by the fact that the POC did not work with adaptation tipping-points (ATPs): the POC Team did not examine under what conditions a given intervention would cease to be effective or acceptable, and other intervention would be needed. This is the rationale behind the assembling of pathways: the identification of an ATP requires a new measure to keep risk bellow a target level. The POC mentions that each *Adaptation Strategy* is implicitly associated to a time-horizon (short-, mid-, or long-term), but does not specify until when such *Strategy* is expected to perform well, or, more precisely, under what conditions a *Strategy* becomes ineffective or unacceptable. Overall, the POC did not plan possible measures to deal with changing (levels of) risk over time.

> APs: measures are applied iteratively over time to keep risk below target levels, and keeping open options to manage future risk.

The APs' map shows short-term actions linked to (chained with) long-term options.

Decisions in the near-future on specific actions do not foreclose future options to act differently (switch or add actions) if climate or societal changes ask for it; and developments in near-future do not foreclose future options.

Responses do not foreclose future options or unnecessarily constrain future choices. *Keeping open options.*

Stepwise / phased implementation of various actions or small projects (but, in some cases, a single larger investment is more cost-effective). Short-term decisions are part of a phased longer-term plan.

Plan's flexibility is increased if the APs' map contains multiple pathways (allows switching between different options), and if measures can be implemented stepwise, or if there is the possibility of switching to other measures.

Diversity of measures (soft, hard, structural, non-structural, across different sectors or actors).

No- / low-regret actions (actions w/ properties like robustness, flexibility, reversibility).

Flexible strategies or measures: can be adapted if the future unfolds differently than foreseen.

Moreover, the POC did not anticipately plan possible options for the long-term, as such, it did not link the interventions envisioned for the short-term with options for the long-term. The Programme does not present any alternative measures that are left 'at hand' for the case they become necessary in the future, especially in the period beyond the next 10 years (POC's lifespan). This reveals a short-term view of time.

The POC-CE states the intention of not foreclosing future options: '*on the one hand, it is necessary to ensure that the options taken in terms of the planning of land uses and activities do not aggravate the vulnerability to coastal risks in the future (…), and on the other hand, ensure that the strategies and measures of adaptation to such risks, which will be adopted, do not preclude future strategies*' (POC-CE 2018, p.31). Nevertheless, it does not explain how this will be ensured. To a certain extent, the lack of planning of possible future strategies for the mid- and long-term (and the non-contextualization of the proposed strategies and interventions in a longer timeframe) may give the false sense that the measures programmed for the near-future (next decade, and, at best, until 2050) are *robust* and *flexible* / *adaptable*. However, to truly ensure that the actions taken in short-term to not block future measures, it would be necessary to think ahead about possible options for the long-term, logically link them with measures foreseen in short-run, and assess them under different future scenarios, which is related with the design of APs. The POC does not explain how it will guarantee that measures taken now do not foreclose possible future strategies. Thus, the idea of keeping open options to manage future risk (of the APs) is not fully ensured.

The POC did not explicitly consider a stepwise / phased implementation of several measures over time. It does not provide a sequence of possible interventions for a given Critical Area over time. As mentioned, the POC does not explain whether the diverse 'interventions' pertaining to each *Adaptation Scenario / Strategy* could be sequenced and implemented over time (and how). The possibility of shifting to other possible measures (or strategies) was not duly addressed nor secured.

The POC, as a whole, contains a wide diversity/variety of coastal adaptation measures, including measures at a regional scale (e.g. integrated sediment management, and regimes of safeguard for the Strips for Safeguarding from Coastal Risks), but also localized strategies of adaptation (*principles of planning* that were defined for each Critical Area). It proposes *hard* and *soft* protection measures, accommodation measures, and planned retreat; and it contains measures to reduce the probability of flooding and erosion, and measures to reduce exposure and vulnerability. However, as we *zoom in (*downscale) to the scale of each Critical Area, it is possible to observe that a single alternative (with one or two interventions) was usually defined, and with little specificity (on the characteristics of measures, timing, location, alternatives, etc.).

In the development and assessment of the four *Adaptation Scenarios / Strategies*, the Team did not explicitly considered the criteria of *robustness*, *flexibility*, and *low-/ no-regrets properties* (reversibility, adaptability, etc.). *Strategies* and interventions were not purposely chosen because they remain *robust* under multiple plausible futures or are *flexible* in relation to uncertain future changes (i.e. are *adaptable*). Nevertheless, some of the measures proposed by the POC are inherently *flexible*, e.g. 'sediment nourishments'. However, the POC could have further itemised them for each Area, by specifying, e.g. the sources of sediments, volumes required to address different levels of risk, periodicity of nourishments, deposition sites in each Critical Area (or outside).

Weak or no planning of options / possible measures for the mid- and long-term. The non-consideration of multiple plausible future scenarios led to a narrow / limited exploration of the range of measures that might be needed in the future (especially in the long-term), namely measures that might be required to deal with multiple plausible futures and changing conditions over time, and a strong focus on interventions that will likely be required in the next decade and, at best, until 2050 (Level I of the Strips for Safeguarding from Coastal Risks, which served as a basis for the delineation of Critical Areas). In its Program of Actions, the POC provides a schedule of actions for the period 2018-2028, but no programming from 2028 onwards, not even a scheme of possible measures for the time-horizons considered (mid-term / 2050, and long-term / 2100). Thus, the POC has not envisioned other alternatives that might be needed if conditions change, new knowledge or scenarios emerge, risks aggravate or accelerate, unexpected changes occur, or if measures (implemented or planned) cease to be effective. This strongly jeopardizes the *sustainability* and *dynamic robustness* of the POC as a long-term plan.

Importantly, the POC-CE was developed based on guidance provided in several studies and reference documents, including spatial planning instruments and sectoral policies, at various scales and fields. Regarding coastal adaptation, is important to note that the POC Team considered the analysis of 'alternatives', as recommended by the GTL Report. Different alternatives were proposed and explored for the critical situations. These 'alternatives' consist of the different '*Adaptation Scenarios / Strategies*'. Such alternatives were subjected to cost-benefit analyses, in which environmental, social, technical, and economic criteria were taken into consideration (POC-CE 2018 f, p.289). Although the GTL Report, which largely influenced the process of elaboration of the POC and its proposals, refers the need of assessing the costs associated to *'different adaptation pathways / paths'*, the POC did not design adaptation pathways. The four '*Adaptation Scenarios / Strategies*' developed consist of four possible alternatives for the near future, from which it was possible to select one. Moreover, both the GTL and the ENGIZC recommend the use of cost-benefit and multi-criteria analyses (GTL 2014 b, p.3; 2014, p.55), but the POC only carried CBAs in the assessment of its four '*Adaptation Scenarios / Strategies*'.

The POC-CE developed four different '*Adaptation Scenarios / Strategies*', each encompassing its own type-interventions (except the *Scenario 1 – planned retreat*), but it did not specify under what conditions each intervention should be implemented, neither whether, and how, interventions will be sequenced in a given *Scenario / Strategy*. As such, these alternative '*Scenarios / Strategies*' do not provide the necessary *dynamic robustness* and *flexibility* that underlie the method of APs.[50] Actually, these four '*Scenarios / Strategies*' were not devised with such characteristics in mind. It can be concluded that, at the scale of the Critical Areas, the POC does not truly provide 'a *robust and flexible* set of measures to deal with uncertain future changes' or '*robust flexible strategies*' (as Key-element 3 requires).

Overall, for each Critical Area, the POC defined the *strategy of adaptation* (*strategic principle of planning / adaptation*) to be followed, including one or two specific interventions (within such strategy) that must be implemented, but provided no specification or details on *where*, *when*, and *how* such interventions will be carried. Then, in the Program of Actions, the adaptation measures were distributed and organized by 'Strategic Axis', not by location. Hence, it is difficult to understand, when looking into a given Critical Area, which concrete measures (set of measures) are being proposed, what are their specific locations, and the timing for their implementation. The POC followed a rather simplistic approach, which provides few / no options for the future in each Critical Area (especially for the mid- and long-term), and which is, at the same time, deterministic by prescribing the strategy of adaptation (*principle of planning*) that must be followed, which may narrow the spectrum of measures available (by excluding measures that pertain to other typologies of adaptation actions) (see more in Note 336).

[50] Here, *robustness* refers to the capacity of performing well under a wide range of plausible future scenarios, *flexibility* is related to the capacity of adjusting measures and / or strategies over time, and leaving options open, and the possibility to switch (shift) to other measures or strategies.

BOX 9

The POC-CE Team developed four '*Adaptation Scenarios / Strategies*', which consist of four possible adaptation strategies available for Critical Areas. Each 'Adaptation Scenario / Strategy' provides a different strategy that contains several type-interventions (except Strategy 1, which only includes planned retreat). Although each 'Adaptation Scenario / Strategy' contains more than one intervention, it does not provide a pathway. The rationale behind the design of a pathway is intimately linked to the identification of thresholds / tipping-points in the existing system or in prior measures – i.e. when a ATP is about to be reached, a new measure must be implemented, and in this way, a pathway emerges. A pathway provides a set of possible measures sequenced according to important thresholds that might be reached over time (a logical concatenation of measures able to tackle threshold over time). However, the POC Team did not follow this rationale. As explained in Key-element 2, the Team did not identify relevant thresholds that might occur, in part because it did not consider different plausible future scenarios (it only assumed a single 'most likely' scenario as given, therefore, there was no need to explore other solutions for more / less extreme scenarios.

As mentioned, each of the four '*Adaptation Scenario / Strategy*' may encompass one or more measures, but the POC does not explain if the diverse measures must be used in combination (complementarily), or if they constitute alternatives available (not all measures must be necessarily applied), and whether the measures should be applied at the same time or in a phased way. Based on cost-benefit analyses of the four 'Adaptation Scenarios / Strategies', the Team decided which Strategy must be used in each Critical Area.

For each Critical Area, the POC-CE has defined the *strategy of adaptation* (*strategic principle of planning* or *strategic principle of adaptation*) that must be implemented, including one / two interventions within the strategy proposed. However, almost always, the POC does not specify which concrete measures, how many, where, and when (or under what conditions) each intervention should be implemented. In the Critical Areas, the proposed Strategy is usually insufficiently detailed and vague.

Suggestions

An eventual consideration of various plausible future scenarios would have called for deeper exploration of the range of possible adaptation measures. This would widen the decision-space and go beyond the simple prescription of the *strategy of adaptation (principle of adaptation*), with one or two interventions, for each Critical Area, which often provides scarce information on which specific measures should be used, where, when, and under what conditions it will be necessary to switch of measure.

The POC could have further defined / specified the following aspects: which interventions are available to tackle different or changing levels of risk in a given Critical Area (and in its diverse zones) over time; distinguish which measures must be implemented in different zones of a Critical Area at the same time (as a package of complementary measures for the same period) and which interventions can be sequenced and applied over time (in the same or in different zones). The POC does not show any explicit sequence of possible interventions for a Critical Area. An eventual sequencing of possible interventions (to tackle changing levels of risk) could lead to a multiplication of the strategies available (as multiple sequences can be designed with the interventions considered, or groups of interventions). The exploration of diverse concatenations – i.e. the design of various possible alternative pathways – for a given Critical Area would be a valuable exercise that would significantly increase the *dynamic robustness* / *flexibility* and *adaptability* of the Programme itself and of its *Strategies*. By having alternative measures and pathways 'at hand', the POC would be better prepared to be adjustable over time and to cope with uncertain future changes.

The actions proposed for each Critical Area are organized along the Program of Actions per *Strategic Axis*. The analysis of the Program of Actions shows that, often, each Critical Area will receive more than one action. Such actions form part of a 'range of actions' to be implemented over the next decade. Thus, the geo-referenced maps presented for each Critical Area could show all actions foreseen for that area, their specific location, their scheduling over time (including the implementation moment). Moreover, the Team could have presented (and mapped) other alternative actions for the next 10 years and beyond (to cope with different scenarios of shoreline retreat or SLR that may unfold in the future). These actions (or groups of actions) could be represented in an APs' map and sequenced according to relevant ATPs that may occur over time – once a tipping-point is about to be reached a new action would be required, and, in this way, a pathway would emerge. Thus, various pathways could be designed.

The POC could have further explored diverse possible strategies and measures for the Critical Areas. The Team could have searched for various adaptation measures to cope with different thresholds (ATPs) over time (not only the next decade, but until 2100). The diverse measures could have been chained to assemble / develop pathways, and the various pathways could be designed in an APs' map. Such map could be elaborated for each Critical Area, but also at broader scales (e.g. allowing the *integrated sediment strategy* to be better explained, in terms of sources, deposition sites, periodicity, etc.).

A quick observation of Figure 12 (p.297) demonstrates that a map of APs map could have been easily developed for each Critical Area. For example: if Figure 12 is rotated 90º left it shows the four possible Strategies in the Y axis with their respective interventions (not sequenced) along the X axis (top), and plausible future scenarios (in the X axis bottom) (Figure 29), but this is still not a APs' map. To overcome this gap, Figure 12 can be rotated 180º from its initial position (or mirrored), which will allow the visualization of interventions along the Y axis, and the Strategies in the X axis. Then, the Strategies are removed and substituted by a certain variable (e.g. SLR, shoreline retreat, flood extension, time), and, then, the Strategies can be designed as pathways in the middle of the map, as concatenations of (individual or combined) measures (Figure 30). This implies a logical ordering of measures in the Y axis.

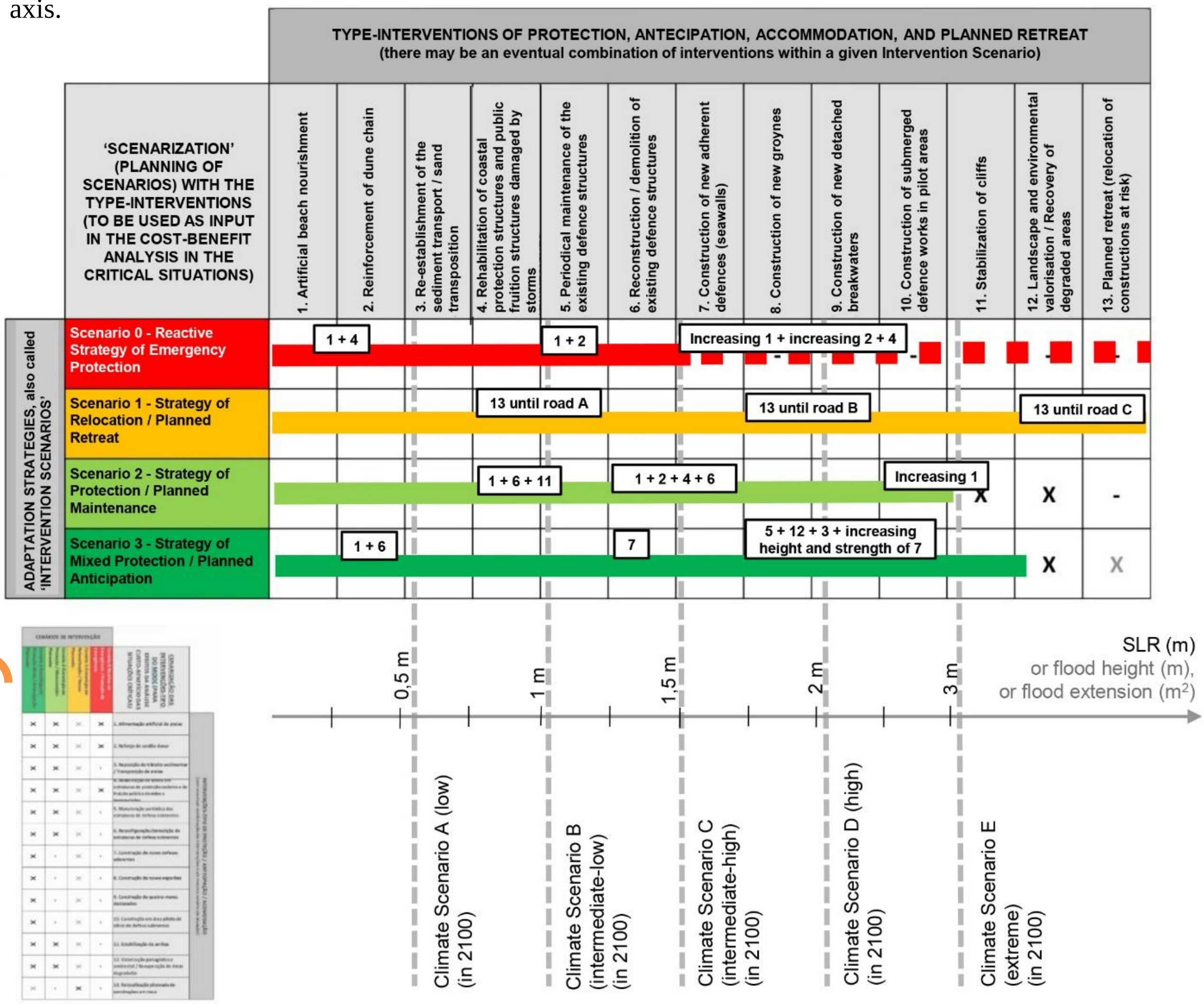


Figure 29. Example of a map of APs that could be developed for each Critical Area using the type-interventions already considered in the POC-CE (Figure 12 is shown in the left bottom), and in which it would be possible to add more interventions. Source: own elaboration.

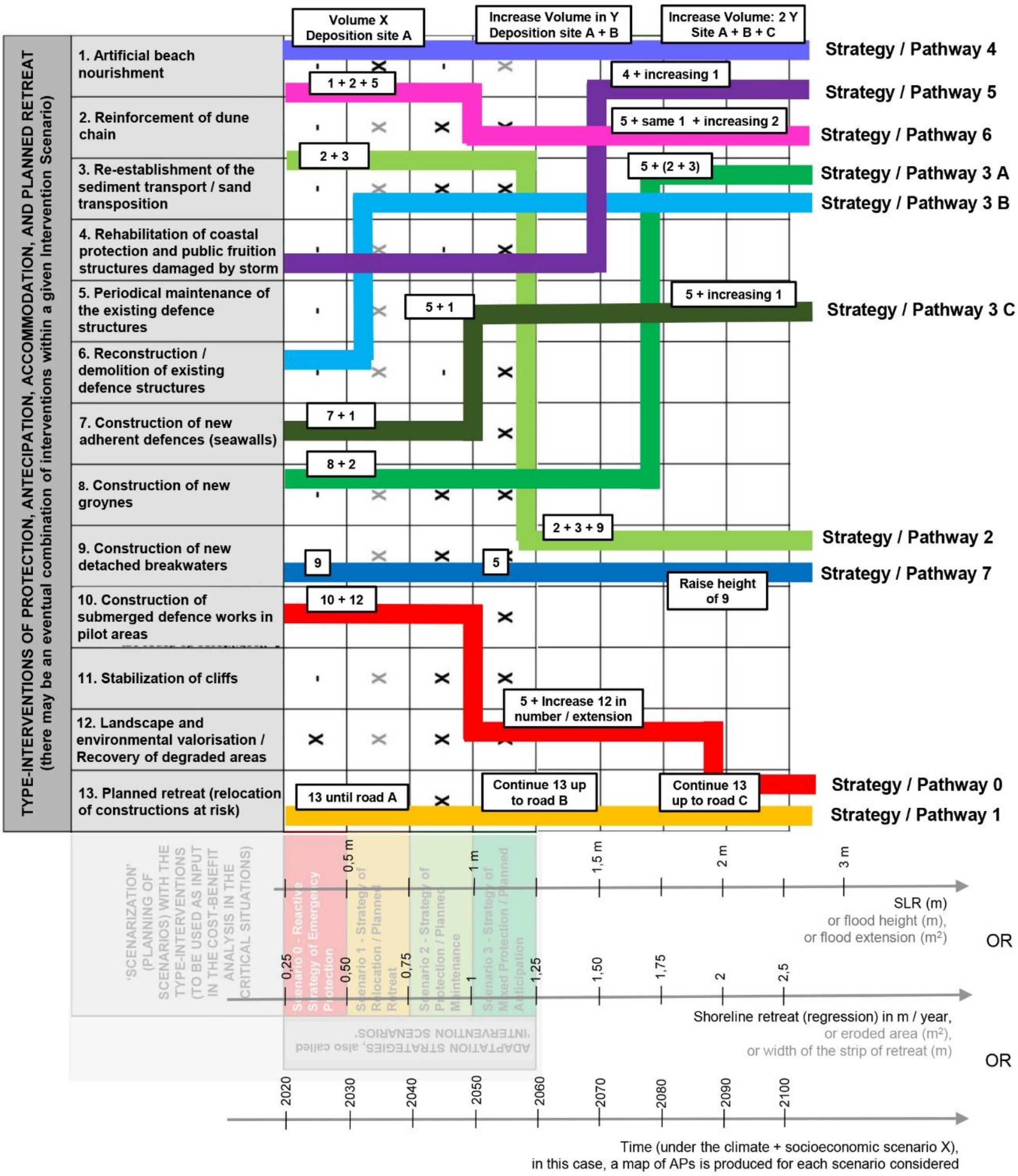


Figure 30. Other example of a map of APs that could be developed for each Critical Areas using the type-interventions considered in the POC-CE, and in which it was possible to add more interventions and strategies. Source: own elaboration.

In synthesis, the POC-CE could have designed several possible pathways for each Critical Area and represented them in an APs' map (route-map), and then mapped each pathway in a georeferenced cartography (in a similar way to the TE2100 case). This would provide alternative pathways for each Area, each pathway containing different measures over time, but also support the decision on the preferred pathway for the short-term (Note 337). Overall, the analysis of the POC-CE shows that the potential to explore and propose diverse alternative strategies – each containing sequenced measures (or groups of measures) to tackle thresholds over time, and linking actions envisaged in the short-term to possible long-term options – remained under-explored. With its strategic scope, the POC could have analysed various possible measures and pathways with more specificity for each site, and represented them in a map of alternative pathways that could be presented in the POC itself. This would raise the awareness that a different measure or pathway might be chosen in the future if necessary.

5.4. Key-element 4: monitoring, re-assessing the Plan, and adjusting

The POC-CE proposes the creation of a monitoring and evaluation system for the coastal zone. It underlines that a continual monitoring of the coastal zone must be prioritized, as it is '*the only way to obtain, in space and in time, data that allows the comprehension of the changes underway, and the generation of future evolutive scenarios and, thus, it provides tools to support decision-making*'. The monitoring system must support the management process of the POC, which, in turn, should assure an adaptive management in time and space (POC-CE 2018, p.43).

The POC mentions that the Critical Areas require special attention and that '*the process of adaptive management and the process of monitoring will be extremely relevant to ensure eventual adjustments following the occurrence of extreme phenomena or other adverse circumstances*' (POC-CE 2018, p.67). The SEA Report refers that '*it is essential to ensure an elevated level of execution of the interventions proposed in the POC, as well as the implementation of its strategy of adaptive management of the coastal zone, which should be based on the permanent monitoring of the natural and built-up systems, as the best way to better understand and follow the evolution of the territory, anticipate critical situations*', and '*such monitoring must consider the variables that might determine different responses in terms of intervention*' (POC-CE 2018 f, p.200). This reveals the great emphasis that the POC puts on monitoring as the major 'ingredient' required to ensure the *adaptability* of the Programme; the monitoring results are expected to support future decisions. This is a good sign of the embedding of the Key-element 4 in the *model of adaptive management* of the POC. However, the POC did not provide (nor explored) such *different responses* (alternative measures) that might be needed in the future if the monitoring results demand this. This points to the false idea that it is not necessary to plan ahead and have alternative measures 'at hand' now, but only when (and if) they become necessary (if the monitoring results ask for them). Moreover, the POC did not specify what variables, nor which values in such variables (triggers), might determine a given 'response' (neither which interventions will be available if a trigger is reached). As the POC did not anticipatedly plan possible measures for the future, although the monitoring system may provide valuable data, this system (*per se*) will not necessarily ensure the *adaptability* of the POC and its strategies. In addition, the POC implicitly assumes that there will be no need to alter the '*principle of planning*' during the POC's lifetime: this strategy will, in general, remain, but its concrete measures and their features) might suffer alterations if the monitoring indicates so.

According to the SEA of the POC, the monitoring system is required to '*assure that the management policies are the most appropriate and that interventions have the desired effects*', to '*measure changes in the systems*', to '*detect the success of the actions*', and to '*allow responding, in useful time, to unpredicted situations* (POC-CE 2018 f, p.284). Nevertheless, the POC-CE does not explain how its monitoring and evaluation system will measure the success of measures, neither how it will detect when it is the right moment (timing) for *responding in useful time*. It can be questioned how 'useful time' will be measured. The POC did not specify relevant thresholds / ATPs for certain variables, nor trigger-values in indicators that pointed to the need of taking action / decision. It did not identify potential decision-points. Thus, it will be difficult to discern when one should adopt a new action, or change / adjust an implemented or planned action. For instance, no explanation is given regarding what will be done to adapt the POC, if the monitoring system shows the ineffectiveness of an implemented measure, or if it detects unexpected changes.

The SEA refers that '*dictated by the coastal dynamics underway and the imponderability and unpredictability of the climatic factors (...), the POC assumed a strategy of adaptive management, in space and in time, and focussed on the areas of greater environmental sensitivity and higher susceptibility to extreme events* (…), *to progressively adjust the occupation and uses of the territory to the emerging risks and extreme events*' (POC-CE 2018 f, p.198, 237). Notwithstanding, the POC does not explain how the Programme itself will be adaptable '*in space and in time*'. It is not provided a description of how the Programme's contents – e.g. the Strips for Safeguarding from Coastal Risks and their respective Norms, and the Critical Areas and the Strategy (and interventions) proposed for them – can be adapted as time unfolds and in space (it is not mentioned whether a measure can be adjusted, or substituted by an alternative measure). In simple terms, the POC does not explain how such 'adaptive management' (with its intrinsic adaptations of the physical system and of the Plan) will be ensured.

The SEA Report of the POC provides suggestions for the POC's monitoring and evaluation system:

- Given the dynamic character of coastal zones, monitoring is essential to '*substantiate the definition of risk / vulnerable zones*', '*to evaluate the impact of interventions, before and after their implementation*' (such aspects are quite relevant after extreme storms that cause changes in coastal geomorphology) (POC-CE 2015 b, p.158; 2018 f, p.279). Such monitoring procedure should '*allow partial and more agile adjustments of the Programme, focussed on sites where changes are occurring, without the need of carrying a process of integral revision of the whole Programme for the entire coastal stretch CE*' (POC-CE 2015 b, p.159; 2018 f, p.279). The POC runs the risk of becoming immediately obsolete if it does not have a monitoring system; and such system would bring advantages terms of costs and efficacy, by increasing the longevity of the POC as a planning instrument and providing data essential for future revisions of the Programme (POC-CE 2018 f, p.279-280).
- The monitoring system should aim to '*create a thorough knowledge basis that allows anticipating or justifying (scientifically) the options of intervention*' (POC-CE 2018 f, p.279). It should ensure *the systematic evaluation of the effects of the implementation of the POC, with the aim of identifying and justifying the need of correcting or adopting new orientations, in terms of Norms or Program of Actions, due to the occurrence of unpredicted situations*, and *the obtention of additional information and verification of the unfeasibility or inadequacy of the proposed orientations* (ibid, p.293).
- The monitoring and systematic evaluation of the implementation of the POC and its effects are essential to ensure that the Norms and the Program of Actions contribute to achieve the objectives set. The monitoring process should: track the evolution of the execution of the POC; identify unpredicted effects and risks that may emerge as circumstances change and which might imply a modification of the POC's content (POC-CE 2018 f, p.305). The observation of the behaviour of the coastal zone over time is fundamental to measure occurred changes and support the spatial planning of these systems, to anticipate measures of adaptation to changes, and to minimize impacts on natural and socioeconomic systems. It is important to intensify the monitoring of risk situations (POC-CE 2018 f, p.317).

In sum, the POC-CE recognizes the importance of monitoring and reassessment, and it proposes the creation of a monitoring and evaluation system (including indicators to be monitored). This system considers the main drivers of change and risk, however, it does not include some variables relevant for detecting trends regarding climate change effects (SLR, changes in storm patterns), nor specifies triggers (trigger-values in variables) that indicate the need to take a new decision / action. This system also does not refer that is it necessary to monitor progresses in scientific knowledge and new climate projections that might emerge. The analysis of the indicators listed in the monitoring and evaluation system showed that more indicators could have been included on the effects of anthropic pressures and the effects of climate change on coastal dynamics, namely SLR, and changes in storm patterns and wave climate. Moreover, the POC's monitoring and evaluation system does not explain how it will ensure that the Programme and its contents – namely the actions implemented and planned for the Critical Areas – will be adjusted / adapted, if the monitoring results call for this or if unexpected changes occur, for example: will it be necessary to shift to other measure, which measures will be available by then, and whether it will be viable to add new measures, and to advance / postpone a given measure in time.

As the programming of measures (Program of Actions) was not supported by the analysis of thresholds/ ATPs, it will be difficult to ensure *flexibility* in terms of the possibility of advancing or postponing measures in time according to external conditions that are monitored. The POC provides no explanation of how strategies and measures might be adjusted or altered: it does not mention the possibility of shifting from a measure to another, no spectrum of future options is provided; there is no map with an array of possible measures for each Critical Area. Instead, the POC only defines / prescribes the 'principle of adaptation' – i.e. the strategy of adaptation – in a quite superficial way (with one or two *type-interventions* included), for each Critical Area, which leaves the 'burden' of planning concrete adaptation measures to the municipal councils. The Program of Actions identifies the actions to be implemented per 'Strategic Axis' (not per location), which hampers the comprehension of the range of actions that is proposed for a given Area. Despite the intention of progressively adjusting the uses and occupation of the territory to the emerging risks and threats, the POC does not specify how such adjustments will be made: whether it will involve several measures incremented over time (multiple phased / stepwise investments), or measures optimized to last (during the period in force of this POC).[51]

5.5. Key-element 5: the ongoing cycle of planning and adaptation and iterative risk management

A real Adaptive Planning and Management approach presupposes an ongoing cycle – a process of development of a *dynamic adaptive plan*, which requires the pursuit of several steps: assessment of risks and potential impacts under a wide range of scenarios; identification of possible measures and design of strategies (pathways) under a wide range of scenarios (anticipatory planning); selection of the preferred pathway (decision-making); implementation, monitoring of external conditions and reassessment of the Plan and, if necessary, review / correct or alter the Plan (its measures or their timing). Importantly, the model of adaptive management proposed by the POC resembles more the approach of Adaptive Management proposed by Holling (1978), which puts greater emphasis on the role of the monitoring phase (in detriment of the other steps). Nevertheless, as the POC-CE recognizes, the monitoring and re-assessment have been historically jeopardized in Portugal. The institutions' capacity for the acquisition, systematization and management of information and knowledge production on coastal dynamics (e.g. sediment dynamics, shoreline evolution, performance of coastal protection structures) has been undermined. This handicap was felt during the elaboration of the POC: '*the absence of the truly monitoring strategy has conditioned the processes of planning and management, which are supposed to be adaptive and duly informed*' (POC-CE 2018, p.42).

In the case of the POC-CE, there is still no experience on the steps of implementation and monitoring.[52] In the future, it will be important to analyse how monitoring will be used to implement and adapt strategies. So far, the idea that the POC has adopted an approach of *adaptive planning and management* is more an 'intention' than a keystone upon which the elaboration of the Programme was based.

[51] Some hard protection measures (e.g. improvement of existing hard defences) offer limited flexibility when compared to other measures that are inherently flexible and better suited to be implemented in small steps (e.g. soft protection measures like sand nourishments, or accommodation measures for built assets). Yet, hard protection measures usually provide greater robustness (their design usually incorporates large safety margins and increases the resistance of the defences). Moreover, in certain cases, single large investments (e.g. construction of hard defences) may be much more cost-effective than multiple smaller stepwise investments. It is important to highlight that hard coastal protection measures like seawalls and breakwaters are implemented for many decades. The TE2100 is an example of how large-scale hard structural measures were postponed. Eventually, the wisest way of ensuring an adaptive plan may be to include diverse kinds of measures (***hard*** and *soft* measures, structural and non-structural measures, namely measures for improving existing coastal defences) (see Note 338).
[52] The POC-CE was approved in August 2020. In the last public consultation period (June 2020), there was contestation and public opposition to several important issues. In the recent months, there were rumours that the POC's approval was dependent on the approval of the project of extension of the external breakwater of the Leixões Port.

5.6. Comparison: Key-elements of an Adaptive Planning and Management *versus* the POC-CE case

Table F provides a comparison: it identifies the key-elements of an 'Adaptive Planning and Management approach' (APM) that are essential to develop a *dynamic adaptive plan* (left column), and outlines (sums up) whether and how these elements were applied in the POC-CE case (right column).

Key-elements of APM, based on reference cases	POC-CE case
Key-element 1: To consider a wide range of *plausible future scenarios* (different climatic, physical, and socioeconomic scenarios), rather than a single probabilistic projection of the future, and use them namely to assess measures and strategies on their effectiveness. This key-element consists of the consideration of a wide range of plausible future scenarios, and their use in the assessment of measures and strategies (pathways) regarding their effectiveness. It is necessary to consider various plausible futures to assess what measures can be used to achieve the objectives regardless of how the future unfolds. The scenarios should represent the main uncertainties about future conditions and changes.	The Team generated: • a single scenario (projection) of the future shoreline retreat (regression) with two time-horizons (2050 and 2100). • a single scenario (projection) of the future floodable zone, for two time-horizons (2050 and 2100). With these two projections, the Team delineated two different risk zones – i.e. the Strips for Safeguarding from Coastal Erosion (Level I and II), and the Strips for Safeguarding from Coastal Floods (Level I and II), respectively. In the generation of both projections (Strips), it was only considered a single scenario of SLR, which was aggregated to other components to calculate the projections. The Team considered a single scenario for SLR: +0,35m in 2050 and +1,50m in 2100. The Strip for Safeguarding from Coastal Erosion (Level I – 2050) and the Strip for Safeguarding from Coastal Floods (Level I -2050) were then used (as environmental scenarios) in the assessment of four main possible Adaptation Scenarios / Strategies, for critical areas. As such, both Strips (single projections) were used for planning purposes – i.e. for exploring and assessing possible strategies. No scenarios were considered for other parameters / variables, e.g.: storminess / changes in storm patterns (storm surges), changing wave climate, river discharges, socioeconomic / urban development.
Key-element 2: To identify critical thresholds/ ATPs (conditions under which the current or a given measure ceases to be effective / acceptable), and a new measure is needed.	**Not addressed.** The Team did not identify critical thresholds (limit-values) or adaptation tipping-points.
Key-element 3: To develop a *robust and flexible* set of measures, to deal with uncertain future changes, through the 'Adaptation Pathways approach' (APs). I.e. to design a '*robust and flexible*' set of actions (containing *robust* and / or *flexible* measures), to respond to uncertain change. This element involves designing *robust flexible strategies* with the APs approach, a strategy can be itself a set of sequenced measures, a pathway. In an Adaptive Planning approach, measures must be *robust* and *flexible*, and '*low/ no-regrets'* as much as possible. The development a *robust and flexible* set of measures requires incorporating *robustness* and *flexibility* and low-regrets properties in the choice of measures and design of strategies. The design of *robust flexible strategies* can be done using the 'APs approach'. The APs is a methodological approach for '*exploring and sequencing a set of possible actions* (or sets) *based on alternative external developments over time*' (Haasnoot et al. 2012, p.485). In the APs, a planner envisions short-term measures chained with long-term possible alternatives (options), and envisages possibilities for switching between them, through pathways.	The POC Team developed four '*Adaptation Scenarios / Strategies*'. Each *Adaptation Scenario / Strategy* may contain one or more 'type-interventions' (measures). These four *Adaptation Scenarios / Strategies* consist of four alternatives available for critical areas, in the near future. Each Adaptation Scenario / Strategy does not consist of a pathway. The Team did not design adaptation pathways. The four 'Adaptation Scenarios / Strategies' do not provide alternative pathways, and they do not fully ensure the *dynamic robustness* and *adaptability* required in an adaptive plan / programme. The POC does not explain if the type-interventions considered within each *Adaptation Scenario/ Strategy* should be implemented at the same time, or whether they constitute alternatives that may be chosen (or not), and whether the interventions should be implemented in a sequence over time. It is not mentioned the possibility of a phased / stepwise implementation of the interventions. It is not explained if it would be possible to switch from an intervention to another within the same *Adaptation Scenario / Strategy*. The same applies to the four *Adaptation Scenarios / Strategies*: it is not mentioned whether it is possible to shift from an 'Adaptation Scenario' to another one, over time. The Team did not analyse under what conditions the type-interventions within each *Adaptation Scenario / Strategy* will cease to be effective or acceptable (i.e. it did not identify ATPs that would require new interventions). Therefore, each *Adaptation Scenario / Strategy* was not devised as a pathway (where a measure is implemented when its predecessor ceases to be effective or performs unacceptably). The Team did not anticipately plan alternative measures (options) for the mid- and long-term. As such, measures envisaged for the short-term are not linked to (chained with) possible options for the long-term.

The APs offers a method to construct a '*dynamic adaptive plan/strategy'* that is *robust* and *flexible.* In the APs, the Plan / Strategy is '*designed to be adjusted over time as more is learnt about the future*' or as changes occur. The timing for new measures, and the measures themselves, can be modified (changed) over time, thus, flexibility is built-in into the long-term strategy itself. In the APs, measures are implemented iteratively over time to keep risk below target levels, and, at the same time, keeping open options to manage future risk. A pathway is a '*package*' of measures sequenced and applied over time. Each pathway contains a set of measures (individual or in groups) that are implemented in sequence to manage risk over time. A pathway is itself flexible (e.g. it is possible to move from a measure to another), and it is also possible to move from a pathway to another. The APs results in an *adaptive plan* that is: *dynamically robust* to uncertain future change and *adaptable* to change (the pathways can be adapted as changes occur in climatic, physical, and socioeconomic conditions).	The POC mentions the intention of not foreclosing future options, by stating that the current strategies and measures should not preclude future strategies, however, it does not explain how it will ensure this. The *flexibility* of having options available for the future (keeping open options to manage future risk) is not fully guaranteed, as there was no anticipatory planning of possible measures for the mid- and long-term. No information is given on the potential stepwise / phased implementation of the interventions within each *Adaptation Scenario / Strategy* (which would provide a pathway). Apparently, the POC seems to provide a wide variety of coastal adaptation measures (including measures to reduce different components of risk (probability of hazard, exposure, and vulnerability). However, when looking at each Critical Area, the POC offers few alternatives: it usually prescribes a strategy of adaptation based on one or two type-interventions, with little specifications on what concrete measures should be implemented, when, where and how. It provides no alternatives beyond the prescribed strategy and its interventions. The POC Team did not use criteria like *robustness*, *flexibility*, or *no-/low-regrets*, to support the selection of a certain *Adaptation Scenario / Strategy* (decision-making). In the development and assessment of the four *Adaptation Strategies*, the Team considered a single projection of the future shoreline evolution (for 2050) and a single projection of the future floodable area (for 2050). As such, if these projections fail, the *Strategies* might fail too.
Key-element 4: To continuously monitor relevant changes and new information, reassess / review the Plan, and adjust it accordingly. This requires: a targeted monitoring of relevant changes (in external conditions, effects of measures), a continual evaluation of new information (e.g. updated scenarios); and the regular reassessment / review of the Plan, and, if necessary, its adjustment (by redefining or modifying measures, pathways, or action plans, according to monitoring results). Important changes are continuously observed and foreseen through monitoring, and future scenarios are reassessed; the Plan is regularly revaluated, and, if necessary, its measures or pathways are adapted. The monitoring of local and global changes is necessary to examine if decisions should be anticipated / postponed, reviewed or altered. The monitoring and revaluation system must be accounted in the Plan.	The need of creating a monitoring and evaluation system is explicitly mentioned in the Programme, and it is recognized as a key requisite for ensuring an adaptive management approach / model, and for ensuring potential adjustments of the Programme and its contents. The POC proposes the creation of a monitoring and evaluation system of the coastal zone and of the POC itself. It defines such Monitoring and Evaluation System and how it will work, including output and outcome indictors that must be monitored. The POC-CE considers the main drivers of change and risk in the indicators to be monitored. However, it has not identified some variables that are relevant for detecting trends regarding climate change effects (e.g. SLR, changes in storm patterns). No information is given about triggers (i.e. trigger-values in variables) that may indicate the need to take a new decision / action. No information is given on decision-points or implementation-points. The monitoring system does not refer that is it necessary to monitor progresses in scientific knowledge and new climate projections that might emerge. The monitoring and evaluation system does not explain how it will ensure that the Programme and its contents – e.g. the measures planned for or applied in the Critical Areas – will be adjusted / adapted, if the monitoring results require so.
Key-element 5: ongoing process of planning and adaptation, and iterative risk management, with its several steps: definition of objectives, analysis of risks and potential impacts now and in the future; identification of ATPs; exploration of possible measures; development of pathways/ strategies, and their assessment under various scenarios; selection of preferred pathway (decision) as input for designing an 'action plan'; implementation, monitoring of external changes and regular reassessment of the Plan and, if necessary, the adjust (correct or alter) it, its measures or their timing. This process safeguards the adaptability of the general Plan over time, so that it can deal with uncertain future change.	The model of adaptive management proposed by the POC resembles the Adaptive Management approach proposed by Holling (1978), which puts greater emphasis on the role of monitoring. The new POC-CE is still waiting for approval. There is still no experience on the steps of implementation and monitoring. It will be necessary to analyse how monitoring will be used to implement and adapt strategies. The POC sought to adopt an approach of adaptive management, but this remains more an 'intention' than a reality upon which the Programme was elaborated.

Table F. Comparison of the key-elements of an *Adaptive Planning and Management approach* identified in Part A, with the POC-CE case. Source: own elaboration.

5.6.1. Sub-elements of Key-element 3: is the POC-CE an *adaptive programme*?

Table G provides a comparison between the main ways through which a plan / programme is adaptable to uncertain future conditions and changes – which mostly consist of important sub-elements of the key-elements 3 and 4 – and whether and how they were addressed in the POC-CE case.

Sub-elements of Key-element 3: how the robustness and flexibility are ensured / safeguarded in the 'set of measures (actions)' of the Plan (in an Adaptive Planning approach), based on the reference cases; how a plan / programme is adaptable: ways through which the Plan can be adapted	
Reference cases	**POC-CE**
The 'APs approach' allows switching between different options in the future. Each pathway contains a set of measures sequenced and implemented to manage risk over time. Each pathway is itself flexible (e.g. is possible to switch from a measure to another), and it is also possible to switch (move) from a pathway to another. (Possibility of switching to other measures; switching between measures / options)	**Not addressed. No pathways were designed.** Although each Adaptation Scenario / Strategy contains several measures (interventions), it is not mentioned whether it will be possible to switch from a measure to another in a given Adaptation Scenario / Strategy. No tipping-points or critical thresholds were identified. As such, it is not shown under what conditions a given measure will cease to be effective and a new measure will be needed. Each Adaptation Scenario / Strategy offers a package of measures, and four possible Adaptation Scenarios / Strategies were developed, and comparatively assessed, in the case of the Critical Areas.
It is possible to switch (move) from a pathway to another. (Possibility of switching to other pathways; possibility of switching between pathways)	**Not addressed.** The POC-CE does not refer the possibility of moving from an 'Adaptation Scenario / Strategy' to another one, according to the rate of change that is observed, as conditions change or as new knowledge arises. The Team did not consider 'higher / worse' scenarios for climatic parameters, neither assessed the robustness of the proposed Adaptation Scenarios / Strategies' under such scenarios.
Having various pathways available. The APs' map presents several different pathways available. + Having various measures (availability of alternative measures).	**Partially addressed**. More than one Adaptation Scenario / Strategy is available to manage flood risk (four Adaptation Strategies were developed). It is not explained until when such Strategies are expected to be useful to manage risk. Similarly, it is not mentioned with which levels of SLR or shoreline retreat, or other parameters, such Strategies are expected to cope with. The Programme does not identify critical thresholds at which another Strategy will be required.
Stepwise / phased implementation of various measures	It is not mentioned whether the interventions within each Adaptation Scenario / Strategy can be implemented over time, in a phased and sequenced way. For the Critical Areas, the POC-CE proposes a 'strategic principle of planning', i.e. a strategy of adaptation, that must be followed, with no detailed planning of measures in space and in time. The detailed planning of adaptation measures is allocated to the municipal level, which must follow the 'principle / type of strategy' prescribed.
Keeping open options (alternatives); not foreclosing future options Decisions in the near-future on concrete actions should not foreclose future options to act differently (and switch or add actions if climate or societal changes ask for it) Responses should not unnecessarily constrain future choices.	The POC-CE intends to ensure that the adaptation strategies and measures that are taken today do not preclude future strategies, however, it does not mention how this will be done. In a certain the POC Team did not design measures and strategies for the mid- and long-term, in order to avoid the 'risk' of committing to a certain measure or strategy in a context of high uncertainty about future SRL and erosion conditions. No envisioning of alternative measures or pathways for the mid- or long-term. It is implicitly assumed that this will be done in the future revisions of the Programme. Given the uncertainty about future water levels and shoreline regression, the POC not planned possible strategies or measures for the long-term.
Possibility of changing (altering) the timing of new measures (bringing forward or postponing)	**Not addressed.** No reference to the possibility of postponing or advancing the timing of implementation of a measure, as changes are observed, as new climate scenarios arise over time. No references to what should be done if conditions change faster or slower than currently expected.
Possibility of adjusting / adapting the Plan (its pathways, measures, or their timing), over time; (allowing the adjustment of the Plan / Strategy devised, based on the results of the monitoring and revaluation system). The Plan can be adapted to changes over time: it is possible to adjust the timing of new measures, or shift from a measure to a new measure (or from a pathway to another). The Plan can be adapted in the following ways: by adjusting the timing for a new measure (decision point and implementation point); by switching to a new measure or to another	**Partially addressed.** The POC-CE mentions the possibility of changing the Programme over time, namely the possibility of adjusting the Program of Actions, Directives, limits of the Critical Areas, over time. However, it provides no specific information about how such contents might be adjusted / adapted (no references to the possibility of switching of measure (within a Strategy) or shifting Strategy in the Critical Areas). It is not mentioned whether and how the Programme will be *adaptable to change* (e.g. to changing climatic and socioeconomic conditions that may develop until 2100), namely how the Program of Actions can be adapted to changes observed in the indicators. It is not safeguarded the possibility of adjusting (altering) the timing for new measures; neither the possibility of switching from an intervention to another intervention, or from an Adaptation Scenario / Strategy to another one. The Programme does not explain how it will address and respond to changes as these are monitored and identified, or each time the Programme is reviewed or updated. The

pathway; or modifying a measure (within a pathway). Flexibility to be adapted to changing conditions over time Possibility of changing of measure or pathway. Possibility of postponing or advancing the timing for an action.	POC intends to conduct a re-appraisal (review) of the Program of Actions every three years, which must be informed by the monitoring results. However, the POC did not specify: relevant values in the indicators that could act as triggers of measures and require the anticipation or postponing of a measure (i.e. triggers-values); or important decision-points; in addition, the POC does not provide alternative measures (options) for the future. It is mentioned that the monitoring and revaluation system will be crucial to allow the adjustment of the Programme, but it is not explained how. The Plan might not be adaptable and *flexible* enough to deal with accelerating / decelerating effects of climate change in relation to current projections. The Program of Actions focusses on the next decade. It is not referred the need of monitoring and assessing new climate projections and scenarios that might arise.
Diversity / variety of measures. Diversity of measures (w/ different purposes, including measures to reduce probability of hazard, measures to exposure, and measures to reduce vulnerability); hard and soft measures, structural / non-struct. Measures across different actors, sectors)	**Yes / partially addressed.** The Team considered differentiated adaptation measures (including soft and hard protection measures, accommodation measures and planned retreat measures). Moreover, the POC proposes a strategy of integrated sediment management and re-establishment of the sediment cycle. Consideration of the integration of accommodation measures within spatial planning instruments at intermunicipal and municipal levels. The Programme seeks to reduce erosion risk and flood risk through diverse measures, for example: measures to adapt the existing flood defence system, improving existing flood defences; construction of new defences; sand nourishments; dune reconstructions; accommodation measures for the built assets and built environments (resilience-building measures for new and existent urban development), flood warning systems and forecasting, emergency preparedness. The Plan contains measures to reduce the probability of flooding (e.g. protection / defence measures), but also measures to reduce the potential impacts of an eventual flood on spatial development. Regarding the prevention and reduction of coastal risks and vulnerability to climate change, the POC proposes actions to avoid the retreat of the shoreline, and actions to reduce the occurrence of coastal floods and overtopping inundations (e.g. the preservation of existing natural defences, the maintenance and rehabilitation of coastal defence structures, the strengthening of dune chains, and sediment nourishments on beaches) (POC-CE 2018 f, p.316).
Use of no- / low-regrets measures (and earlier in time); and win-win measures	**Partially addressed.** Measures were not selected with criteria like flexibility or low-/no-regrets properties (reversibility and adaptability) in mind. For example, measures were not selected because they reduce risk immediately and cost-efficiently under a wide range of climate scenarios (i.e. they are low-/ no-regret) or because they provide multiple benefits (regardless of the scenario that unfolds). However, the POC has (intuitively) proposed some measures are inherently flexible or reversible (e.g. sediment nourishments, which can be easily increased in volume and frequency).
Use of robust measures + flexible measures Incorporating engineered / structural flexibility, and adaptation of engineered structures. Use of robust measures: Actions create a robust system that may better cope with extreme events. E.g. Actions increase a system's resilience (capacity to cope with and recover from uncertain future flood risk) or incorporate large safety margins (increase a system's resistance). Use of flexible measures: Flexible strategies or measures can be adapted if the future unfolds differently than foreseen; ability to cope with uncertain futures; actions are chosen to remain flexible in the face of uncertain future changes	**Not fully addressed**. The POC-CE did not intentionally take into consideration criteria such as dynamic robustness and flexibility in the exploration, identification and assessment of possible Adaptation Scenarios / Strategies and their type-interventions. and select measures. However, some of the actions and interventions proposed correspond to robust measures and flexible measures. The POC defines measures of maintenance and repair works for some existing defence structures or coastal engineering works. However, it provides little information how these defence structures can be updated / adjusted, in a way that accounts for future climate change effects, namely SLR. No information is given on how the new project for the extension of the breakwater of the Leixões Port should take into account the effects of climate change in its design (whether it should consider a structure that might be modified in the future, or construct larger foundations to withstand higher flood water loadings, or designing larger 'safety margins' (over-engineering structures to cope with greater change than predicted). The POC-CE mentions the intention of ensuring that the new large-scale engineering structures or coastal engineering works, such as port defence works, are designed in a way that accounts for future climate change effects, namely SLR.
Safeguarding land for future adaptation measures	**Partially addressed.** The POC-CE defines the Strips for Safeguarding from Coastal Risks as areas that are mostly non-aedificandi, to limit the exposure to risks. It defines the actions allowed, conditioned and forbidden in such Strips.
Integration of climate adaptation into new infrastructure projects (*mainstreaming*); Integration of FRM / adaptation measures with other investments / agendas; mainstreaming adaptation into other investments and agendas.	**Partially addressed.** Integration of climate adaptation into coastal spatial planning and management. The POC could have further explained whether and how it will be possible to seize opportunities that might arise; search for win-win options, for example, opportunities to integrate adaptation / risk management measures into large-scale investments that are planned to occur (e.g. the extension of the breakwater of the Leixões Port).

Table G. Comparison of the main ways through which the Reference Cases delivered an *adaptable plan / programme* with the case of POC-CE. Source: own elaboration, based on Part A of this Thesis and on the analysis of the POC-CE.

6. Barriers to the application of an Adaptive Planning and Management approach in the POC-CE

6.1. Barriers to, difficulties in, applying an Adaptive Planning and Management approach

This section synthesizes some of the main barriers and hindrances that have precluded a truly application and operationalization of an approach of Adaptive Planning and Management in the POC-CE case.

Firstly, the elaboration of the POC faced various constraints, which may continue during its implementation:

- Few methodologies and scarce scientific and technical resources were provided to the Project Team.
- There was a short deadline for the development of the Programme.
- There is a lack of rigorous and updated data (essential in dynamic territories like coastal zones); information is dispersed across several institutions, and their provision in due time has been weak.
- There are institutional and management insufficiencies, and an inadequate mobilization of human, technical and financial resources necessary to implement and follow-up the proposed measures.
- Some spatial plans, namely municipal spatial plans, allow the occupation of certain urban zones without a due evaluation of its impacts in the face of the ongoing dynamics in the coastal zone.
- Difficulties in implementing some proposed measures in the field, as shown by the 1st POOC (POC-CE 2015, p.422-423; 2018 f, p.192-193). The analysis of the level of execution of the POOC-CE (in force) allows the identification of some hindrances and limitations (Note 339).

Some of the main obstacles the introduction and concretization of an Adaptive Planning and Management approach that were found in the POC-CE are outlined (see also Note 340):

- The intrinsic rigidity and stability of the national legislation (legal framework), despite the recent claims for a more strategic role for the POCs and the public discourse of APA who claims that an approach of Adaptive Management has been adopted in all new POCs.
- The debility of institutions and the lack of technical staff and human resources to carry out and further develop the POC's proposals (and put them into practice), namely at the municipal level. In most municipalities, there is no technical team / staff specifically focused on coastal planning and management neither coastal risk management / adaptation. There is a clear scarcity of qualified and specialized human resources to address this issue at municipal councils. This may constitute a strong barrier to the use of methodological approaches of Adaptive Planning and Management (which imply working with various future scenarios and designing several pathways).
- Although good methodologies may emerge (namely in the scientific community), they may not be applied because there is no explicit indication for their use by the entity responsible for steering the process of elaboration of the spatial plans (in this case APA, which is responsible for the POCs and for coastal management) and for the provision of guidance to the Project Teams. Indeed, in interviews carried during this research with several coastal municipalities (about their willingness to use an Adaptive Planning and Management approach including the 'APs method', most municipalities showed interest in adopting the approach at the scale of the municipal coastal zone, but mentioned that, to do this, APA (or CCDRN) would have to explicitly prescribe the methodology to them – in a top-down approach. On the other hand, the consultancy groups and Project Teams charged of the elaboration of the POCs usually lack time to search for adequate methodological approaches to develop a *sustainable dynamic adaptive plan* (and this is not their main role).

  The analysis of guidance and policy documents that served as a reference framework to the elaboration of the new POC shows that some of these documents already recommend aspects (tools or ingredients) that are characteristic of the approaches of Adaptive Planning and Management. Most often, these documents briefly recommend the use of Adaptive Management and refer to aspects that are directly related to each of the key-elements (e.g. the use of low-/no-regrets measures, not foreclosing future options in order to increase 'flexibility'). However, none of these documents offers a clear methodological guide that explains the process of steps required to develop an adaptive plan / programme and each of the key-elements of an Adaptive Planning and Management approach. It is also worth mentioning that, apparently, there is no impediment in the Portuguese legislation (national law, spatial plans, national strategies, policy documents and strategic documents) that could hinder the introduction and application of an Adaptive Planning and Management approach in the POCs.

The main aspects that seem to hinder the real fulfilment of an approach Adaptive Planning and Management in the case of the POC-CE are related to:

- Institutional and financial bureaucracy, e.g. it is usually necessary to allocate money to each year, and confusions arise if such money is not spent in the programmed year, or if more money than expected is needed.
- Complexity on the roles and responsibilities, e.g. who should be responsible for elaborating the maps of adaptation pathways – the POC Team (under the supervision of APA), or the municipality (in conjunction with APA) – and how should the municipality integrate an APs map of APs (with a strategic and exploratory nature) in its spatial plans (which have normative and regulatory character).
- Lack of a technical staff / team specifically trained and with technical expertise and competences on coastal planning and management (including the management of coastal risks / adaptation). To a certain extent, municipalities tend to wait for higher-level authorities to provide them with concrete instructions on methodologies. This is also a form of 'stability' / institutional stickiness and rigidity. On the other hand, APA has gathered and provided a significant amount of information about climate adaptation and the design of adaptation plans / strategies in its website, but no concrete recommendations or specifications about the approach of Adaptive Management that it claims to have adopted in the new POCs.
- The POC Team, in its turn, has avoided to excessively commit to the methodologies applied, and to the measures proposed. To a certain extent, it did not detail or further develop the 'strategy of adaptation' ('principle of planning') in the Critical Areas, because this will likely entail controversy. By not tackling this issue, the Team is missing the opportunity of appropriately planning under uncertainty about future changes and conditions. The POC Team did not fully answered to each of the five key-elements of an Adaptive Planning and Management approach: it did not prepare for a wide range of plausible future scenarios, it did not examine what critical thresholds might be reached over time under different scenarios, it did not explore and anticipately plan alternative measures and options to manage changing risk in the short-, mid- and long-term, under various plausible futures; it defined a monitoring and evaluation system of external conditions and of the Programme itself but did not explain how this system will allow the adaptation of the POC and its contents; and finally, the ongoing process of development of the adaptive plan / programme and adaptive management is not represented in any diagram or scheme neither fully safeguarded. There is an over-reliance on the monitoring results as essential to adapt the Programme, but it is not explained how the Programme can be adapted as the monitored information arises.

Monitoring and re-assessment have been historically jeopardized, in part, due to the quite complex coastal governance system with its overlapping jurisdictions (POC-CE 2018, p.42). The inexistence or shortage of, or difficult access to, data on the evolution of the coast, lack of regular collection and interpretation, and lack of quality and organization, have been some of main weaknesses of the Portuguese coastal spatial planning and management, which preclude an in-depth understanding of the coast, and the application of predictive models that support decision-making in a perspective of adaptability. In many cases, the interventions have had an emergency character (POC-CE 2018e, p.118).

6.2. Towards a true implementation of an Adaptive Planning and Management in the coastal zone

The 1st POOCs introduced a new culture of coastal risk management in the Portuguese coast. APA highlights that there is still, and there will always be, work to be done in terms of incorporation of climate scenarios into planning, and modernization of coastal spatial planning and management, namely in terms of assimilation of competences by municipalities, articulation of port authorities and environmental entities, and in terms of measures such as the rehabilitation of existing protection structures and sediment management; it mentions that the 2nd generation of POCs sought to address these issues (CEZCM / APRH 2020).

In the future, a real approach of Adaptive Planning and Management, including all its key-elements, will likely be required to appropriately tackle events and risks that are difficult to predict. Many of the effects of climate change are associated to the likely increase in the frequency and intensity of extreme weather events, and associated floods and erosive processes. Such extreme weather events are, by nature, quite difficult to predict. Therefore, a proactive / anticipatory planning of alternative measures for the future (under different future scenarios) will become more valuable than thinking about possible solutions after the occurrence of damages (which would be still in line with a reactive philosophy, even if the programmed measures were already implemented). It will likely be increasingly necessary to incorporate a diversified, '*robust and flexible* set of measures' for each critical area in plans / programmes, in order to tackle different plausible levels of risk in the short-, mid- and long-term. In this sense, the use of an Adaptive Planning and Management approach might prove more effective to address uncertain and changing coastal risks in the future. For a list of steps forward, see Note 341.

6.3. Final remarks: the POC-CE *versus* the claims of an Adaptive Planning and Management of coastal zones

The case of the POC-CE (a case of planning of coastal adaptation / coastal risk management measures) has been compared to the five main elements of Adaptive Planning and Management. Importantly, this case claims that it has purposely followed an adaptive management approach to arrive at an adaptation strategy.

Although the new POC claims to have adopted an 'Adaptive Management approach', and there were already several strategic and policies documents referring to 'adaptive planning and management' and its main ingredients, such guidance was not intentionally absorbed in the elaboration of the new POC. To be assimilated in the elaboration of POC, these documents should have been explicitly prescribed by the APA to the Project Team responsible for elaborating the POC-CE.

There will always be limitations in long-term planning that are associated to the deep uncertainties around drivers of changes and risks, to the limited scope of the planning process (in terms of objectives, stakeholders, spatial and temporal scales considered), or to past and current policies and laws. Planners and decision-makers will have to address these challenges as well as possible. So far, the POC-CE case offers no evidence on the phases of implementation of measures and monitoring and evaluation. Thus, no evidence-based findings can be derived yet. However, by analysing the practice of planning and comparing it to the five key-elements of Adaptive Planning and Management derived from the Reference Cases in Part A (and from existing scientific literature on Adaptive Planning approaches for dealing with uncertain future changes), it is possible to set some directions to operationalize such approaches and identify mistakes that should be avoided in the future.

CASE II: PROGRAMME OF THE COASTAL ZONE ALCOBAÇA-CABO ESPICHEL (*PROGRAMA DA ORLA COSTEIRA ALCOBAÇA-CABO ESPICHEL– POC-ACE*)

1. PRESENTING THE POC-ACE

The *Programme of the Coastal Zone Alcobaça – Cabo Espichel* (POC-ACE) was developed by a Project Team composed of two project companies (*CEDRU* and *Biodesign – Ambiente e Paisagem*), under the leadership of the Portuguese Environment Agency (APA). The POC-ACE corresponds to the review and fusion into a single Special Programme of three prior *Coastal Zone Management Plans* (*Planos de Ordenamento da Orla Costeira – POOCs*) that existed in the coastal zone of the hydrographic region of Tejo and Oeste: the POOC Alcobaça-Mafra (approved in 2002), the POOC Cidadela-São Julião da Barra (approved in 1998), and the POOC Sintra-Sado (approved in 2003) (POC-ACE 2018, p.13).

In accordance with the Decree-Law n.º159/2012, the Law nº 31/2014 (*LBSOTU*), and the Decree-Law n.º 80/2015 (*Regime Jurídico dos Instrumentos de Gestão Territorial*), the review of the three POOCs and their elaboration into a single spatial planning instrument results from:

- The existence of insufficiencies and inadequacy in the proposals and norms of the POOCs, and changes in physical aspects of the territory, and in the planning and management of human activities.
- The need to put into practice the *National Strategy for the Integrated Management of the Coastal Zone* (ENGIZC 2009), especially the principles of precaution and prevention of risk situations and deliver adaptation to climate change.
- The need to articulate the spatial planning of the coastal stretch Alcobaça-Cabo Espichel with the plan '*Plano Regional de Ordenamento do Território do Oeste e Vale do Tejo*' (*PROT-OVT* 2009).
- The need to include areas not encompassed by the prior POOCs, namely the Lagoon of Óbidos and the Berlengas archipelago, and areas under port jurisdiction (POC-ACE 2018, p.13-14).

A renewed strategy was necessary to initiate adaptation to climate change and to prosecute a new form of governance that is integrated and of shared responsibility (POC-ACE 2018, p.14).

The POC-ACE was developed based on recent changes in the legal framework and several reference documents (on the various policy documents and spatial planning instruments that served as a reference, see Chapter I) (POC-ACE 2018, p.29). Moreover, the elaboration of the POC-ACE has followed various legal documents issued in the last 20 years, namely: the *National Programme of Spatial Planning Policy* (PNPOT 2007), the ENAAC, the ENGIZC, the Regional Plan for the Metropolitan Area of Lisbon ('*Plano Regional de Ordenamento do Território da Área Metropolitana de Lisboa*', 2002), the regional plan 'Plano Regional de Ordenamento do Território do Oeste e Vale do Tejo' (2009) (POC-ACE 2018, p.20). The POC also sought to deliver the general objectives set by the Decree-Law n.º159/2012 for the national coastal zone (POC-ACE 2018, p.21).

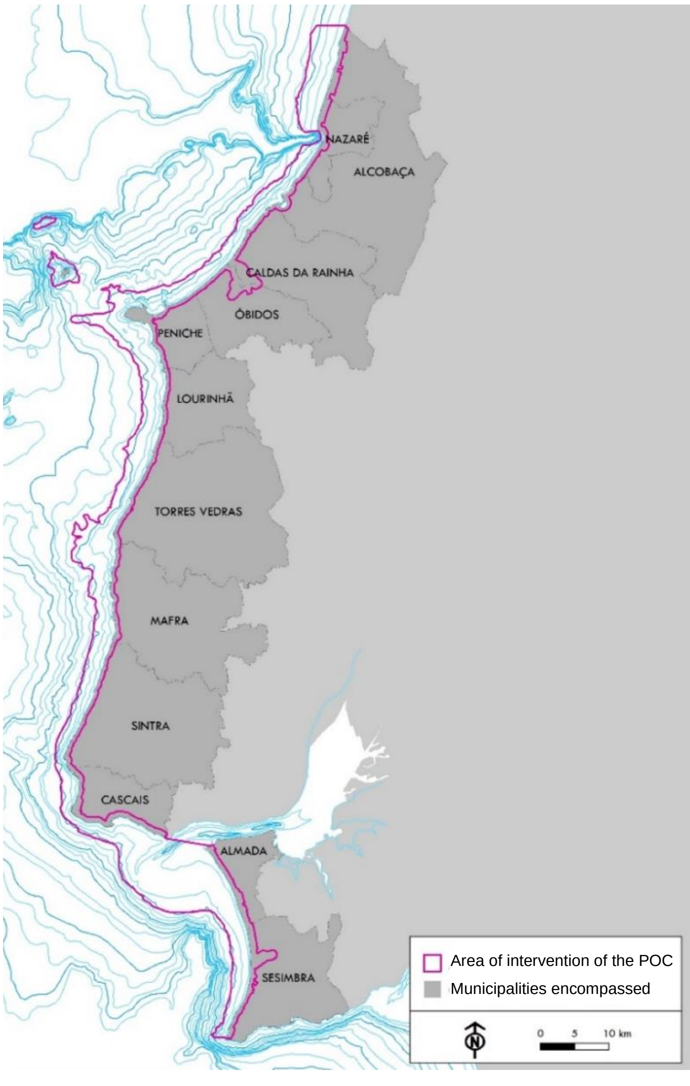
1.1. AREA OF INTERVENTION OF THE POC-ACE

According to the Law n.º58/2005 (*Lei da Água*), the area of intervention of the POC-ACE encompasses maritime coastal waters and interior waters, the respective seabed and margins, and the maritime and terrestrial protection strips (*Faixas Marítima e Terrestre de Protecção*) located within the area of the Administration of the Hydrographical Region of Tejo e Oeste. In addition, according to the Decree-Law n.º 159/2012, the area of intervention of a POC includes two main zones:

- the Maritime Protection Zone (*Zona Marítima de Protecção – ZMP*), i.e. the zone located between the limit of the seabed and the bathymetric of 30m (referenced to the hydrographical zero).
- the Terrestrial Protection Zone (*Zona Terrestre de Protecção – ZTP*), which encompasses the 'Margin' of seawaters and a strip with 500m width from the limit of the Margin landwards which

may be adjusted to a maximum width of 1000m if this is necessary to integrate relevant biophysical systems (POC-ACE 2018, p.21; 2018 d, p.13) (Note 342). As defined by the Law n.º 54/2005, the Margin is a strip of territory contiguous to the line that delimits the seabed, and generally it has a width of 500m from the line of maximum high tide, and is part of the Hydric Domain (ibid).

The area of intervention of the POC corresponds to the coastal zone from Alcobaça (north) to Cabo Espichel (south). It encompasses the coastal territories of the municipalities of Alcobaça, Nazaré, Caldas da Rainha, Óbidos, Peniche, Lourinhã, Torres Vedras, Mafra, Sintra, Cascais, Almada, and Sesimbra, the archipelago of Berlengas and the lagoons of Óbidos and Albufeira (Figure 31, left). The coastal stretch Alcobaça-Cabo Espichel (ACE) has nearly 224 km of length. This stretch is marked by large areas with high ecological and conservationist value, but also by construction pressures and a long-established bathing tradition. It has cliffs and low-lying sandy zones (POC-ACE 2018, p.21; 2018 d, p.13-14). Figure 31 (right) shows the main fishing ports of the area ACE.



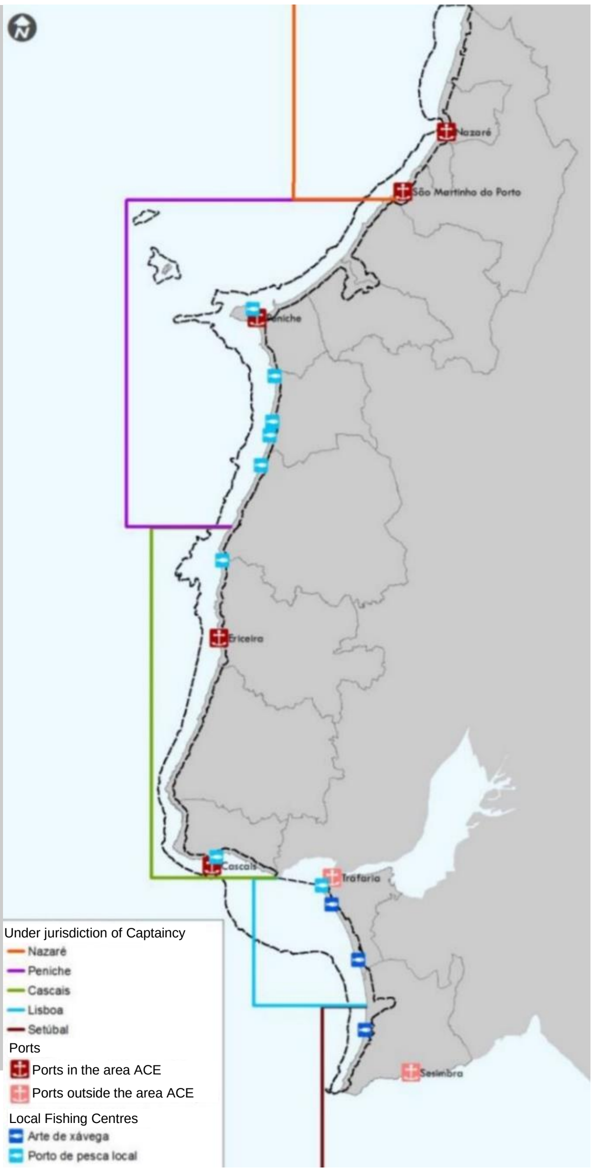


Figure 31 (left). Area of intervention of the POC-ACE. **Figure 31 (right)** Areas under the jurisdiction of ports or local fishing ports in the area of intervention. Source: POC-ACE 2018 d, p.16; 2018, p.65.

In the area ACE there are four main stretches of urban development: 1) the stretch Cascais/Estoril, a consolidated touristic destination; 2) the stretch of Sintra and the stretch of Almada, both punctuated by urban centres, natural areas and beaches with low seasonality; 3) the stretch of the Região do Oeste with smaller coastal settlements associated to fishing and beach activities (Nazaré, Peniche, Ericeira); and 4) the coastal stretch southwards of Lagoa de Albufeira where there only a few dispersed built-up areas (POC-ACE 2018, p.25). The stretches Alcobaça-Sintra and Almada-Sesimbra are marked by several urban settlements with economic activities related with the sea (small harbours, fishing, tourism, seafood industry). Due to the strong construction pressures over the last decades, several areas of disperse occupation have developed in prior rural land, namely holiday houses and seasonal residences. The stretch Cascais-São Julião da Barra is one of the main urban areas of the coastal zone ACE, it belongs to the Metropolitan Area of Lisbon, it is structured along the railway and seaside roadway in an urban continuum with residential buildings and touristic activities (ibid, p.23).

1.1.1. Drivers of increasing risks and change

The coastal zone ACE is characterized by diversified coastal systems: cliffs intertwined with inserted beaches in the northern part of Tejo river (i.e. cliff-beach system interleaved with enclosed beaches), and extensive low-lying sandy areas in the southern part of Tejo, particularly in the city of Almada (between Cova do Vapor and Fonte da Telha) (POC-ACE 2018, p.26; 2018 d, p.51). The coast ACE encompasses cliffs and low-lying sandy zones that already present high vulnerability to coastal erosion, which is expected to critically aggravate with the effects of climate change (POC-ACE 2018, p.14).

The stretches with a low-lying sandy littoral are subjected to the risks of sea overtopping inundations, coastal floods (associated to storms and extreme weather events), and coastal erosion. The wave climate induces to a quite significant littoral sediment transport (drift), and, on the other hand, there has been a decrease in the sediment supply to the littoral caused by human activities in river basins and in the coastal zone. Both factors have led to a high sediment deficit and associated serious erosion problems. The erosion hazard is extreme in areas of Nazaré, Peniche, Areia Branca, and, especially, between Cova do Vapor and Fonte da Telha. The low level of the coastline contributes to this steep vulnerability. The risks of coastal flooding and coastal erosion are expected to progressively aggravate with the effects of climate change, namely with SLR and potential changes in wave and storm patterns (e.g. increase in the frequency and intensity of storms, and possible changes in wave / storm routes) (POC-ACE 2018, p.27).

In the stretches with cliffs, the main hazard has been estimated as the combination of the susceptibility to the occurrence of instability in the face of the cliff with the extension of the risk strips that are delineated from the cliff crest landwards. This hazard is particularly relevant in Alcobaça, Óbidos, Lourinhã, Sintra and Sesimbra. The existence of consolidated urban centres near the crest of unstable cliffs, and the recent urban expansion to adjacent areas, constitute some of the main vulnerabilities of the territory ACE (there are 27 km of urban fronts located in such ‘risk strips’) (POC-ACE 2018, p.27).

According to the scheme of sediment cells of the GTL Report (GTL 2014), the coastal zone ACE encompasses: part of the Sub-cell 1c (Cabo Mondego-Nazaré), Cell 2 (Nazaré-Peniche), Cell 3 (Peniche-Cabo Raso), and Cell 4 (Cabo Raso-Cabo Espichel). The most problematic situation is located in Cell 4. The Cell 4 is divided in three sub-cells: 4a (Cabo Raso-Carcavelos), 4b (outer estuary of Tejo, including the coast of Caparica), and 4c (Costa da Caparica-Cabo Espichel) (POC-ACE 2018, p.27, 40). Since the 1940’s, the sandbank of Bugio in the mouth of Tejo River and the estuary channel have suffered sediment extractions and dredging works, with an unknown total magnitude, but probably around several millions of m^3, and the sediment deficit generated has not been fully compensated. Therefore, the ‘*sediment redistribution continuously occurring within the sub-cell 4b has propagated the sediment deficit to the entire Cell 4 and has originated a regressive behaviour that can be observed in most beaches of Costa da Caparica*’ (POC-ACE 2018, p.27, based on GTL 2014).

The POC-ACE (2018, p.27, based on Pinto et al. 2007) mentions that between 1999 and 2007, the shoreline between Cova do Vapor and São João da Caparica has retreated nearly 26m (3,3m / year), reached 42m in the northern sector (and in the dune chain at the south of the beach Búzio Bar it retreated around 31m in 2002-2007). Veloso-Gomes et al. (2007) note that from 2000 onwards, the stretch Cova do Vapor-Costa da Caparica was strongly affected by serious sediment losses, particularly in the beach of São João da Caparica (where the sandbar has migrated landwards and the urban forefront is directly exposed to sea action, especially during storms) (POC-ACE 2018, p.28). The tendency of retreat (regression) of the shoreline now observed, and visible in the beaches of Costa da Caparica, in the sandbar that extends westwards, and in the disappearance of the Bugio sandbank, can be explained by the sediment redistribution that continuously occurs in the outer estuary of Tejo (POC-ACE 2018, p.28).

Although several operations of sediment nourishment have been carried in the beaches, they have not reduced the sediment deficit because the sediments nourished have been obtained from this stretch itself (e.g. from the mouth of the Tejo river), but have contributed to reduce coastal risks in this area. There have been exchanges of sediments of great magnitude between the submerged part and surface part of the beaches in Costa da Caparica. In general, the sediment nourishments have mitigated the negative impacts caused by storms on the shoreline and built-up areas located on the coast (especially when compared with the damages that would have been caused if such interventions had not been carried) (Pinto et al. 2007, *in* POC-ACE 2018, p.28).

According to the POC (based on GTL), the inversion of the erosive behaviour (namely in the sediment cell 4) may be achieved by reducing the sediment deficit through sediment nourishments with sand extracted from 'borrow sites' outside the outer estuary of Tejo (POC-ACE 2018, p.28, 179).

The coastal zone ACE is subjected to diverse drivers of pressures, namely anthropic pressures[53]. The increasing occupation and artificialization of the coastline and the reduction of the volume of sediment transported by the littoral drift, have contributed to the degradation of coastal biophysical systems. These pressures will tend to aggravate with the effects of climate change, namely with SLR and potential changes in the storm patterns and wave climate (POC-ACE 2018 d, p.55).

Anthropic and urban pressures

The zone ACE is one of the coastal stretches with highest urban concentration of the country, and it is subjected to strong pressures for constructing (associated to the metropolitan context, urban and touristic dynamics). Several areas of the territory ACE present high vulnerability to coastal erosion, in low-lying sandy stretches and in cliffs (POC-ACE 2018, p.33).

During the last decades, the population living in coastal settlements has increased in the area ACE (127347 residents in 2011), and the value of economic assets located up to 500 m from the coastline has increased even more; many of such assets might be affected in the mid-term due to evolving coastal dynamics, namely shoreline retreat (regression) in low-lying sandy littoral and in cliff littoral, and the increase in the intensity and dimension of sea overtopping inundations and floods (POC-ACE 2018, p.90). There are strong demographic pressures in some at-risk areas (POC-ACE 2017, p.81).

BOX 10. The coastal system between Alcobaça and Cabo Espichel is mostly composed of cliffs and inserted sandy beaches. In the stretch at the north of Lisbon, the human influence in the processes of sediment supply and transport in the littoral is not significant. In this sector, the current sediment balance is slightly lower than the existent in the past (with no significant alterations). The eventual reduction in the quantity of sediments that are supplied to this littoral is related with the construction of dams and other human interventions in waterlines (POC-ACE 2018, p.37). In the stretch at the south of Tejo river, the littoral has an arched shape and forms a continual sandy coast from Costa da Caparica to the beach Praia das Bicas; from Praia das Bicas southwards, the littoral adopts a cliff shape (POC-ACE 2018, p.73). The sector Cova do Vapor-Costa da Caparica poses the biggest challenges in terms of coastal protection (it is the main critical zone of the POC-ACE) (POC-ACE 2018, p.37). Given the vulnerability and the regressive evolution of this sector, in the late 1950's and early 1970's several coastal defence works were built, e.g. the groynes of Costa da Caparica. Such structures allowed *holding* the shoreline in a relatively stable position until the beginning of this century, although there has been a continual loss of sediments between the groynes and a structural degradation of these defences. After the year 2000, the beaches and dunes in this sector were seriously affected, which led to emergency interventions in the winters of 2002/2003, 2006/2007, and 2014. This sector absorbed nearly 18,4% of the investments in coastal defence carried in Portugal between 1995 and 2014. The sediment loss, which is particularly relevant in the beach of São João, has led to sea overtopping events with impact on touristic and beach supporting facilities along the beach front (POC-ACE 2018, p.37).

---

[53] Over the last decades, there has been a high pressure for constructing, which reflected in the expansion of urban settlements, the consolidation of urban continuums, and the proliferation of built-up areas in rural areas. The network of urban settlements in presents, in some cases, a deficient urban planning under strong construction pressures, which led to the fragmentation of ecological corridors and urban space, emergence of illegal housing settlements, predominance of holiday houses with seasonal occupation, strong car flows during high season. Moreover, the contiguity of some urban areas with beaches and cliffs contributes to the high vulnerability of the seafronts (POC-ACE 2018 d, p.69). The area ACE encompasses the Atlantic seafront of the Metropolitan Area of Lisbon, and its maritime beaches have a high demand (they are one of the main economic resources). The attractiveness of the beaches has consolidated due their diversity, singularity, aptitude for sports and the improvement of the conditions of bathing utilization, which resulted from the Plans of Beaches of the prior POOCs (POC-ACE 2018 d, p.66).

Climate change effects in coastal risks

According to the POC, the coast ACE is particularly vulnerable to the effects of climate change, namely SRL and the potential increase in the frequency and intensity of extreme weather events (POC-ACE 2017, p.73). Climate change effects and extreme weather events are expected to lead to an increase in the magnitude and frequency of sea overtopping inundations and coastal floods (associated to storms), and coastal erosion (POC-ACE 2017, p.167, 81).

In the cliff sectors, there is a strong probability of occurrence of mass movements (landslides), and the existence of buildings near unstable cliffs poses great challenges to coastal management, namely in the coast at the North of the mouth of Tejo river, where it is expected an acceleration of the erosive processes due to the effects of climate change (POC-ACE 2018 d, p.51).

The low-lying sandy littoral has suffered strong erosive process and presents a high vulnerability to sea overtopping inundations and floods, which has been exacerbated by the strong human occupation of strips at risk in the mid- and long-term. It is expected an aggravation of such coastal risks due to climate change effects, namely SLR, and changes in storm patters and wave regimes (e.g. potential increase in the frequency and intensity of storms and alterations in wave / storm routes) (POC-ACE 2018 d, p.51).

Importantly, the occupation of the littoral is subjected, *per se*, to risks associated to coastal dynamics, which, under climate change and its effects, will likely lead to the aggravation of the levels of hazardousness and impacts, for example, through the amplification of consequences and a greater periodicity (frequency) of extreme weather events (POC-ACE 2017, p.62).

<u>SLR:</u> Given the deep uncertainties around the future projections of SLR, the POC-ACE has initially considered two scenarios of SLR for 2100 – a scenario of 0,50m, and an extreme scenario of 1,5m – and for the time-horizon of 2050, a plausible SLR of 0,30m in relation to the level of 1990 (POC-ACE 2018, p.38). Later, for the projection of the future erosion and sea overtopping inundations and floods, and generation of scenarios for such coastal risks for 2050 and 2100, the POC-ACE has assumed a value of SLR of +0,30m (for 2050) and +1,50m (for 2100) (POC-ACE 2017, p.73).

The population in coastal settlements, and a significant part of the built assets located in the coastal zone, will be potentially affected in the mid-term due to the evolution of coastal dynamics, namely by the retreat (regression) of the shoreline in low-lying sandy littoral and cliff littoral, and by the increase in the intensity and frequency of sea overtopping inundations and floods. The evolution of these phenomena will require interventions increasingly costly, regardless of the form of intervention used. The studies carried in the Phase of Characterization of the POC-ACE demonstrated that coastal erosion problems, as well as the exposure to coastal risks, have had an increasing magnitude in the area of intervention, and will tend to aggravate due to the effects of climate change in weather and oceanographic conditions (POC-ACE 2018, p.90).

Analysis of the sediment balance (deficit) in the coastal zone ACE

As mentioned, the GTL developed a scheme of sediment cells of the mainland Portuguese coast, and for each cell, it calculated the sediment balances correspondent to a reference situation and the current situation, through the quantification of the entrances (sources) and exits (sinkholes) of sediments, and represented them in Figures (POC-ACE 2018, p.40) (see Note 303). The GTL analysis of the sediment balance in the area of intervention of the POC-ACE, showed that:

- In the sub-cell 1c (which includes the littoral between Alcobaça and Nazaré), the littoral drift coming from North is the main source of sediments (1,1 Mm^3/year), which are totally captured by the Nazaré underwater canyon (1,1Mm^3/year). Thus, the sediment volume transported along this coastal cell (11x10^5 m^3 / year) was entirely subtracted to the littoral system in the Nazaré canyon.

- In the cell 2 (Nazaré-Peniche), the littoral drift has a null result. The sediment supply is reduced (nearly 10^4 m^3/year) and associated to the erosion of the littoral cliffs and the solid flow of rivers; the main sinkholes are the lagoon Lagoa de Óbidos and the dune system of Peniche (with a magnitude similar to the sources). Hence, this system is relatively stable (anthropic influence is not significant).
- In the cell 3 (Peniche-Cabo Raso), there is a deficit of sediments. The main sediment sources are coastal waterlines, and the main sinkhole is the dune system of Guincho (POC-ACE 2018, p.42).
- In the cell 4 (Cabo Raso-Cabo Espichel), the littoral drift converges to the outer estuary of Tejo. Cell 4 contains three sub-cells: 4a (Cabo Raso-Carcavelos), 4b (outer estuary of Tejo and the littoral of Caparica) and 4c (Costa da Caparica-Cabo Espichel). According to the GTL, in the reference situation, the wind corridor of Guincho was responsible for most of the sediment supply to this coastal stretch, and from this stretch to the outer estuary of Tejo. In that situation, this stretch was in accretion. However, since the 1950's, the sediment supply to this sector associated to the wind corridor of Guincho-Oitavos has been practically inactive. Thus, the beaches of Estoril, which are closed systems, present a littoral drift that is almost null. Moreover, since the 1940's, there have been numerous sand extractions and dredging operations in the Bugio sandbank and Tejo entrance, with an unknown total magnitude (probably several millions of m^3), which led to an enormous sediment deficit that was not compensated. Thus, '*the sediment redistribution that continuously occurs within the sub-cell 4b has propagated the sediment deficit to the entire cell and led to the regressive behaviour that is currently observed in the beaches of Costa da Caparica*' (POC-ACE 2018, p.45).[54]

Within the area ACE, there is a sediment deficit in some coastal stretches, namely between Peniche and Cabo Raso and in the field of groynes of Costa da Caparica. In some zones, there is a retreat (regression) of the shoreline, and sea overtopping inundations and floods associated to coastal storms have occurred and are expected to aggravate. According to the POC, the urban settlements at greater risk are: Azenhas do Mar, Facho, Areia Branca, Porto Dinheiro, Pedra do Ouro, Praia da Areia Branca, sandy Peniche, Paredes de Vitória, Salgado, Consolação, Costa da Caparica, Fonte da Telha, Cova do Vapor. The area between Cova do Vapor and Costa da Caparica, and the urban forefront of Costa da Caparica, present a high susceptibility to coastal risks (critical situations). The Team estimated that the retreat of the shoreline for 2100 in the urban forefront of Costa da Caparica will be 251m (POC-ACE 2017, p.81). The POC recognizes the difficulties in predicting the future alterations of the shoreline due to the complexity of the involved phenomena and the uncertainty associated to future climatic scenarios (ibid).

The strong anthropic pressures on coastal biophysical systems and the increasing demand for beaches in the ACE area, and, at the same time, the existing sediment deficit and the expected effects of climate change, namely SLR, make some zones extremely vulnerable to coastal risks (POC-ACE 2018 d, p.66).

[54] As mentioned, the GTL divided the mainland coast into sediment cells. The area of intervention of the POC-ACE includes: the sub-cell 1 (Cabo Mondego-Nazaré), cell 2 (Nazaré-Peniche), cell 3 (Peniche-Cabo Raso), and cell 4 (Cabo Raso-Cabo Espichel). The cell 4 is considered a critical stretch; the erosive problems in this stretch, namely in Costa da Caparica, are related with the sediment deficit resultant from extractions of sediments of great volume carried since the 1940s. In addition to the problem of erosion, there is an increasing risk of inundation / flooding caused by the recent urban occupation in low-lying zones (POC-ACE 2018 d, p.179).

1.2. Principles upon which the POC-ACE was based

The POC-ACE was elaborated based on the principles set in the Decree-Law nº 159/2012, namely the principles of 'sustainability and intergenerational solidarity', 'cohesion and equity', and 'prevention and precaution' (POC-ACE 2018, p.33-34).

The principle of **'sustainability and intergenerational solidarity'** was assumed as central. According to the POC, the zone ACE is one of the stretches of the national coast where an integrated coastal management poses greater challenges, in terms of compatibilization of uses and activities with the protection and valorisation of ecosystems and of delivery of a precautionary approach in the face of coastal risks (POC-ACE 2018, p.33,14). For the POC, the introduction of a greater resilience in this coastal zone requires the preservation and amplification of the environmental services and ecological functions of the natural systems, coupled with the maintenance of social and economic functions, and a developmental model aimed at the contention of land use and transformation (POC-ACE 2018, p.33). Thus, this principle implies promoting the compatibilization between socioeconomic development and conservation of nature, biodiversity and geodiversity, in a framework that fosters the quality of life of the future and current coastal populations (POC-ACE 2018 a, p.15).

Regarding the principle of **'cohesion and equity'**, the POC seeks to seize different opportunities that might emerge in each territory (to ensure the adequacy and suitability of generalized solutions to local specific situations) and deliver a multi-level coastal governance that involves all relevant actors in the reduction of current and future vulnerabilities. This principle must be ensured by the various government levels, namely with regard to the relocation (planned retreat) of urban areas at risk (which may have implications for areas outside the coastal zone ACE) and the policy of sediment management (the most adequate 'borrow sites' may be located outside the area of intervention) (POC-ACE 2018, p.34).

This principle involves ensuring social and territorial balance, and a shared accountability of society, institutions and local actors for coastal management, and implementing a multilevel governance model based on subsidiarity, interinstitutional cooperation and evaluation of results (POC-ACE 2018 a, p.15).

For the POC, the principle of **'prevention and precaution'** involves predicting and anticipating problems, adopting a cautionary attitude in the face of the deficit of knowledge or insufficient capacity of intervention, and minimizing risks and negative impacts (POC-ACE 2018 a, p.15). The area of intervention encompasses quite diverse situations in terms of risks for people and assets, e.g. the risk of coastal erosion is more relevant in the sector 'Cova do Vapor-Fonte da Telha' (which is more exposed to the progression of the sea, and the current vulnerability of this sector is expected to aggravate due to climate change effects, namely SLR and changes in storm routes and intensity) (POC-ACE 2018, p.34). The POC assumes that coastal adaptation must be a priority, and it should allow future generations to become more able to choose the most suited adaptation solutions. In the face of a progressive increase of risks (due to climate change and existing and future anthropic pressures), the options regarding land use and land occupation should ensure that future generations are not faced with greater complexity. According to the POC, it is urgent to adopt measures of adaptation to coastal phenomena and extreme weather events that allow next generations to opt between the continuation of an approach of protection of coastal settlements or the removal of buildings (planned retreat). Moreover, the minimization of risks, namely the risk of sea overtopping, must include an approach of coastal protection based on sediment management and on the recovery of the sediment profile of the shoreline, which will require solutions that go beyond the area of intervention of the POC (such as re-establishing the sedimentary cycle based on hydrographic basins or in 'borrow sites' outside the *Maritime Protection Zone*, or defining areas for the relocation of uses and occupations existent in high-risk zones) (POC-ACE 2018, p.34-35).

The Program of Actions is guided by the principles of the POC-ACE (POC-ACE 2018 a, p.15).

1.3. Strategic Model of the POC-ACE: *Vision*, General Objectives, and Specific Objectives

The Strategic Model of the POC-ACE defines a *Strategic Vision* (which is based on the strategic principles), four Strategic Sectoral Objectives that are subdivided into specific objectives (i.e. *Strategic Lines*), and two Strategic Transversal Objectives (POC-ACE 2018, p.35; 2018 d, p.30) (Figure 32).

STRATEGIC MODEL OF THE POC-ACE

VISION

A coastal zone prepared for climate change and for a fruition in safety, with a preserved natural, landscape and cultural heritage, with a good state of water bodies, and which promotes developmental opportunities based on the differentiation and valorisation of territorial resources and on the capacity to competitively and sustainably harnessing terrestrial, marine and maritime potentials.

STRATEGIC PRINCIPLES

PREVENTION AND PRECAUTION

Predict and anticipate problems, by adopting a cautionary attitude in the face of knowledge deficit or insufficient capacity of intervention, and minimizing risks and negative impacts.

SUSTAINABILITY AND INTER-GENERATIONAL SOLIDARITY

Promote the compatibilization between socioeconomic development and the conservation of nature, biodiversity and geodiversity, to foster the quality of life of current and future populations

COHESION AND EQUITY

Ensure the social and territorial equilibrium and balanced distribution of resources and opportunities among the diverse social and generational groups and territories.

PARTICIPATION AND SHARED RESPONSABILITY

Boost the involvement and shared responsibility of society, institutions and local actors in coastal management, implement a multi-level governance model, based on subsidiarity, institutional cooperation, & result evaluation

STRATEGIC SECTORAL OBJECTIVES

COASTAL RISKS

OS1. Prevent and reduce coastal risks and the vulnerability to climate change.

NATURAL VALUES

OS2. Ensure the protection and conservation of natural and landscape heritage.

HYDRIC RESOURCES

OS3. Promote the protection of hydric resources and ensure the objectives of water quality.

COMPETITIVENESS

OS4. Promote the economic competitiveness of the coastal zone based on the sustainable utilization of territorial resources.

STRATEGIC SECTORAL LINES / SPECIFIC OBJECTIVES

LE1.1. Ensure the preservation of the current shoreline based on the re-settling of sediment balance existent in a natural regime.

LE1.2. Ensure the preservation of 'borrow sites' and the utilization of sediments dredged from port channels, sandbars and access channels, for the nourishment of beaches.

LE1.3. Contain the territorial exposure to coastal risks, by establishing regimes of safeguard for the 'risk strips', in a mid- and long-term perspective.

LE1.4. Promote the planned adaptation of urban settlements to coastal erosion, sea overtopping inundations and floods.

LE1.5. Ensure the public fruition of Public Mariti. Domain in safety.

LE2.1. Protect the dune ecosystems and cliffs, by preserving the natural heritage and geodiversity of the coastal zone.

LE2.2. Protect and valorise the marine habitats and the coastal lagoon systems.

LE2.3. Promote the valorisation, recovery, and rehabilitation of coastal ecosystems.

LE2.4. Protect and value the character and identity of the coastal landscapes.

LE3.1. Ensure the quality of coastal bathing waters.

LE3.2. Contribute to the good state of water bodies by reducing or eliminating the impacts through an adequate management of pressures.

LE3.3. Promote the valorisation and protection of coastal lagoons, by complying with the objectives set for sensitive areas in the Water Law.

LE3.4. Promote a sustainable utilization of water, based on a long-term protection of the available hydric resources.

LE4.1. Ensure conditions for the development of port activity.

LE4.2. Ensure the preservation of soil and the valorisation of agricultural and forest heritage.

LE4.3. Promote the sustainable exploitation of marine resources.

LE4.4. Promote the valorisation of touristic resources of the coastal zone and the qualification of touristic destinations.

STRATEGIC TRANSVERSAL OBJECTIVES

BEACHES

OT1. Valorise and qualify the maritime beaches as a natural, social and economic resource

LE5.1. Ensure the preservation of beaches, dune systems and associated cliffs, and surrounding spaces.

LE5.2. Ensure the safety and protection of users and beach supporting facilities.

LE5.3. Improve the quality of access and reception of users, namely the users with conditioned mobility.

LE5.4. Ensure the control of flows and the promotion of soft transport modes in the access to beaches.

LE5.5. Promote a flexible and adaptive management that allows responding with efficacy to environmental, social and economic changes

MONITORING, EVALUATION, AND INTEGRATED MANAGEMENT

OT2. Ensure a multilevel, participated, and proactive governance of the coastal zone, based on monitoring and evaluation processes

LE6.1. Ensure the regular and systematic monitoring of the sediment dynamics of the coastal zone, of the evolution of the shoreline, and of the performance of coastal protection / defence works.

LE6.2. Reinforce the technical, institutional, and operational cooperation between entities with jurisdiction of the coastal zone management, scientific entities, and civil society.

LE6.3. Promote research and the development of new approaches of coastal protection and integrated management of the coastal zone.

LE6.4. Promote the technical training and the provision of tools to support local coastal planning and adaptation to climate change.

LE6.5. Raise awareness of coastal communities and visitors on the sensitivity and importance of coastal ecosystems, and on the need of adopting a cautionary behaviour in the face of risks & climate change

Figure 32. The Strategic Model of the POC-ACE. Source: translated from the POC-ACE 2018, p.36, and POC-ACE 2018 d (Directives), p.30. See Note 346.

The *Strategic Vision* was delineated based on the Prospective Diagnostic, the principles of integrated management defined in the ENGIZC, the recommendations of the GTL Report (which were addressed through the definition of a range of measures to minimize the exposure to risk, under scenarios of climate change), as well as the guidelines set in the PNPOT for the Metropolitan Area of Lisbon and the region of Oeste and Vale do Tejo (POC-ACE 2018, p.35; 2018 a, p.22) (see Note 343). Then, the POC Team defined the Sectoral and Transversal Objectives, and their respective Specific Objectives, based on the reference principles and on the proposed Strategic Vision. These Objectives guide the POC's Territorial Model, normative content, and Program of Actions (which lists the main investments to be taken in the next decade) (POC-ACE 2018, p.36). The Objectives will be delivered through the POC's Territorial Model and associated normative content, namely through the definition of the regimes of safeguard and Critical Areas (and their respective delimitation), and through the implementation of interventions programmed in the Program of Actions (POC-ACE 2018 d, p.29).

Regarding the **Sectoral Objective 1 (OS1)**, the main challenges identified by the POC are:

- To reduce the high vulnerability to coastal erosion, namely in the sector between Cova do Vapor and Fonte da Telha, and promote the stabilization of the shoreline where the sediment losses have led to situations of retreat (regression) of the shoreline and sea overtopping floods with great impacts.
- To contain the erosive behaviour of the stretches with greater sediment deficit, and balance the system through sand nourishments with sand extracted from 'borrow sites'.
- To improve the management of the policy of sediments, in line with the GTL recommendations, by promoting an enhanced knowledge of the territory and the harnessing of adequate borrow sites (located outside the area of intervention of the POC) and the most effective transport to beaches.
- To promote a culture of precaution that ensures a greater efficacy in the contention of land use and occupation in the areas of risk, through the adoption of a discipline of spatial planning highly restrictive on the conditions for construction in vulnerable areas in cliff littoral or low-lying sandy littoral.
- To increase the articulation between the drivers of climatic and geological risk and the land uses and occupations, with the aim of mitigating risks and assuring greater protection of people and assets.
- To implement strategies of adaptation of climate change in the more vulnerable stretches, namely built-up areas that present a higher level of exposure, and prepare the territories for the future vulnerabilities and for an aggravation of the exposure associated to SLR.
- To eliminate informal car parking areas at the top of cliffs, namely instable cliffs, and ensure the reduction of drivers of erosion in cliffs and the recovery of vegetation.
- To ensure a regular monitoring of the cliffs and beaches, to allow an improved knowledge of the evolution of the territory and support a proactive approach that mitigates risks and increases the capacity of protection of people and assets in the areas with greater vulnerability.
- To improve knowledge on the climatological and geomorphological situation of the area ACE, and ensure the monitoring of the climatic phenomena to delineate timely and adequate responses to risk.
- To promote new opportunities generated by the restrictions associated to geological and climatological phenomena and to the sensitivities and dependencies of the lagoon systems (POC-ACE 2018, p.45).

Component of the POC	Strategic approach
Strat. Model	OS1 and its specific objectives (i.e. *Strategic Lines*)
Territorial Model / Normative	Define in the Territorial Model the spaces with greater exposure to coastal risks (coastal erosion, sea overtopping inundations and floods) in cliff littoral and low-lying sandy littoral, through the definition of Strips of Safeguard that consider the current exposure but also the evolution in the mid-term (50 years) and long-term (100 years) of erosive phenomena. Define in the Territorial Model, in the Maritime Zone of Protection (ZMP), strategic areas for sediment management where there are borrow sites of sediments with adequate characteristics for the re-setting of the sediment balance of beaches. Define, in function of the Risk Strips and the planning options in force, the artificialized areas in situation of great vulnerability that must be subjected to interventions of planned retreat and subsequent recovery of natural systems. Define the framework of action of the Administration for mitigation of coastal risks and management of sediment resources.

	Define the regime of restriction of the use and occupation of soil for the Strips of Safeguard from Coastal Erosion, Strips of Safeguard from Sea Overtopping Inundations and Floods, Strips of Safeguard in Cliff Littoral (including the Strips of Safeguard towards the Sea, the Strips of Safeguard towards the Land Level I and Level II), and Areas of Potential Instability, that deliver the objectives of reduction of exposure to risks.
Model of Intervention	Program interventions for the protection and natural defence of the urban forefronts with greater exposure to coastal erosion, sea overtopping inundations and floods, namely beach nourishment (maintenance of the width of sandy area). Program interventions that promote a greater sediment equilibrium and a greater efficacy of the natural sediment dynamic, namely through the dredging and transportation of sediments to beaches. Program interventions of planned retreat of public facilities and houses located in areas of high susceptibility to risk. Program interventions that promote the function of protection of existing coastal defence structures, namely through the maintenance and improvement of such structures.

Table H. Integrated and strategic approach for the safeguard from coastal risks. Source: POC-ACE 2018, p.46.

For more on the **Sectoral Objectives OS2**, **OS3**, and **OS4**, see Note 344.

Regarding the **Transversal Objective OT1**, some challenges identified by the POC are (see Note 345):
- To ensure the compatibilization of the uses and occupations of sandy areas and *the flexible and adaptive management of maritime beaches*, with the strategy of sediment management, namely with protection interventions based on the preservation or reinforcement of beaches and dune systems.
- To promote an increasing flexibility in the forms of occupation of the Hydric Domain, through the creation of soft, removable, or modular structures that are better adapted to extreme weather events.
- To deliver a policy of integrated sediment management that seeks to re-establish the sediment balance in natural regime and favours beach nourishment as a protection strategy (POC-ACE 2018, p.69).

Regarding the **Transversal Objective OT2**, some challenges identified by the POC are (see Note 346):
- To reinforce the analysis and assessment of coastal risks at national and municipal scales, to ensure the prevention and mitigation of risks, safety of populations and greater resilience of territories.
- To monitor, evaluate and concretize an integrated management of coastal risks, which requires considering scenarios of climate change and for time-horizons of mid- and long-term, in a rationale of preventive actuation that accounts for the vulnerabilities and potentialities of the coastal zone and its environmental values, including the regular and systematic monitoring of the sediment dynamics, of the evolution of the shoreline and of the performance of the coastal defence / protection works.
- To develop actions of education on the environment and sustainability and that reinforce the awareness of risks and the adoption of safe behaviours.
- To integrate, in the spatial planning instruments in force, the identification and characterization of areas of risk and vulnerable areas, and typify the mechanisms of safeguard, in accordance with the principles, vision and directives of the POC-ACE.
- To assess the sedimentary needs of the stretches that require nourishment, volumetry, characteristics.
- To assess, in articulation with Port Administrations, the existence of dredging deposits that meet the sedimentary conditions required for nourishing beaches or zones of the Terrestrial Zone of Protection.
- To ensure the monitoring of coastal systems, biotic communities, and environmental quality.
- To increase the knowledge on the marine ecological structure, namely in the scope of process of characterization and classification of new protected areas, and valorisation of subaquatic landscapes.
- To promote good practices in the traditional regional economic activities, such as local fishing.
- To promote the intermunicipal articulation with the aim of maintaining the landscape and economic value of the areas with notable landscapes that encompass more than one municipality.
- To promote the sustainable use of the soil in the hydrographic basin, by preventing problems stemming from the impermeabilization of soil, the increase in drained outflow, the aggravation of floods, erosion, and sediment transport to waterlines, and ensure the safeguard of people and assets.
- To ensure the compatibilization of the vocations of port areas with other uses and activities of the area of intervention, and the protection of hydric resources (POC-ACE 2018, p.74).

2. THE APPROACH OF *ADAPTIVE PLANNING AND MANAGEMENT* PROPOSED BY THE POC-ACE

The POC-ACE also sought to adopt an approach of '*adaptive planning and management*'. According to the POC itself, it is important to develop an '*adaptive planning*' – i.e. '*a planning more adaptive to the contextual changes and that accounts for the variability of phenomena and situations which the Plan will be faced with*' (POC-ACE 2018, p.92).

As mentioned, in a recent interview, the APA's President claimed that the new POCs have assumed '*a new stance regarding the planning of the littoral by aiming to ensure a governance and management that are continual in the face of the acting coastal dynamics (which are uncertain)*', and have adopted '*a new approach of integrated and adaptive management of the coastal zone, and have proposed more suited solutions (of prevention, protection, accommodation or planned retreat) according to the current situation and the expected future dynamics*'(CEZCM / APRH 2020). Given the characteristics of the coastal zone, and its vulnerability to SLR, '*the principles of prevention and precaution were taken as central and strategic for the definition of the model of adaptive planning and management that constitutes the trademark of all new POCs*'. Moreover, '*a continual management of the littoral requires specialized scientific and technical knowledge and a monitoring system able to share information and support decision-making at national, regional and local levels*' (CEZCM / APRH 2020).

Importantly, the POC-ACE has sought to deliver the strategic objectives set by the DL nº159/2012 for the elaboration of the new POCs, among them, '*promoting the sustainable development of the coastal zone through a prospective, dynamic, and adaptive approach*', and the ensuring the '*flexibilization of the management measures*' (POC-ACE 2018, p.21).[55] Furthermore, the Spatial Plan for the Maritime Space (*Plano de Ordenamento do Espaço Marítimo*), which served as a reference for the elaboration of the POC-ACE, already aimed at ensuring an integrated planning and the adaptive management of the uses of the maritime space in close articulation with the management of the coastal zone and instruments of coastal spatial planning (POC-ACE 2018, p.177).

Moreover, during the process of elaboration of the POC-ACE, the Strategic Environmental Assessment – SEA (POC-ACE 2017) has identified issues that the POC should address (challenges for its elaboration according to the objectives set in the legal framework, namely in the DL n.º 159/2012), among them: '*establishing the regime of safeguard for the strips of risk (prevention of situations of risk) in the face of the diverse uses and occupations of the coastal zone*'; ensuring the '*flexibilization of the management measures for adaptation to the inner dynamic of beaches*', and fostering '*a prospective, dynamic, and adaptive approach that boosts its competitiveness as a productive space that generates wealth and employment*' (POC-ACE 2017, p.58, 66, 77, 101). For the SEA, to '*develop an adaptive management in the face of territorial dynamics*', it is necessary to promote (enhance) the articulation between the various actors involved in the coastal zone (POC-ACE 2017, p.153, 160).

The aim of following an *adaptive management approach* is stated in the POC's Strategic Model, in specific in the '*Strategic Transversal Line LE5.5 – Promote a flexible and adaptive management that allows responding with efficacy to environmental, social, and economic changes*' (POC-ACE 2018, p.36, 145). In this Line, important challenges identified by the POC are '*to ensure the flexible and adaptive management of the maritime beaches*' and '*to promote an increasing flexibility in the forms of occupation of the Hydric Domain*' (POC-ACE 2018, p.69).

[55] The elaboration of the new POCs, as instruments of spatial planning for the coastal zones, is regulated by the Decree-Law n.º159/2012, which defines the principles to be observed in the management of the coastal zone (sustainability and intergenerational solidarity, cohesion and equity, prevention and precaution, subsidiarity, participation, shared accountability, and operationality). The prosecution of such principles materializes in the concretization of six general objectives of the POC-ACE (*in* POC-ACE 2018 d, p.11).

Despite the aim of pursuing an '*adaptive planning and management approach*', the POC-ACE does not provide more details on, nor further explanations, of such approach, on what it entails and how to carry it. Moreover, it is not explicitly mentioned that the POC should be a *dynamic adaptive programme* (containing *robust flexible strategies*), as a pre-requisite that could have been previously set for the Programme. However, an in-depth analysis of the various documents of the POC showed that it contains references to an '*approach of adaptive planning and management*', as well as references to aspects related with the key-elements identified in Part A as essential in an Adaptive Planning approach for developing an *adaptive plan / strategy*. Some of these references are outlined bellow:

- The Directives state *'the aim of developing a proactive adaptive management of* (urban) *settlements, which must ponder* the option of *planned retreat supported by cost-benefit analyses* (POC-ACE 2018 d, p.71).
- The Norm NG1 on coastal risks calls for the adoption of '*a vision of local development the takes into consideration the principle of precaution, and in which the definition of land uses and occupations in the coastal zone pays due attention to the future vulnerabilities and threats associated to the erosive processes and the expected SLR, supported by climatic scenarios*' (POC-ACE 2018 d, p.53). This is related with the Key-element 1 (scenarios).
- The Norm NG1 also underlines that it is important to '*ensure the monitoring, assessment, and integrated management of coastal risks, and consider scenarios of climate change for time-horizons in the mid- and long-term, in a rationale of preventive action that accounts for the vulnerabilities and opportunities of the coastal zone and its environmental values*' (POC-ACE 2018 d, p.53). This is related with the Key-element 4 and the Key-element 1.
- The Norm NG14 on urban settlements (Directives) mentions that it is mandatory to '*ensure that the urban planning considers the vulnerabilities stemming from climatic scenarios of mid- and long-term and responds not only to the current needs, but also to future challenges, by not allowing the aggravation of the exposure to risks*' (POC-ACE 2018 d, p.70). This is related with the Key-element 1 (scenarios) and the Key-element 2 (not allowing the aggravation of risks).
- The Norm NG12 on maritime beaches (Directives) refers the need of ensuring '*an integrated and adaptive management that goes beyond, in spatial and operational terms, the scope of action of the Plans of Intervention on Beaches and the area of the Hydric Domain*', it implies '*the compatibilization of the uses and occupations of the sandy area, and of the flexible adaptive management of maritime beaches, with the strategy of sediment management envisioned for the national coastal zone, namely with interventions of coastal protection involving the reinforcement or preservation of beaches and dune systems*' (ibid, p.66-67).
- Regarding coastal urban settlements, the POC advocates that it is '*indispensable to promote a sustainable planning of the coastal settlements by integrating key principles of adaptability, namely: flexibility, to follow the annual climatic cycle; reversibility, by anticipating the development of the littoral in the long-term and envisaging anticipated hypotheses of relocation; sobriety, by grasping the limitations of responses in the face of the dimension of the challenges brought by the coastal geo-system; and ingenuity, by incorporating into urban development the rationale of adaptation of natural systems*' (POC-ACE 2018 d, p.69).
- The POC argues that the exercise of '*scenarization*' (development of *scenarios of intervention*, i.e. adaptation strategies) is quite useful in spatial planning, '*as a tool to support decision-making in the short-term, as a model that ensures that the options taken in the present do not jeopardize future generations and opportunities existent or emergent in the territory, and as an instrument of support to a planning that is more adaptive to contextual changes*' (POC-ACE 2018, p.92). This relates with sub-elements of Key-element 3.
- The Program of Actions mentions that the POC's governance model aims to deliver '*a strategic, proactive management of the coastal zone*' supported by a 4-year monitoring of the Programme and of the coastal zone (POC-ACE 2018 a, p.12; 2018, p.160, 145). Such monitoring is essential for the regular evaluation of the Program of Actions and '*to ensure a strategic, planned adaptive management of the coastal zone*' (ibid). This is related with the Key-elements 4 and 5.

3. Content of the POC-ACE

In line with the Decree-Law n.º80/2015 and the Decree-Law n.º159/2012, the POC-ACE is composed of the following elements (POC-ACE 2018, p.14):

c) Directives (*Directivas*).
d) Territorial Model (*Modelo Territorial*), i.e. the spatial representation of the Directives.

Complementarily, the POC contains the following documents (POC-ACE 2018, p.14; 2018 d, p.33):

v) Report of the Programme (*Relatório do Programa*)
vi) Program of Actions including the Financing Plan (*Programa de Execução*)
vii) Environmental Report (*Relatório Ambiental*)
viii) Qualitative and quantitative indicators to support the evaluation of the Programme.

3.1. Territorial Model

The Territorial Model of the POC reflects the spatialization of the strategy of sustainable development defined for this territory, and it seeks to deliver the *Vision* and *Strategic Objectives* of the Programme (POC-ACE 2018, p.79).

The Territorial Model of the POC-ACE includes two different zones in the area of intervention:

- **Maritime Protection Zone** (*Zona Marítima de Protecção – ZMP*). It encompasses the entire maritime space within the area of intervention. It is the zone where the compatibilization between the preservation of resources with ecological relevance and the development of specific economic activities requires the establishment of regimes of protection that safeguard the quality of the hydric resources, preserve the marine ecosystems, and allow the concretization of the strategy of sediment management essential coastal protection (e.g. at the south of Tejo mouth) (POC-ACE 2018, p.79). The Maritime Protection Zone corresponds to the strip between the limit of the seabed and the bathymetric of 30m (POC-ACE 2018 d, p.36). The spatialization of measures of protection in this Zone aims to ensure the protection of the marine environment, ensure the good state of coastal and territorial water bodies, including the prevention and elimination of marine pollution, and ensure the preservation of spaces of biological productivity, ensure the safeguard of geological resources (given their importance as a sedimentary source for re-balancing the deficit identified in coastal drift) (ibid).
- **Terrestrial Protection Zone** (*Zona Terrestre de Protecção – ZTP*). It encompasses the terrestrial space of the area of intervention, where the presence of biophysical resources and the increasing coastal risks require the establishment of regimes of protection, determined by criteria of safeguard of resources and natural values and of safety of people and assets (POC-ACE 2018, p.79). In this space, there are coastal biophysical spaces indispensable for the physiographic and ecological balance of this territory, and areas that, due to their physical characteristics (e.g. non-built natural spaces) provide protection and contention of the pressures in these systems (POC-ACE 2018 d, p.38).

The Territorial Model is also structured in:

- **Fundamental Components** – which spatialize the regimes of protection and of safeguard, which are materialized into Specific Norms that establish the activities forbidden, conditioned and allowed in the areas encompassed by the regimes.
- **Complementary Components** – which identify the territorial resources, of environmental, social and economic relevance, which do not require the adoption of measures of safeguard but are subjected to General Norms due to their strategic importance for the sustainable development of the coastal zone (POC-ACE 2018, p.79) (Figure 33).

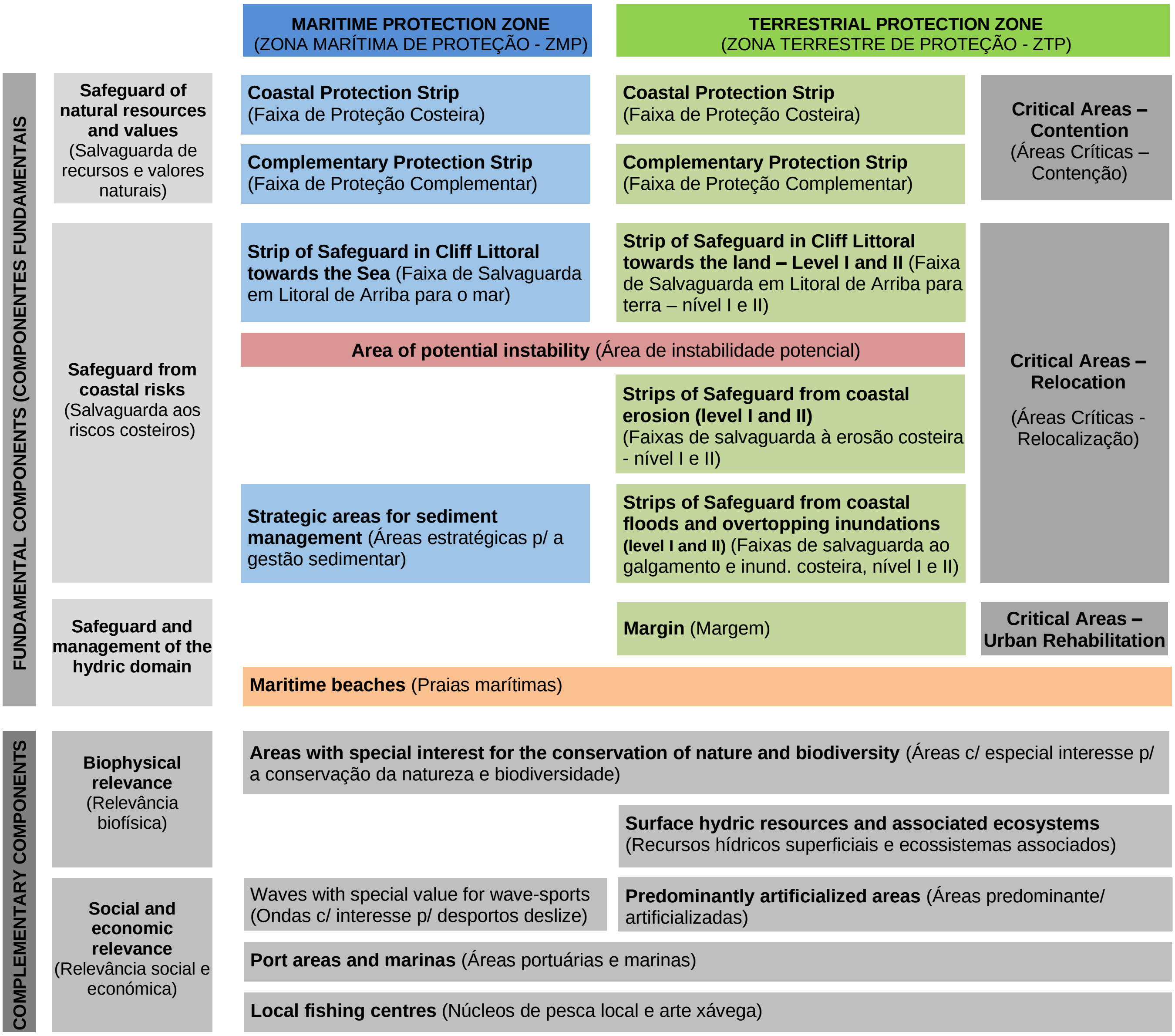


Figure 33. Structure of the Territorial Model of the POC-ACE. Source: translated from the POC-ACE 2018, p.80; 2018 d, p.34

Within the Regime of Safeguard of Natural Values and Resources, there are the following components:

- **Coastal Protection Strip** in the Maritime Protection Zone (*ZMP*). It is the maritime area indispensable for the sustainable utilization of the coastal zone, and it has essential functions for the coastal dynamic. Its safeguard is essential for the protection of the littoral and the preservation of maritime beaches. It encompasses structural coastal ecosystems and relevant habitats of marine biodiversity. This Strip consists of the area between the line of maximum high tide and the closure depth of the beach which coincides with the bathymetric line of -16m. In cliff littoral, it corresponds to the area between the crest of the cliff and the closure depth (-16m bathymetric) (POC-ACE 2018, p.82; 2018 d, p.36).
- **Complementary Protection Strip** in the ZMP. It is the maritime area essential to ensure the competitiveness of sea economy and sustainable utilization of resources, and to guarantee that the current and future economic activities develop in a compatible way with the objectives of protection of natural resources, namely the safeguard of marine resources and coastal physiographic balance. It consists of the maritime area adjacent to the Coastal Protection Strip in the ZMP, between the bathymetric lines of -16m and -30m, including coastal and territorial waters (POC-ACE 2018, p.82).
- **Coastal Protection Strip** in the Terrestrial Protection Zone (ZTP). It is the first strip of interaction with the maritime zone, which contains elements representative of coastal biophysical systems, namely

beach-dune systems and associated vegetation, dunes, cliffs and contiguous spaces that interfere with the erosive dynamics. In cliff littoral, this Strip was delineated from the crest of the cliff. The coastal biophysical systems require a specific protection that respects the carrying capacity of such systems and safeguards the identity of the landscape. This Strip has essential functions for the balance of the coastal systems and the preservation of the shoreline, and it requires the compatibilization of diverse uses and activities with due attention to the vulnerability of the coastal systems (ibid, p.82).

- **Complementary Protection Strip** in the ZTP. It is a buffer zone contiguous to the Coastal Protection Strip or framing *Predominantly Artificialized Areas*. It contains natural or partially artificialized spaces. It is essential for the contention of construction and conservation of natural resources and spaces in close dependency or interaction with coastal biophysical systems (ibid, p.83) (Note 347).

Within the Regime of Safeguard from Coastal Risks, there are the following components:

- **Strip of Safeguard in Cliff Littoral towards the Sea**. It consists of the area adjacent to the foot of the cliffs or other slopes, which may be potentially hit by the fallen materials (blocks) resultant from mass movements. This Strip was delineated from the lower limit of the cliff (foot) towards the sea, with a fixed width or a width dependent on the height of the cliff (POC-ACE 2018, p.85; 2018 d, p.40).
- **Strategic Areas for Sediment Management (Level I and II)**. These areas correspond to sediment deposits currently identified as having potential for constituting borrow sites for the nourishment of beaches, regardless of future studies that might identify other spaces. These Areas were identified based on reference information of the Plan '*Plano de Ordenamento do Espaço Marítimo*' and cartography of the Instituto Hidrográfico. The Areas of Level I are potential borrow sites located between the bathymetric lines -20m and -30m (which may be outside the POC's area of intervention); the Areas of Level II are areas under the jurisdiction of ports and access channels where there are dredging works for maintenance or deepening of ports or estuaries. In some cases, given the inexistence of sediments at depth up to the 30m (limit of ZMP), the Team identified potential deposits up to the bathymetric line -50m (POC-ACE 2018, p.85-86; 2018 d, p.37, 38).
- **Strip of Safeguard in Cliff Littoral towards Land – Level I and II**. The Strip of Level I is the area adjacent to the crest of cliffs or other slopes, which presents greater probability of being affected by mass movements. The Strip of Level II is the area adjacent to the Strip I landwards, and it has the additional function of absorbing potential mass movements with atypical widths. The Strip of Level I was delineated from the upper limit of the cliff (crest) landwards, in a horizontal plan and perpendicularly to the cliff contour, and it is expressed with a fixed width or a width dependent on the height of the cliff. The Strip of Level II was delineated from the Strip of Level I landwards, with a fixed width or a width dependent on the height of the cliff (POC-ACE 2018, p.85; 2018 d, p.40).
- **Strips of Safeguard from Coastal Erosion Level I and II**. These Strips consist of areas potentially affected by coastal erosion and shoreline retreat (regression) in the time-horizons of 2050 (Level I) and 2100 (Level II). The delimitation of these Strips resulted from the extrapolation for the next decades of evolutive tendencies observed in the recent past (POC-ACE 2018, p.85; 2018 d, p.39). These Strips also account for the effects of climate change (POC-ACE 2018 d, p.40).
- **Strips of Safeguard from Coastal Floods and Sea Overtopping Inundations Level I and II**. These Strips correspond to areas potentially affected by sea overtopping inundations and coastal floods in the time-horizons of 2050 (Level I) and 2100 (Level II). The determination of these strips was based on the calculation of the combined effect of: the medium sea level, the elevation (rise) induced by astronomic tide, the level induced by a storm surge, and the extension of water / wave overtopping, and this calculation may include SLR induced by climate change (POC-ACE 2018, p.85-86; 2018 d, p.39).

- '**Critical Areas – Relocation**'. Areas included by the Strips of Safeguard from Coastal Risks, where the high hazardousness in the mid-term requires, in the context of the strategy of coastal adaptation, the concretization of interventions of planned retreat (POC-ACE 2018, p.85).
- **Areas of Potential Instability**. These areas consist of slopes located in the ZMP or ZTP, whose instability does not result directly from the erosive action of waves in the cliff foot (natural or artificial slopes where there may be instability and mass movements) (POC-ACE 2018, p.86; 2018 d, p.41).

In the <u>regime of safeguard and management of the hydric domain</u>, there are the following components:

- **Margin**. It is the strip of territory adjacent to the limit of the seabed, with a width legally established. It consists of the margin of seawaters or other navigable or floatable waters. It has an essential role in the protection and safeguard of water bodies, preservation of physical and biological processes and dynamics associated to the land-water interface. It was delineated based on geographical information and technical criteria defined in legislation, which does not hinder a future redefinition in a procedure of delimitation of the Public Hydric Domain (POC-ACE 2018, p.118; 2018 d, p.39) (Note 348).
- **Critical Areas – Urban Rehabilitation**. These are areas predominantly artificialized located within the Margin and outside the Strips of Safeguard, where it is important to suite the regime of safeguard with the prosecution of objectives of urban rehabilitation given the state of degradation of the built-up areas. The Areas are: part of the settlements of Nazaré and São Martinho do Porto, Ilha do Baleal (Peniche), Fosso da Muralha (Peniche), and Boca do Inferno (Cascais) (POC-ACE 2018, p.118).
- **Maritime Beaches**. These are sandy zones with different landscape characteristics, bathing aptitude, environmental sensitiveness, and intensity of use. In line with the DL n.º159/2012, the beaches must be object of valorisation and qualification, and be subjected to a classification and measures to discipline their uses and activities. The beaches were delimited and classified according to the five typologies set in the DL n.º159/2012: type I – urban beach; II – peri-urban beach; III – seminatural beach; IV – natural beach; V – beach with restricted use (POC-ACE 2018, p.118; 2018 d, p.41).

Overall, the regimes of protection, safeguard, and management, identified in the Territorial Model, aim to deliver the Strategic Objectives of the POC, namely the safeguard and natural resources and values, the safeguard from coastal risks, and the safeguard and management of the hydric domain (POC-ACE 2018, p.80) (Note 349). In addition to the regimes of safeguard, and to concretize the objectives of the POC in priority spaces, the Territorial Model defines 3 types of Critical Areas (POC-ACE 2018, p.81):

- *<u>Critical Areas – Contention</u>*. Predominantly artificialized areas (not consolidated) located in spaces with great biophysical value affected, where it is important to contain the land uses and occupations.
- *<u>Critical Areas – Relocation</u>*. Areas encompassed by the *Strips of Safeguard from Coastal Risks*, where the high hazardousness expected in the mid-term require, within the strategy of coastal adaptation, the implementation of priority interventions of planned retreat (removal and relocation of built assets).
- *<u>Critical Areas – Urban Rehabilitation</u>*. Artificialized areas located in the Margin, not encompassed by the regimes of safeguard from coastal risks, where it is important to suite the regime of safeguard and management of hydric resources with the prosecution of priority interventions of urban rehabilitation.

Finally, within the Complementary Components, there are the following components (see Note 350):

- *Superficial Hydric Resources*.
- *Areas with Special Interest for the Conservation of Nature and Biodiversity*.
- *Waves with Special Value for Wave Sports - Level I and II*.
- *Predominantly Artificialized Areas*. These areas present a built-up occupation of land, in a compact or discontinuous extended way, i.e. infra-structured urban fabric with a minimum area of 2,5 ha. These areas do not present values that justify their inclusion in a Strip of Protection. In their delimitation, the Team considered a minimum area of 2,5ha and a minimum distance between

buildings of 50m; which may include urban green spaces and urban voids. In exceptional cases, a minimum area of 1ha was admitted, if such area distances less the 150m of a PAA.

- *Port Areas*. Areas under port jurisdiction in Nazaré, São Martinho do Porto, Peniche, Ericeira, Marina of Cascais, Lisbon Port, and areas for port operation (not under port jurisdiction, e.g. access channels to Lisbon Port (Barra Sul and Barra Norte) and site of sediment deposition Cachopo Norte).
- *Local Fishing Centres* (POC-ACE 2018, p.123-124; 2018 d, p.28, 44-46).

3.1.1. Strips of Safeguard from Coastal Risks

In line with the principles of prevention and precaution, the Territorial Model identifies the Strips of Safeguard in Cliff Littoral and in Sandy Low-lying Littoral. These strips spatialize the regimes of safeguard that aim to contain the exposure of people and assets to the risks of cliff instability, erosion, sea overtopping inundations and coastal floods. With these regimes, the POC seeks to ensure territorial protection from vulnerabilities, but also assure that the evolution of land uses / occupations is compatibilized with the probable climatic evolution and the consequent aggravation of the territorial vulnerability. Overall, these Strips aim to safeguard from coastal risks – an objective indispensable to the guardianship of national public interests. According to the POC, the definition of these Strips took into consideration the physical characteristics of the littoral, the level of vulnerability, and the time-horizon of exposure (POC-ACE 2018 d, p.39).

The Strips of Safeguard in Cliff Littoral consist of strips of territory parallel to the shoreline that present greater sensitiveness to erosive dynamics near the crest of the cliff (upper limit of the cliff) and aim to safeguard from, and mitigate the impacts resultant from, the instability and events of retreat (regression) of cliffs and other slopes in the coastal zone (POC-ACE 2018 d, p.40).

The Strips of Safeguard in Low-lying Sandy Littoral aim at the safeguard from, and mitigation of impacts resulting from, the dynamics and mobility of the coastal strip – namely from erosion and the associated shoreline retreat (regression) – and from sea overtopping inundations and coastal floods, up to the time-horizons of 2050 (Level I) and 2100 (Level II). These Strips account for the effects of climate change (POC-ACE 2018 d, p.40). The current and future threats, namely erosion and the consequent loss of territory, are expected to aggravate due to climate change effects (POC-ACE 2017, p.167).

3.1.1.1. Strips of Safeguard in Cliff Littoral: *Strip of Safeguard in cliff littoral towards the Sea*, and *Strip of Safeguard in Cliff Littoral towards Land*

The ‘Strip of Safeguard in Cliff Littoral towards the Sea’ consists of the area adjacent to the foot of the cliffs or other slopes, which may be potentially hit by the fallen materials (e.g. blocks or unstable masses) resultant from mass movements. It was delineated from the lower limit of the cliff (foot) seawards, with a fixed width or a width dependent on the height of the cliff (POC-ACE 2018, p.85; 2018 d, p.40).

The ‘Strip of Safeguard in Cliff Littoral towards Land – Level I’ consists of the area adjacent to the crest of cliffs or other coastal slopes, which presents greater probability of being affected by mass movements of different types and dimensions. This Strip was delineated from the upper limit of the cliff (crest) landwards, in a horizontal plan and perpendicularly to the contour of the cliff, and expressed with a fixed width or a width dependent on the height of the adjacent cliff (POC-ACE 2018, p.85; 2018 d, p.40).

The ‘Strip of Safeguard in Cliff Littoral towards the Land - Level II’ consists of an area adjacent to the Strip I landwards, and it has the additional function of absorbing potential mass movements with atypical widths; this Strip was delineated from the Strip of Level I landwards, and it is expressed with a fixed width or a width dependent on the height of the cliff (POC-ACE 2018, p.85; 2018 d, p.40).

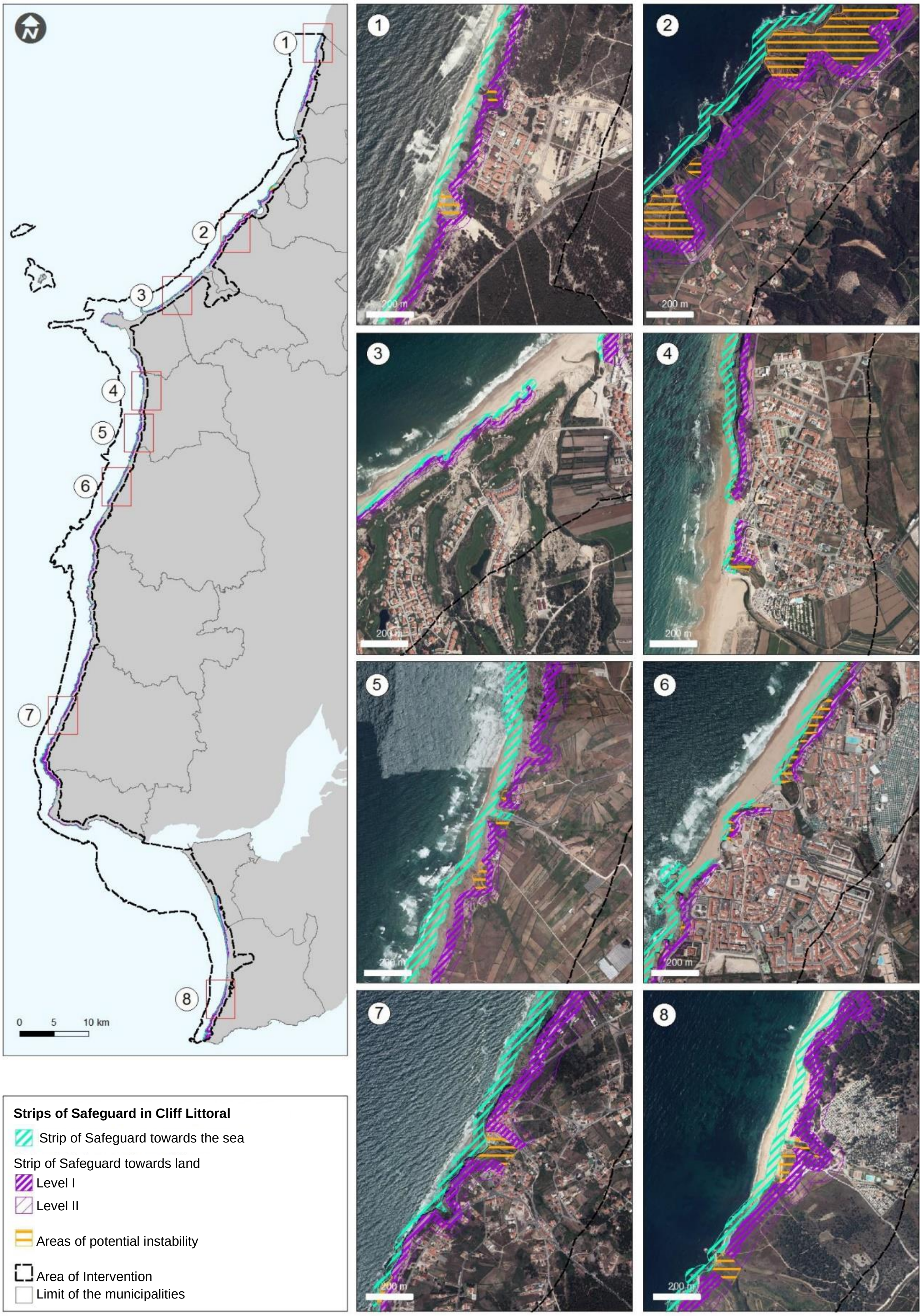


Figure 34. Spatialization of the regimes of safeguard from coastal risks in cliff littoral. Source: POC-ACE 2018, p.87.

3.1.1.2. Strips of Safeguard in Low-lying Sandy Littoral: *Strips of Safeguard from Coastal Erosion*, and *Strips of Safeguard from Coastal Floods and Sea Overtopping Inundations*

The 'Strips of Safeguard from Coastal Erosion Level I and II' correspond to the areas potentially affected by coastal erosion and shoreline retreat (regression), in the time-horizons of 2050 (Level I) and 2100 (Level II). These Strips were determined and delimited based on the extrapolation, for 2050 and 2100, of the evolutive tendencies observed in the recent past (POC-ACE 2018, p.85-86; 2018 d, p.39). These Strips also account for the effects of climate change (POC-ACE 2018 d, p.40), namely SLR. In the delimitation of the zones threatened by shoreline retreat, the POC took into consideration the average evolution of each coastal stretch (POC-ACE 2017, p.73).

The 'Strips of Safeguard from Sea Overtopping Inundations and Coastal Floods Level I and II' correspond to the areas potentially affected by sea overtopping inundations and coastal floods, in the time-horizons of 2050 (Level I) and 2100 (Level II). These Strips were determined and delineated based on the calculation of the combined effect of: the medium sea level, the elevation (rise) induced by astronomic tide, the level induced by a storm surge, and the extension of water / wave overtopping, and this calculation may include SLR induced by climate change (POC-ACE 2018, p.85-86; 2018 d, p.39).[56]

Given the uncertainty that surrounds the future projection of the variables with interest for the calculation of the risk erosion, and of the risk of coastal flooding, in the calculation / generation of projections for erosion, and for sea overtopping inundations and floods, the POC-ACE has assumed the following values for SLR: **+0,30m (for 2050)** and **+1,50m (for 2100)**. These values were used in the estimation (projection) of the future retreat of the shoreline and of the maximum height of sea overtopping inundations and coastal floods (POC-ACE 2017, p.73).

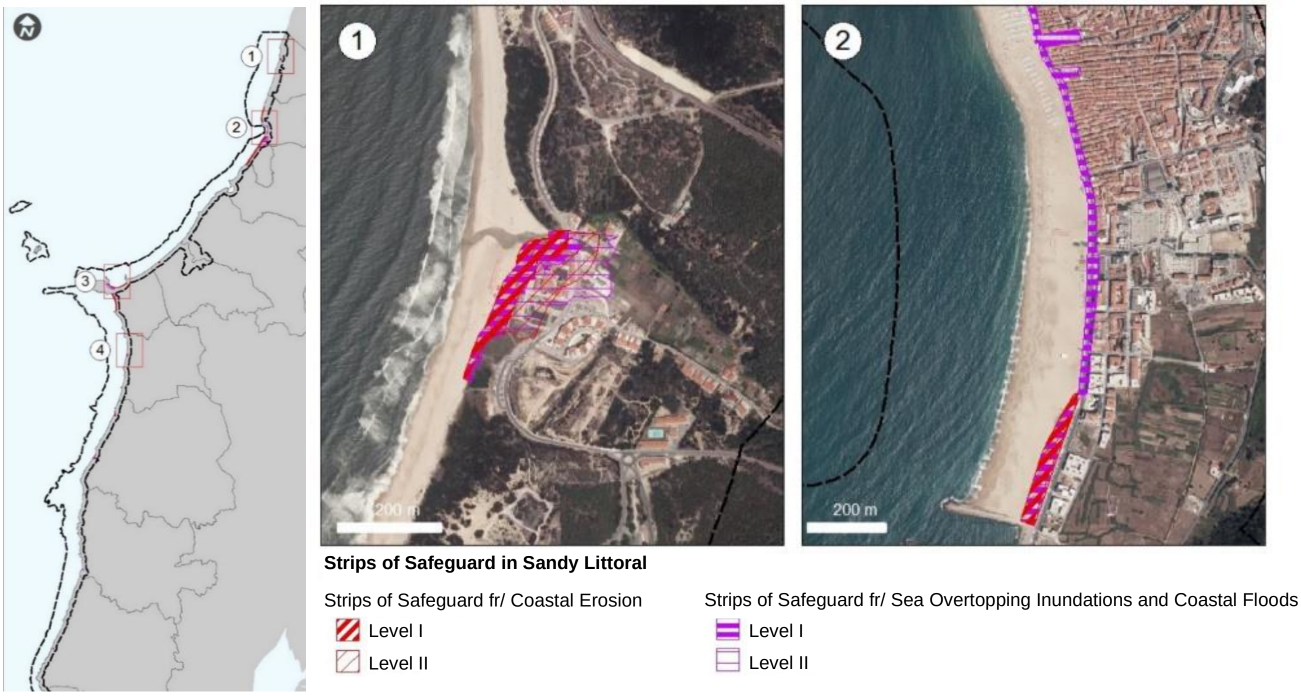


Figure 35 a). Spatialization of the regimes of safeguard from coastal risks in low-lying sandy littoral. Source: POC-ACE 2018, p.88.

[56] Estas faixas resultam do '*efeito combinado da cota do nível médio do mar, da elevação da maré astronómica, da sobre-elevação meteorológica e do espraio/galgamento da onda, podendo ainda incluir a subida do nível médio do mar em cenário de alteração climática*'. The sources of reference information for delineating the Strips for Safeguaring from Coastal Erosion, and the the Strips for Safeguaring from Sea Overtopping Inundations and Coastal Floods, as indicated in the POC-ACE (2018, p.86), were the following: *Estudo de "Consultoria para a Criação e Implementação de um Sistema de Monitorização do Litoral abrangido pela área de Jurisdição da ARH do Tejo (Faculdade de Ciências da Universidade de Lisboa para a Agência Portuguesa do Ambiente, I.P. / Administração da Região Hidrográfica do Tejo (2013); (equipa de Geologia Costeira do Instituto Dom Luiz (IDL)/Faculdade de Ciências da Universidade de Lisboa (FCUL) (2014); Penacho et al. (2013a, 2013b) e Marques et al. (2013).*

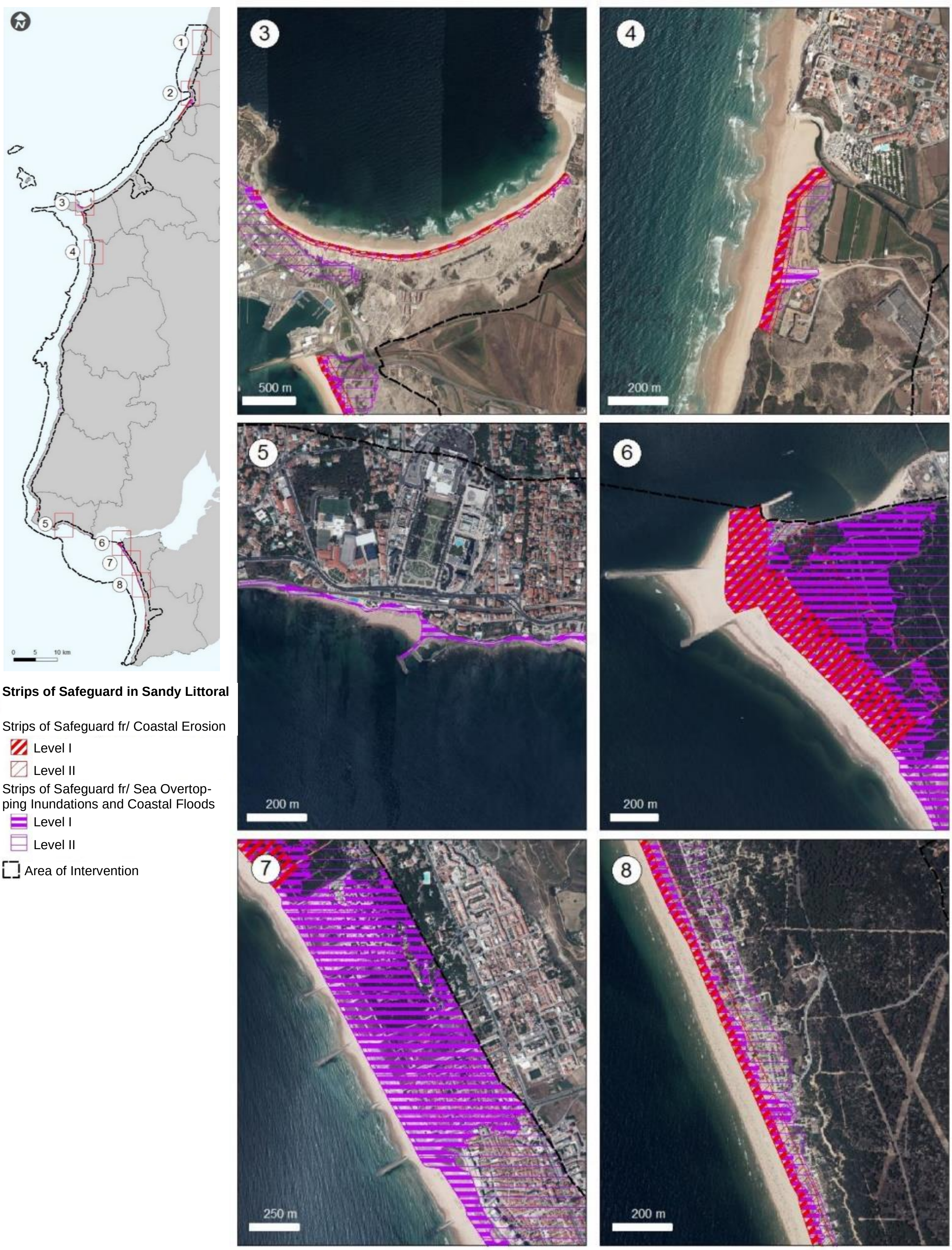


Figure 35 b). Spatialization of the regime of safeguard from coastal risks in low-lying sandy littoral. Source: POC-ACE 2018, p.88.

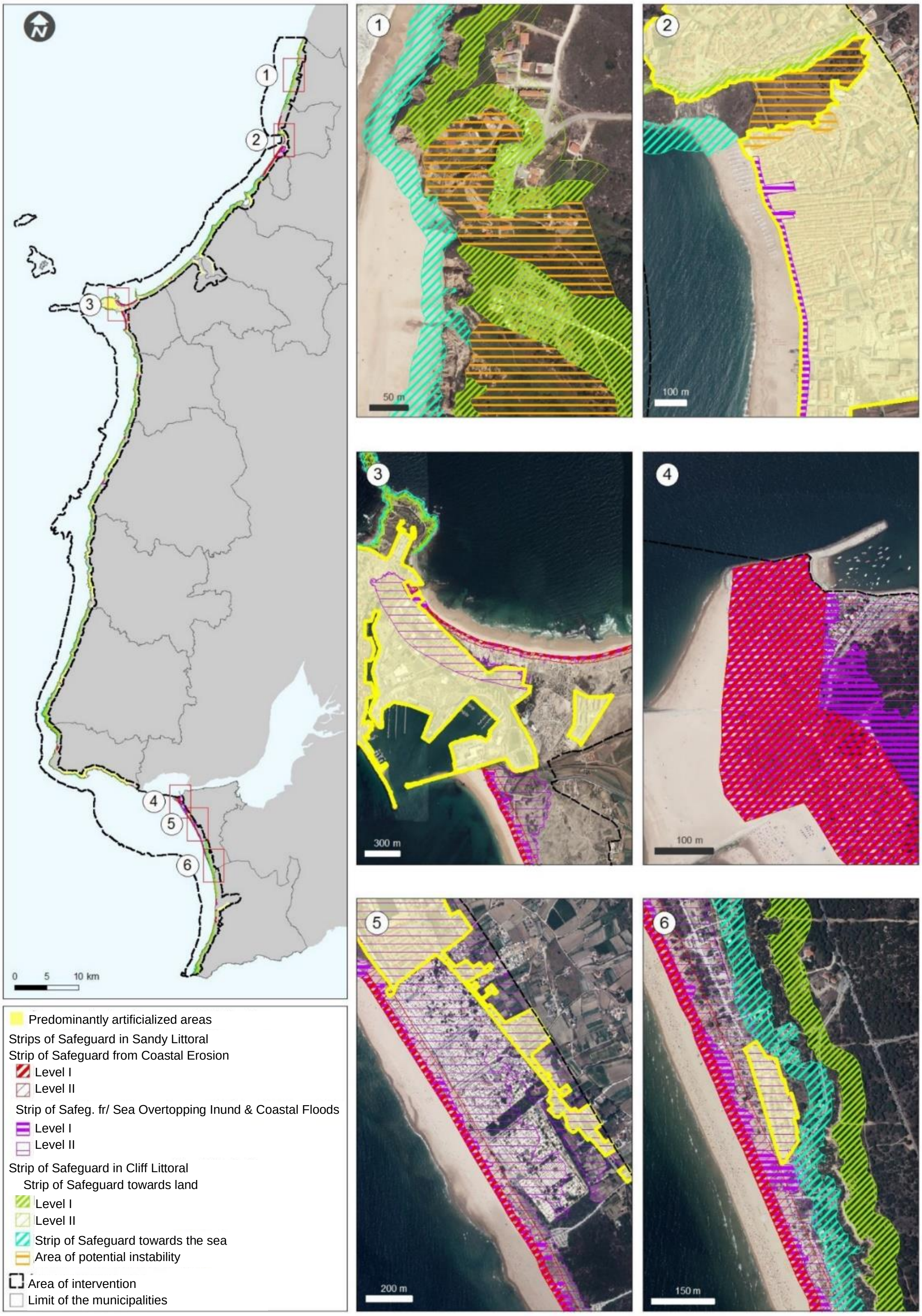


Figure 36. Predominantly Artificialized Areas, overlapped with the Strips of Safeguard from Coastal Erosion, Strips of Safeguard from Sea Overtopping Inundations and Floods, and Strips from Safeguarding in Cliff Littoral. Source: POC-ACE 2018, p.47.

3.1.1.3. SLR PROTECTIONS CONSIDERED IN THE GENERATION OF THE STRIPS OF SAFEGUARD IN SANDY LITTORAL

The POC recognizes that there is still a deep uncertainty around the projections of global SRL for 2100 (POC-ACE 2018, p.37-38). A recent study[57], which assumed that the future behaviour of the area of intervention in terms of SLR will be similar to the observed in the past, has estimated that, based on the extrapolation of values of SLR of the last two decades (1991 to 2010) observed in the tide gauge of Cascais, the projections of SLR for 2050 and 2100 will be 0,29m and 0,95m, respectively (in relation to the value of 2000) (POC-ACE 2018, p.37-38). The estimates presented by the 5th Assessment Report of the IPCC indicated values between 0,44m and 0,74m above the level of 1986-2005 depending on the emission scenario considered. The POC admits that the global projections may be representative of the behaviour of the area of intervention, but there are deep uncertainties associated to such projections.

The reference studies that served as a basis for POC-ACE indicated two plausible scenarios for 2100:

- A scenario of SLR of **0,50m** (which is aligned with the IPCC AR5 projections).
- An extreme scenario of SLR of **1,5m** (which is recommended by the scientific community as appropriate for coastal planning and coastal risk management purposes) (POC-ACE 2018, p.38).

For the time-horizon 2050, the POC assumed a plausible SLR of **0,30m** in relation to the level of 1990 (POC-ACE 2018, p.38).

Given the uncertainty that surrounds the future projection of the variables with interest for the calculation of the risks (hazards) of erosion and sea overtopping inundations / floods, and, in line with the principle of precaution, in the generation of scenarios for such coastal risks, the POC-ACE has assumed the following values for SLR: **+0,30m (for 2050)** and **+1,50m (for 2100)**. These values were used in the estimation (projection) of the future retreat of the shoreline and of the maximum height of sea overtopping inundations and coastal floods (POC-ACE 2017, p.73). In the delimitation of the zones threatened by shoreline retreat (regression), the POC-ACE also took into consideration the average evolution of each coastal stretch (POC-ACE 2017, p.73).

Analysis of hazards in sandy littoral

The POC Team developed projections of the future retreat (regression) of the shoreline associated to coastal erosion, and then analysed the adequacy of the obtained 'strips' by overlapping them with the '*Zones Threatened by the Sea*' (*Zona Ameaçada pelo Mar*) defined by the first POOCs.

The analysis carried by the POC-ACE Team showed that:

- At the north of the Tejo mouth, the strips of retreat (regression) associated to coastal erosion cover (overlap with) most of the area delimited as '*Zone Threatened by the Sea*'. The width of such Strips is around 20-30m for 2050 and 50-80m for 2100 (POC-ACE 2018, p.38). On the other hand, the strips corresponding to sea overtopping inundations and floods have a reduced expression (in the cartography) (do not present significant values) (POC-ACE 2018, p.38).
- At the south of Tejo mouth, between São João da Caparica and Cabo Espichel, the 'Zone Threatened by the Sea 2050' presents a homogeneous width in most beaches (average values of 30-40m). The width of the 'Zone Threatened by the Sea 2100' is higher (more than 250 m width) in the south of the groynes of Costa da Caparica, and 100-130 in the south of the beach Praia da Rainha. The beach of São João da Caparica presents a high rate of retreat of the shoreline, which amplifies the

[57] Projeto de "*Consultoria para a Criação e Implementação de um Sistema de Monitorização do Litoral abrangido pela área de Jurisdição da ARH do Tejo*", realizado pela Faculdade de Ciências da Universidade de Lisboa (FCUL), for APA – ARH Tejo.

accumulated retreat in the time-horizons of 2050 and 2100 (165m and 360m, respectively). At the south of the groynes of Costa da Caparica, the width of the 'Zones Threatened by the Sea' reaches its highest values between the beach Praia da Saúde and the beach Praia Nova (38 m and 251 m in 2050 and 2100, respectively). In this sector, the beach-dune system is contiguous to urban areas, and the built-up area is too close to the inland limit of the 'Zone Threatened by the Sea 2050', and largely contained by the 'Zone Threatened by the Sea 2100' (POC-ACE 2018, p.38).

Drawing on the analysis of the hazardousness in sandy littoral, the POC-ACE highlights that:

- The hazardousness, assessed through the analysis of the extension of the Strips of Safeguard in Sandy Littoral, is extreme (high) in Nazaré (south), sandy areas of Peniche, Praia da Areia Branca, Cova do Vapor, Costa da Caparica, and Fonte da Telha.
- There are nearly 12000m of urban forefronts encompassed by 'Strips of Safeguard in Sandy Littoral', where coastal erosion will threaten safety in the near future (POC-ACE 2018, p.38).
- Around 13740 people live in buildings located within the 'Strips of Safeguard in Sandy Littoral'.
- The potential damages reach the higher values in Costa da Caparica and Fonte da Telha.
- The settlements of Peniche (sandy areas), Cova do Vapor, south of Costa da Caparica, and Fonte the Telha, present higher risk in terms of erosion phenomena (POC-ACE 2018, p.39).

Analysis of hazards in cliff littoral

In sectors with cliff littoral, the assessment of the POC showed that the retreat (regression) of the crest of cliffs was, in most cases, lower than the corresponding 'Strips of Risk' (there were only 7 cases where the retreat caused by movements exceeded the width of the Strips of Risk) (POC-ACE 2018, p.39).[58]

Regarding the assessment of the adequacy of the Strips of Risk adjacent to the base (foot) of the cliffs, the POC-ACE mentions that the maximum reaches of the material mobilized in registered movements were lower than the Strips of Risk. In 85% of the movements registered, the reaching of the mobilized materials was lower than 58% of the width of the Strip of Risk. Only in 7 of the 94 registered cases, the reaching registered exceeded the width of the Strip of Risk (POC-ACE 2018, p.39).

Drawing on the analysis of the hazardousness in cliff littoral, the POC-ACE highlights that:

- The hazardousness, assessed as the combination of the susceptibility of occurrence of instability in the cliff face and the extension of the Strips of Risk (represented from the crest of the cliff landwards), is extreme in: Vale Furado, Casais da Boavista, Vale de Janelas, Areia Branca, Porto Dinheiro, Azenhas do Mar (North), Cabo da Roca, and Bicas.
- There are 27230m of urban forefronts intersecting the *Strip of Risk* adjacent to the cliff crest or Additional Strip, where safety may be threatened in near future. 3828 people live in *the Strip of Risk*.
- The potential damage, assessed as the combination of the extension of urban forefronts located near the cliff crest, the existence of built assets in the Strip of Risk adjacent to the Cliff Crest, the number of people living in 2011 and the rate of population variation in 2001-2011, is higher in: Praia das Maçãs, Boca do Inferno, São João do Estoril, Nazaré, Santa Cruz, Ericeira, and Azenhas do Mar.
- According to the risk matrix, the settlements at greater risk of instabilities in the cliff crest are: Pedra do Outro, Facho, Areia Branca, Porto Dinheiro, and Azenhas do Mar (POC-ACE 2018, p.39).

[58] 97,8% of the occurred movements did not originate retreat of the crest of the cliff higher than 67% of the width of the Strip of Risk of the prior POOCs. The Strips of Risk absorbed 99,2% of the registered movements, there were only 7 cases (in 914 movements) where the width of the Strip was exceeded by the retreat registered. The performance of the Strip of Risk is deemed satisfactory in terms of prevention of risks.

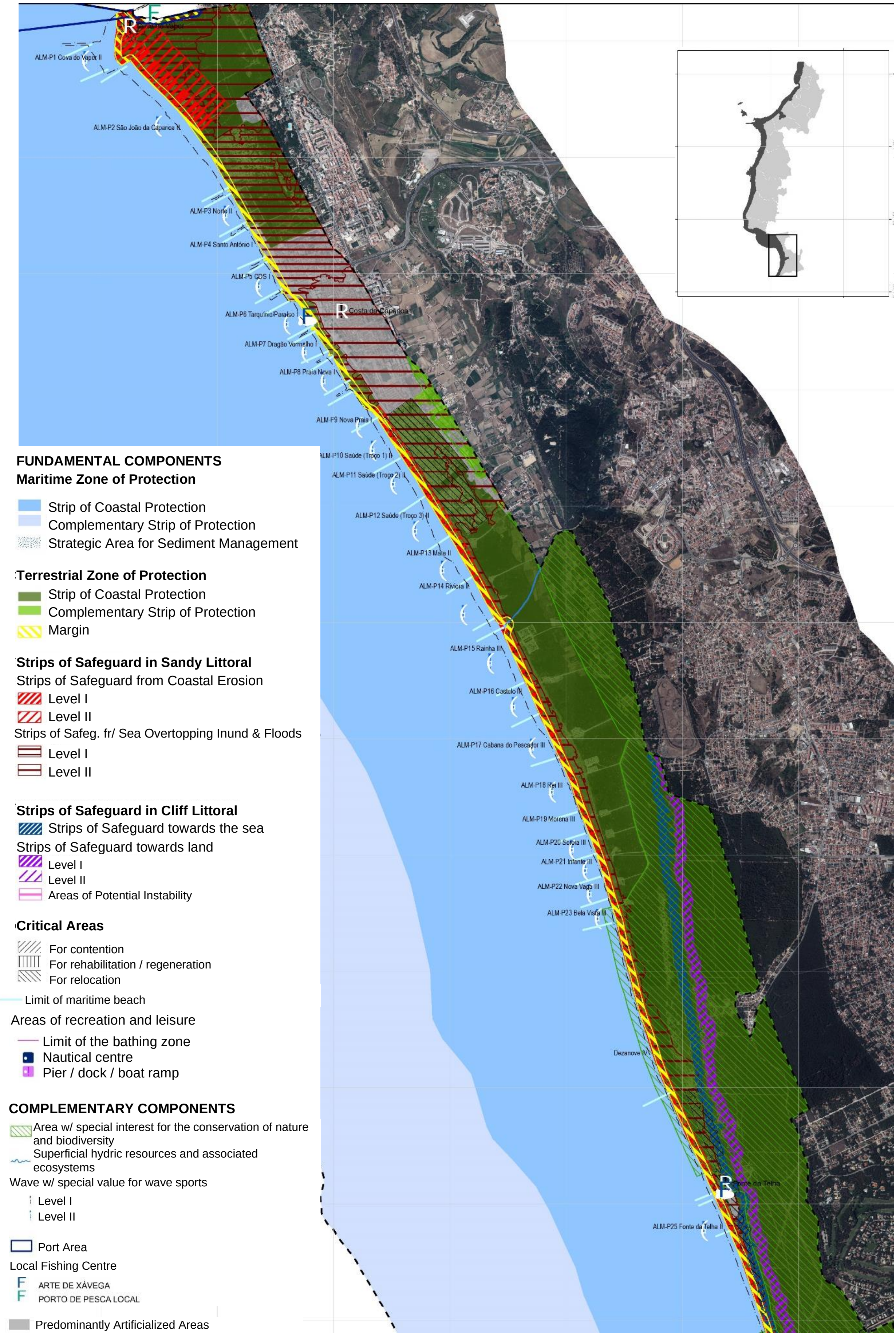


Figure 37. Part of the Territorial Model of the POC-ACE, between Cova do Vapor and Fonte da Telha. Source: POC-ACE 2018. POC_MT_LayoutBase_A0_Folha 7.

3.1.2. Critical Areas – Relocation

The 'Critical Areas – Relocation' identified in the POC are the coastal settlements of (integrally or part of them) of: Água de Medeiros (Alcobaça), Vale Furado (Alcobaça), Praia da Consolação (Peniche), Foz do Sizandro (Torres Vedras), Cova do Vapor (Almada), Fonte da Telha (Almada), camping sites of Costa da Caparica (Almada). The sources of information for delineating these 'Critical Areas' were, among others: the Strips of Safeguard in Cliff Littoral towards Land, the Strips of Safeguard from Coastal Erosion (Level I and II), the Strips of Safeguard from Sea Overtopping Inundations and Coastal Floods (Level I and II), and the Areas of Potential Instability (POC-ACE 2018, p.86) (Note 351).

Figure 38. 'Critical Areas – Relocation'.
Source: POC-ACE 2018, p.89.
1) Água de Medeiros; 2) Vale Furado; 3) Foz do Sizandro; 4) Cova do Vapor; 5) Fonte da Telha; 6) Parques de Campismo a sul da Costa da Caparica.

3.1.3. Other strategies proposed in the POC-ACE

Sediment management

According to the POC, the analysis of the recent evolution of the area of intervention demonstrates the existence of a negative sediment balance (a significant sediment deficit), which leads to coastal erosion and the associated retreat (regression) of the shoreline; thus, for the POC, the management of sediment resources must assume a primary role in the strategies of intervention to mitigate coastal erosion (POC-ACE 2018 d, p.55; 2018 a, p.16; 2018, p.179). In specific, the Program of Actions highlights that the recent evolution of the national littoral shows the existence of significant sediment deficits, therefore, 'sediment management' should assume a primary role in the strategies of intervention and mitigation of the erosive process (POC-ACE 2018 a, p.16). The concretization of a strategy of protection based on the re-establishment of the sediment balance should be supported in a policy of integrated sediment management that involves all entities with responsibilities in this field (POC-ACE 2018 d, p.55).

Based on the GTL, the POC mentions that the inversion of the erosive behaviour (namely in Cell 4 'Cabo Raso-Cabo Espichel) may be achieved by reducing or annulling the sediment deficit that has been generated by anthropic action, through sediment nourishments with sand extracted from 'borrow sites' located outside the outer estuary of Tejo (POC-ACE 2018, p.28, 179). It is expected that with an allocation of 10 million m^3 of sediments with appropriate granulometry, the system might enter in 'equilibrium'. However, the POC admits that this volume might need to be adjusted (increased or decreased) in function of the system's needs, and the final values will depend on specific studies and experiments. It is possible that such intervention allows the system to recover an equilibrium, with the consequent reduction of the risk of sea overtopping inundations, coastal floods and erosion, and leading to a situation of stability similar to the situation now observed at the norther tip of the Setúbal Peninsula. Nevertheless, it is probable that in the mid- and long-term (2050 and 2100, respectively), a new sediment deficit might arise. For this reason, in addition to sediment nourishments and the fixation ('holding') of the shoreline through the maintenance of hard coastal protection works and ecological restoration interventions in dune systems (as those carried in the beach of São João da Caparica), it is imperative to plan the relocation (planned retreat) of uses and occupations in areas of greater vulnerability like Cova do Vapor, the camping sites of Costa da Caparica and Fonte da Telha, as well as the removal of numerous buildings located on the dune system between the beaches of Saúde and Mata (POC-ACE 2018, p.28).

The Program of Actions of the POC assumes that the inversion of the erosive behaviour might be achieved by reducing the sediment deficit mainly through a strategy of nourishment of beaches and reinforcement of dune chains, and that such strategy will allow the system to recover its balance, and, consequently, reduce the risks of sea overtopping inundations, floods, and erosion, and maintain the integrity of the shoreline (POC-ACE 2018 a, p.16).

Regarding protection, the POC has assumed as a central measure a policy of re-establishment of the sediment balance through operations of sediment nourishment with sediments obtained in the continental shelf, in the mouth of Tejo river, and from dredging works in the lagoons of Óbidos and Albufeira, as well as the harnessing of the potential of hydrographic basins for carrying sediments to the littoral (POC-ACE 2018 d, p.52).

Coastal urban settlements, and the incorporation of principles of adaptability

For the POC, the prosecution of the adaptation policy proposed, which acts at three strands of intervention (protection, accommodation, and planned retreat) is particularly relevant in built-up areas encompassed by Strips of Safeguard: in such spaces an intense effort of adaptation is needed, and the most critical cases will require relocation. In coastal urban settlements, the spatial plans must contain mechanisms to locally assess the evolution of the policy of sediment management and to develop an integrated sustainable planning that is able to set responses suited to each situation (within the adaptation policy) and converge diverse financial, programmatic, and spatial planning instruments, at local, regional, and national level (POC-ACE 2018 d, p.70). Regarding coastal urban settlements, the POC advocates that it is '*indispensable to promote a sustainable planning of the coastal settlements by considering (and integrating) the key principles of adaptability, namely: flexibility, to follow the annual climatic cycle; reversibility, by anticipating the development of the littoral in the long-term and envisaging anticipated hypotheses of relocation; sobriety, by grasping the limitations of responses in the face of the dimension of the challenges brought by the coastal geo-system; and ingenuity, by incorporating into urban development the rationale of adaptation of natural systems*' (POC-ACE 2018 d, p.69).[59]

For the problem spaces, the POC has envisaged two main ways of action: 'new interventions' (solutions) to preserve the shoreline, and, on the other hand, the relocation of buildings with high susceptibility to risks, with the aim of reducing the loss of assets and services (POC-ACE 2017, p.167).

Importantly, the POC-ACE has largely followed the recommendations provided by the GTL (Box 10) and also recommendations of the *Strategic Environmental Assessment* (SEA) of the POC (Note 352).

BOX 10: recommendations of the GTL Report

The POC-ACE has largely followed the recommendations provided by the GTL Report. Regarding the strategies of adaptation envisaged for the coastal zone, the GTL recommended the elaboration of studies on adaptation, and integrated assessments of measures of adaptation (protection, accommodation, and relocation) under scenarios of climate change, and of costs associated to different 'adaptation pathways' up to time-horizons of long-term (2100).

Moreover, the GTL Report proposes a strategy of planned retreat for the coastal zones where there is a high risk of sea overtopping inundations and floods, coastal erosion, or cliff instability (it should be considered relocation as a priority response). The strategy of relocation presupposes the non-occupation of the coastal zone, including of urban or urbanizable areas, with new construction or expansions of existing constructions. The Report also proposes the development of prospective studies on relocation for areas at great risk based on cost-benefit analyses that include the mid- and long-term.

In addition, the GTL advises that 'sediment management' should assume a primary role in the strategies of intervention and mitigation of the erosive process in the coastal stretch ACE, namely in Costa da Caparica (the erosion problems are related with the sediment deficit that has existied since the 1940s; and in addition to the problem of erosion, there is an increasing risk of inundation / flooding caused by the urban occupation of low-lying zones (*in* POC-ACE 2018 d, p.179).

The GTL has divided the mainland coast into sediment cells. The area of intervention of the POC-ACE includes: the sub-cell 1, and the cells 2, 3 and 4. The cell 4 (Cabo Raso-Cabo Espichel) is considered a critical stretch due to its erosion problems (and sediment deficit) and increasing risk of inundation / flooding due to the urban occupation in low-lying zones. According to the GTL, the inversion of the erosive behaviour in Cell 4 may be achieved by reducing or annulling the sediment deficit that has been artificially created, through sediment nourishments with sand extracted from 'borrow sites' located outside the outer estuary of Tejo (POC-ACE 2018, p.28, 179). It is likely that this intervention allows the system to recover its balance, with the consequent decrease of the risk of sea overtopping inundations, floods, and erosion. However, in the mid-term (2050) and long-term (2100), with SLR, a new deficit might be created with the consequent retreat of the shoreline in Costa da Caparica. In this sense, the GTL indicates that there are essentially 3 solutions that must be assessed through modelling studies and cost-benefit analyses: i) sediment nourishment of beaches with increasing volumes; 2) the relocation of uses and occupations; 3) fixation of the shoreline through hard coastal protection works like the construction of a dyke of increasing height.

The GTL estimated that the cost of coastal protection in the cell 4 until 2020 and 2050, based on the continuation of the current policy of protection (which it considers to be predominantly reactive and based on hard works) would be 450M Euros. For the same time period, a policy based on the re-establishment of the sediment cycle equivalent to the littoral sediment drift was estimated to cost 432 M Euros, corresponding to the mobilization of 135 M m3 of sediments. These estimates show that both policies have similar costs, but the solution of re-establishment of the drift has the advantages of minimizing the loss of territory, be more easily reversible, favour the permanence of sand, maintain the landscape values, and be more similar to the natural situation. Moreover, the GTL considered that it is more prudent that the strategy of nourishment includes punctual / occasional interventions of high magnitude and low frequency (shots), to overcome the deficit quicker (*in* POC-ACE 2018 d, p.179).

For more on other strategies proposed by the POC-ACE see Note 353.

[59] Regarding beaches, there has been a deterioration of facilities of support of beaches caused by the coastal dynamics but also by the reduced flexibility of such facilities to respond to the morphological alterations of beaches and to the instability of the shoreline (with the decrease of the sandy area, and occurrence of sea overtopping inundations) (POC-ACE 2017, p.118, 117).

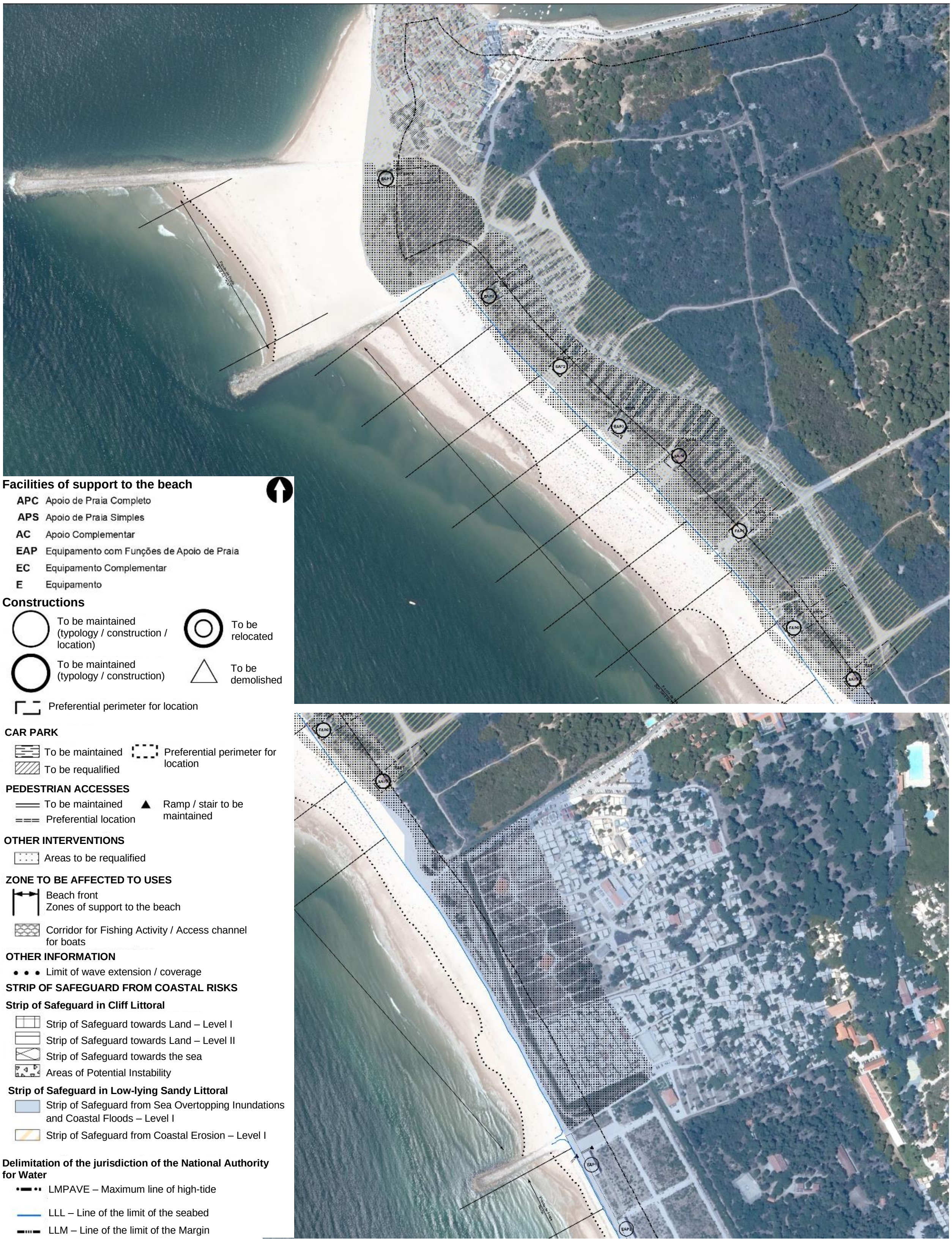


Figure 39. Parts of the Plan of Beach of Cova do Vapor and Costa da Caparica. Source: POC-ACE 2018, ALM-P1-P2 Cova do Vapor-SJ Caparica. In its Plans of Beaches, the POC also presents its proposal of intervention on the maritime beaches. For example, in the Plan of Beach of Cova do Vapor and São João da Caparica, the POC proposed the following 'strategies of intervention': articulate the planning of uses and occupations of the beach with the interventions of sediment nourishment and ecological restoration of the dune system (i.e. the strategy of adaptation to climate change defined by the POC for this zone). The facilities of support to the beach and the contiguous car park might need to be relocated eastwards (the POC defines the perimeters of preferential implantation), in order to allow the reinforcement of the frontal dune system, namely the increase of its basis and height (considering the level of 11m (above sea level) as the level of a sea overtopping flood with a return period of 100 years). The concretization of such intervention, namely the relocation of beach supporting facilities to areas outside the Hydric Domain, will imply a previous agreement with the owners of the parcels affected. The area classified as 'area to be requalified' consists of areas proposed for the recovery of dunes. The location of the beach supporting facilities must consider the adaptive management of the beach, and articulate with the need of requalifying and reinforcing the dune system (as a response of coastal protection). The location of car parks and beach supporting facilities must attain to the evolution of the coastal system, to the results obtained with intervention of sediment management, and with the need to widen the basis of dune and increase its height. The perimeters of preferential implantation are guiding of the eventual need of promoting the retreat of constructions in the time-horizon of the POC.

3.2. Directives

The Directives of the POC-ACE consists of norms with incidence in different spaces of the coastal zone ACE and in the activities that occur or might occur in them. Such norms aim to support and guide the management of activities and utilizations, and ensure the compatibilization of national and sectoral interests in the coastal zone, in a perspective of protection and valorisation of resources, prevention of coastal risks and safeguard of people and assets, in line with the principles of sustainable territorial development. The Norms proposed were grouped in three types, according to their content and purpose:

- General Norms (*Normas Gerais – NGs*). These are guidelines directed to public entities who must attain them in their scope of action and planning, and which aim at the safeguard of objectives of national interest with a delimited territorial incidence, in function of the existing values and resources, and at ensuring the conditions for the permanence of the systems indispensable to the sustainable utilization of the territory.
- Specific Norms (*Normas Específicas – NEs*). These norms establish the actions allowed, conditioned and forbidden, which concretize the regimes of safeguard of the POC. The content of these norms must be incorporated in spatial planning instruments, namely in Municipal Director Plans. The NEs defined for the Maritime Protection Zone (ZMP) must be articulated and compatibilized with the proposal of the instruments of spatial planning for the maritime space.
- Management Norms (*Normas de Gestão – NGes*). These norms contain the principles and criteria for the use and management of beaches with bathing aptitude and surrounding areas, of Local Fishing Centres, of leisure and recreational areas of the Lagoons of Óbidos and Albufeira. These Norms promote the protection and valorisation of hydric resources, namely the qualification of beaches and the ecological quality of lagoons and public waters (POC-ACE 2018 d, p.49).

The General Norms (NGs) are structured according to the themes associated to the Strategic Objectives that defined, as follows: theme 'coastal risks', theme 'natural values', theme 'hydric resources', theme 'competitiveness', theme 'maritime beaches', and theme 'urban settlements' (POC-ACE 2018 d, p.50).

The regimes of safeguard set in the Specific Norms (NEs) have a spatial incidence defined in the Territorial Model, therefore, the limits of the areas subjected to these regimes – i.e. Margin, Strips of Safeguard from Coastal Risks, Coastal Protection Strip and Strip of Complementary Protection in the Terrestrial Zone of Protection – must be transposed to municipal spatial plans (POC-ACE 2018 d, p.51).

The General Norms, in line with the recommendations of the GTL Report, seek to concretize an adaptation policy that encompasses protection, accommodation, and planned retreat / relocation. For the POC, the combination of these three coastal adaptation strategies is the most adequate solution since it allows a greater sustainability of the options in social, economic, and environmental terms (ibid, p.52).[60]

The NEs regarding the Strip of Coastal Protection, Complementary Protection Strip, Strips of Safeguard, and Margin, apply cumulatively, and the most restrictive rules prevail. The NEs regarding the Strips of Safeguard, when these are located in urban perimeter, apply in a differentiated and graded way:

a) Strips of Safeguard from Coastal Erosion and from Sea Overtopping Inundations and Coastal Floods:
   i. Level 1 – in Urban Forefront (first line of construction parallel to the sea, in the urban perimeter).
   ii. Level 1 – outside the urban forefront.
   iii. Level 2 – within the urban perimeter.

b) Strip of Safeguard of Cliff Littoral – Level 1 and Level 2 (POC-ACE 2018 d, p. 84).

[60] Regarding protection, the POC assumes, as a central measure, a policy of re-establishment of the sediment balance through operations of sediment nourishment with sediments obtained in the continental shelf, in the mouth of Tejo river, and from dredging works carried in the lagoons of Óbidos and Albufeira, and the harnessing of the potential of hydrographic basins for carrying sediments to the littoral (ibid, p.52).

Some of the measures proposed in the Directives that are directly or indirectly related with an approach of Adaptive Planning and Management, and its key-elements, are highlight next.

- The NG14 (on urban settlements) mentions that it is mandatory to '*ensure that the urban planning considers the vulnerabilities stemming from climatic scenarios of mid- and long-term, and responds not only to the current needs, but also to future challenges, by not allowing the aggravation of the exposure to risks* (POC-ACE 2018 d, p.70). This is related with the Key-element 1.
- It also underlines that it is necessary to *'integrate the principle of precaution in urban planning, by distancing, as far as possible, built assets from the shoreline, and the areas adjacent to the crest of cliffs and the areas subjected to sea overtopping inundations and floods, and by promoting the reduction of the intensity of use and occupation of the vulnerable zones and progressively relocating the existing constructions and structures to areas outside the Strips of Safeguard* (POC-ACE 2018 d, p.70). This is related with sub-elements of the Key-element 3.
- The NG1 (on coastal risks) refers that it is mandatory to *'ensure the monitoring, assessment and integrated management of coastal risks, and consider scenarios of climate change for the time-horizons of mid- and long-term, in a rationale of preventive action that accounts for the vulnerabilities and opportunities of the coastal zone and its environmental values, including the regular and systematic monitoring of the sediment dynamics, evolution of the shoreline, and performance of the coastal protection / defence works'* (POC-ACE 2018 d, p.53). This is related with the Key-elements 1, 2, and 4. Moreover, it mentions the need of '*adopt(ing) a vision of local development the takes into consideration the principle of precaution, in which the definition of land uses and occupations in the coastal zone pays due attention to the future vulnerabilities and threats associated to erosive processes and the expected SLR, supported by climatic scenarios'* (POC-ACE 2018 d, p.53). This is related with the Key-elements 1 and 2.
- The NG5 (on the protection of hydric resources) refers that *'climatic scenarios must be considered in the modelling and occupation of the public space and in the dimensioning of new infrastructures or rehabilitation of existing ones, namely in what concerns alterations in precipitation patters and superficial drainage and SLR, by ensuring the integration of innovative technical solutions, such as the increase in the flood storage capacity and the dissipation of the energy of water, non-occupation of more sensitive urban forefronts, and re-directing overtopping floods to less sensitive zones'* (POC-ACE 2018 d, p.60). This is related with the key-element 1, and the diverse possible adaptation measures suggested by the POC are related with sub-elements of Key-element 3.
- The NG12 (on the maritime beaches), mentions that the conciliation of the diverse functional vocations of the beaches, such as recreation, contemplation, consumption, and observation, '*requires an integrated and adaptive management that goes beyond, in spatial and operational terms, the scope of action of the Plans of Intervention on the Beaches and the areas of the Hydric Domain*'. This implies ensuring '*the compatibilization of uses and occupations of the sandy area, and the flexible and adaptive management of the maritime beaches*, *with the strategy of sediment management envisaged for the national coastal zone, namely with interventions of coastal protection that involve the preservation and reinforcement of the beaches and dune systems*' (POC-ACE 2018 d, p.66-67). This is related with an Adaptive Planning approach in general, and with sub-elements of Key-element 3.

For more on the NGs regarding coastal risks, please see Note 354.
For more on the NGs regarding other subjects but also related with the reduction and prevention of coastal risks, see Note 355.
For more on the NEs regarding the Strips of Safeguard from Coastal Risks, see Note 356.

3.3. Program of Actions

The Program of Actions of the POC-ACE (*Programa de Execução e Plano de Financiamento*) is structured according to the Strategic Objectives of the POC and their respective Strategic Lines. As seen, for each of the Strategic Objectives there are several corresponding Specific Objectives associated, also called 'Strategic Lines'. In the Program of Actions, the various interventions (projects and actions) to be carried are distributed (presented) per Strategic Objective and per Strategic Line (POC-ACE 2018, p.145; 2018 a, p.12, 15).[61]

The Program of Actions describes the programmed projects and actions, the entity responsible for their execution (which is better prepared, given its jurisdiction, experience or competences) and the partner entities (other entities fundamental for the execution of actions, which share costs or for technical reasons), and the phasing (programming) of the interventions (POC-ACE 2018, p.146; 2018 a, p.12). Some of the proposed actions will be executed through partnerships (with more than one entity / actor); in such cases, the POC identifies the leading entity and the partner entities (POC-ACE 2018, p.146). The implementation of the POC will require an articulated action of diverse entities, and the integration of public policies (POC-ACE 2018 a, p.12) (Figure 40 and Table I).

The interventions (projects and actions) presented in the Program of Actions will be mostly funded through EU Structural Funds (FEEI) for the period 2014-2020 (POC-ACE 2018 a, p.11). For more on the Program of Actions, see Note 357 and Note 358.

Regarding 'Coastal Risks and Climate Change', the POC-ACE proposes a set of projects of coastal protection to avoid the retreat (regression) of the shoreline and associated erosion problems, and, simultaneously, reduce the occurrence of sea overtopping inundations and floods, and preserve existing natural defences, namely: artificial beach nourishments, dredging works and sediment management; resettlement of populations in the Strips of Safeguard (Level I and II) in situations of high hazardousness; maintenance and rehabilitation of coastal defence structures; improvement of the performance of coastal defence structures; interventions of mitigation of risk in cliffs; adoption of solutions of soft contention in sandy littoral zones, as well as reinforcement of dune chains (POC-ACE 2018 a, p.23-25; 2017, p.167).

The Sectoral Objective OS1 (Coastal Risks) presents the highest volume of investment, namely the Strategic Line LE1.1. The OS1 concentrates 48 actions (12% of the total) and represents an estimated investment of nearly 92,7 million Euros (46,6% of the total). The Transversal Objective OT1 (Beaches) gathers the greatest number of actions (202, nearly 50,3% of the total), and such actions are distributed across the Strategic Lines that structure such Objective, namely the LE5.3 (POC-ACE 2018 a, p.23).

[61] The Program of Actions derives from the Strategic Model, particularly its Strategic Objectives and Strategic Lines, and from the principles set in the ENGIZC, in the Decree-Law nº 159/2012, in the Law nº 31/2014, and in the strategy of adaptation recommended in the GTL Report (POC-ACE 2018 a, p.11). However, some Strategic Lines do not correspond to materializable interventions, but are guidelines or priorities to be concretized through the Territorial Model and the regulatory frame (namely, the LE1.3, LE3.4, LE4.2, LE5.5, and LE6.2 (POC-ACE 2018, p.145; 2018 a, p.15).

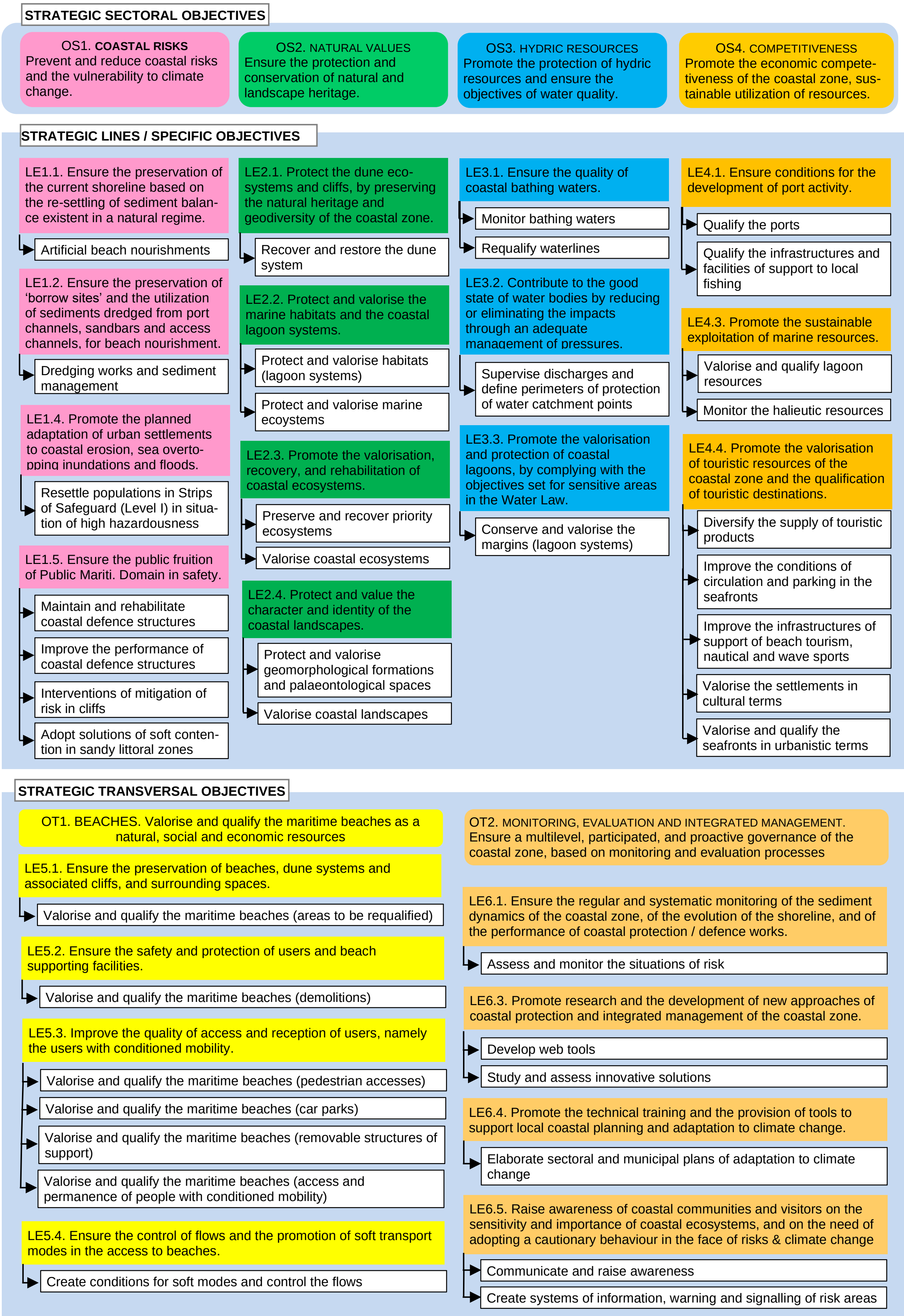


Figure 40. Structure of the Program of Actions – objectives, strategic lines, and their respective interventions (projects). Source: POC-ACE 2018 a, p.17.

Strat Objective	Strategic Line	Project	Actions
OS1. Coastal risks Prevent and reduce coastal risks and the vulnerability to climate change.	LE1.1. Ensure the preservation of the current shoreline based on the re-settling of sediment balance existent in a natural regime.	Artificial beach nourishment	1
	LE1.2. Ensure the preservation of 'borrow sites' and the utilization of sediments dredged from port channels, sandbars and access channels, for nourishment of beaches.	Dredging works and sediment management	3
	LE1.4. Promote the planned adaptation of urban settlements to coastal erosion, sea overtopping inundations and floods.	Resettle population in Strip of Safeguard (Level I and II) in situation of high hazardousness	9
	LE1.5. Ensure the public fruition of Public Maritime Domain in safety.	Maintain and rehabilitate the coastal defence structures	9
		Improve the performance of coastal defence structures	1
		Interventions of mitigation of risk in cliffs	23
		Adopt solutions of soft contention in sandy littoral zones	2
OS2. Natural values Ensure the protection and conservation of natural and landscape heritage.	LE2.1. Protect the dune eco-systems and cliffs, by preserving the natural heritage and geodiversity of the coastal zone.	Recover and restore the dune system	3
	LE2.2. Protect and valorise the marine habitats and the coastal lagoon systems.	Protect and valorise habitats (lagoon systems)	4
		Protect and valorise marine ecosystems	4
	LE2.3. Promote the valorisation, recovery, and rehabilitation of coastal ecosystems.	Preserve and recover priority ecosystems	6
		Valorise coastal ecosystems	3
	LE2.4. Protect and value the character and identity of the coastal landscapes.	Protect and valorise geomorphological formations and palaeontological spaces	5
		Valorise coastal landscapes	2
OS3. Hydric resources Promote the protection of hydric resources and ensure the objectives of water quality.	LE3.1. Ensure the quality of coastal bathing waters.	Monitor bathing waters	3
		Requalify waterlines	2
	LE3.2. Contribute to the good state of water bodies by reducing or eliminating the impacts through an adequate management of pressures.	Supervise discharges and define perimeters of protection of water catchment points	16
	LE3.3. Promote the valorisation and protection of coastal lagoons, by complying with the objectives set for sensitive areas in the Water Law.	Conserve and valorise the margins (lagoon systems)	2
OS4. Competitiveness Promote the economic competitiveness of the coastal zone, sustainable utilization of resources.	LE4.1. Ensure conditions for the development of port activity.	Qualify the ports	6
		Qualify the infrastructures and facilities of support to local fishing	11
	LE4.3. Promote the sustainable exploitation of marine AND lagoon resources	Valorise and qualify lagoon resources	3
		Monitor the halieutic resources	1
	LE4.4. Promote the valorisation of touristic resources of the coastal zone and the qualification of touristic destinations.	Diversify the supply of touristic products	10
		Improve the conditions of circulation and parking in the seafronts	7
		Improve the infrastructures of support of beach tourism, nautical and wave sports	11
		Valorise the settlements in cultural terms	10
		Valorise and qualify seafronts in urbanistic terms	27
OT1. Beaches. Valorise and qualify the maritime beaches as a natural, social, and economic resources	LE5.1. Ensure the preservation of beaches, dune systems and associated cliffs, and coastal natural spaces and landscapes	Valorise and qualify the maritime beaches (areas to be requalified)	62
	LE5.2. Ensure the safety and protection of users and beach supporting facilities.	Valorise and qualify the maritime beaches (demolitions)	18
	LE5.3. Improve the quality of access and reception of users, namely the users with conditioned mobility.	Valorise and qualify the maritime beaches (pedestrian accesses)	19
		Valorise and qualify the maritime beaches (car parks)	54
		Valorise and qualify the maritime beaches (removable structures of support)	1
		Valorise and qualify the maritime beaches (access and permanence of people with conditioned mobility)	4
	LE5.4. Ensure the control of flows and the promotion of soft transport modes in the access to beaches.	Create conditions for soft modes and control the flows	44
OT2. Monitoring, evaluation and integrated management. Ensure a multi-level, participa-ted, and pro-active governan-ce of the coastal zone, based on monitoring and evaluation processes	LE6.1. Ensure the regular and systematic monitoring of the sediment dynamics of the coastal zone, evolution of the shoreline, and performance of coastal defence / protection works	Assess and monitor the situations of risk	3
	LE6.3. Promote research and the development of new approaches of coastal protection and integrated management of the coastal zone.	Develop web tools	1
		Study and assess innovative solutions	3
	LE6.4. Promote technical training and the provision of tools to support local coastal planning and adaptation to climate change.	Elaborate sectoral and municipal plans of adaptation to climate change	2
	LE6.5. Raise awareness of coastal communities and visitors on the sensitivity and importance of coastal ecosystems, and on the need of adopting a cautionary behaviour under risks & climate change	Communicate and raise awareness	4
		Create systems of information, warning and signalling of risk areas	2

Table I. Distribution of the actions per project, Strategic Line, and Strategic Objective of the POC-ACE. Source: POC-ACE 2018 a, p.23-25.

With a view to the concretization of the Sectoral Objective OS1, and its Strategic Lines (LEs, i.e. specific objectives), the POC set the following interventions (projects):

- The **LE1.1** includes interventions of beach nourishment (with the aim of promoting a greater protection through the natural defence offered by beaches, the maintenance of the width of the sandy area, and the development / maintenance of economic and recreational activities of beaches).
- The **LE1.2**. includes actions of dredging and transport of sediments to beaches, in order to promote a greater sediment balance and a greater efficacy of the natural sedimentary dynamic.
- The **LE1.4** includes the demolition of facilities and houses in sites of high susceptibility to risk and the subsequent resettlement of populations and re-naturalization. In some parts of settlements and some buildings located in areas of mid / high susceptibility, and given the monitoring results, other types of adaptation actions may be equated (e.g. protection or accommodation of residential areas or facilities, relocation of specific structures, or increase in the permeability of soil).
- The **LE1.5** includes actions of maintenance and rehabilitation of the existing coastal defence structures, namely revetment structures, concrete seawalls, and groynes, as well as improvements of the performance of defence structures, stabilization of cliffs in critical stretches in a way the boosts their function of coastal protection; and *soft protection* solutions in sandy littoral like geomorphological and ecological reinforcements of dune systems (POC-ACE 2018, p.146).

Actions	Promoting Entity	Investment (Euros)
Artificially nourishing the sandy areas of the beaches of Almada	APA	30 750 000
Dredging the zone upper to the Óbidos Lagoon and treat the dredged materials	APA	15 857 799
Ecologically restore the area of the Detailed Plan of Fonte da Telha	APA	7 474 398
Stabilize the cliff at the north of Azenhas do Mar	APA	3 441 000
Minimize the risk in the cliffs of Porto das Barcas	APA	3 000 000

Table J. Main interventions regarding Coastal Risks. Source: translated from POC-ACE 2018, p.148.

With a view to the concretization of the Sectoral Objective OS2, and its Strategic Lines (LE, i.e. specific objectives), the POC set the following interventions (projects):

- The **LE2.1** includes actions of recovery and restoration of the dune chains, to limit the risk of rupture and the access to dune ecosystems (e.g. by motor vehicles).
- The **LE2.2** includes actions of protection and valorisation of habitats (namely lagoon systems) in order to avoid and limit the loss and degradation of natural habitats and biological heritage, as well as actions of protection and valorisation of marine resources and local biodiversity.
- The **LE2.3** includes actions of preservation and recovery of priority ecosystems (e.g. by controlling exotic invasive species), landscape recovery of degraded areas, valorisation of coastal ecosystems, and other actions that promote the reduction of anthropic pressures on coastal biophysical systems.
- The **LE2.4** includes actions to protect (maintain) and valorise the character, singularity, and value of the landscapes, and their ecological functions and scenic quality (POC-ACE 2018, p.149).

With a view to the concretization of the Sectoral Objective OS3, and its Strategic Lines (LE, i.e. specific objectives), the POC set the following interventions (projects):

- The **LE3.1** includes actions to improve the quality of waterlines, namely the clearance, rehabilitation, and regularization of waterlines (with the aim of maintenance, improvement or re-establishment of the natural drainage system) and actions of monitoring of the quality of coastal bathing waters (to verify if they are adequate for bathing purposes, in accordance with the legislation in force).
- The **LE3.2** includes actions of investigation and supervision of discharges, definition of perimeters of protection around water catchment points, and remodelling (refurbishment) of sewage systems.
- The **LE3.3** includes actions of conservation and valorisation of the natural characteristics of the margins of lagoon systems, including the improvement of the landscape and hydro-morphological conditions of the limits of lagoons (POC-ACE 2018, p.150).

With a view to the concretization of the Sectoral Objective OS4, and its Strategic Lines (LE, i.e. specific objectives), the POC set the following interventions (projects):

- The **LE4.1** includes actions to improve, qualify and reinforce the infrastructures and facilities of support to fishing activity and port activity.
- The **LE4.3** includes actions associated to the creation of bivalve, which aim to improve the conditions of exploitation and commercialization, as well as the monitoring of fishing activities.
- The **LE4.4** includes actions to reinforce the capacity and conditions of bathing tourism and wave sports, actions of cultural valorisation of settlements, namely qualification and valorisation of the singularity of historical-cultural heritage, improvement of infrastructures of support, diversification of the touristic products (e.g. nature tourism, pedestrian paths, cultural tourism); actions of planning of seafronts (e.g. urban requalification, valorisation and zoning of public spaces in the interface urban forefront / seafront, and improvement of car circulation and parking) (POC-ACE 2018, p.151).

To achieve the Transversal Objective OT1, and its Strategic Lines, the following interventions were set:

- The **LE5.1** contains the actions envisaged in the Plans of Intervention on Beaches, and for the beach-dune systems and associated vegetation and contiguous spaces that interfere in the erosive dynamic. It includes actions of dune recovery, recovery of degraded vegetation and valorisation of other areas.
- The **LE5.2** contains actions envisaged in the Plans of Intervention on Beaches, namely the demolition of constructions (e.g. beach facilities or support facilities) in order to valorise and qualify beaches.
- The **LE5.3** includes diverse actions of valorisation and qualification of maritime beaches, namely actions of improvement of pedestrian accesses and car accesses to beaches, in consonance with the preservation of ecological resources; as well as actions to reduce impacts on biophysical systems (e.g. implementation of wooded elevated walkways, creation of appropriate car parks, improvement of the access conditions for people with conditioned mobility).
- The **LE5.4** includes actions to promote soft modes of circulation (e.g. bicycle paths) and relocation of car parks to areas outside urban seafronts (favouring pedestrian access, and harmonizing the urban fruition of seafronts with their susceptibility to erosion and sea advance) (POC-ACE 2018, p.153).

To achieve the Transversal Objective OT2, and its Strategic Lines, the following interventions were set:

- The **LE6.1** contains actions of regular monitoring and evaluation of the maintenance of the efficacy and performance of existing structures and of the risk areas. It includes the evaluation and monitoring of risk situations (e.g. of coastal erosion, sea overtopping inundations and floods, mass movements and instability in cliffs), as well as studies and other monitoring initiatives of the built-up areas located in risk zones and a permanent evaluation and control of risks.
- The **LE6.3** contains actions to study and assess the creation of new defence structures in more critical situations / sites, namely innovative solutions, as well as actions to allow an easy access and availability of integrated information about the coastal zone.
- The **LE6.4** contains actions to develop instruments and tools to support decision-making and a correct management and adaptation to new climatic, sedimentary, morpho- and hydrodynamic assumptions.
- The **LE6.5** includes actions to develop warning systems, improve the information provided and the signalling of risk areas identified, including warning signals in Risk Areas and awareness-raising campaigns about existing hazards and communication programmes (POC-ACE 2018, p.155).

Action	Promoting Entity	Investment
Install signals and indications in Risk Areas	APA	500 000
Elaborate the Municipal Plans of Adaptation to Climate Change	APA	400 000
Monitoring the coastal protection / defence structures	APA	300 000
Monitoring coastal dynamics and morphology of beaches	APA	300 000
Monitoring the risk areas	APA	300 000

Table K. Main interventions regarding Monitoring, Evaluation, and Integrated Management. Source: POC-ACE 2018, p.155.

3.4. POC-ACE'S GOVERNANCE MODEL: INTEGRATED MANAGEMENT, AND MONITORING AND EVALUATION

The governance model of the POC-ACE aims to promote '*a strategic, proactive and participated management*' of the coastal and a multi-level governance, supported in a four-year process of monitoring and evaluation of the Programme and the coastal zone (POC-ACE 2018, p.145, 160, 154; 2018 a, p.12).

The POC recognizes the need of a process of integrated coastal management and shared responsibility to allow a sustainable development of the coastal zone. One of the priorities of the POC is to ensure the integration of public policies with incidence in the territory ACE and an articulated action between the diverse entities with competences in this coastal zone. A shared accountability implies concerted responses and joint efforts of the involved actors in the execution of actions, and, thus, an effective governance model (POC-ACE 2018, p.145-146)[62] (see Note 359).

According to the POC, the definition of a governance model that allows an effective integrated management (as proposed by the Decree-Law n.159/2012, Law n.º 31/2014, and GTL Report), and the concretization of an integrated (systemic, transversal, intersectoral, and interdisciplinary) approach that ensures an integrative and prospective vision of the coastal zone (as defined in the ENGIZC), require mechanisms of engagement of diverse actors during the POC's elaboration and implementation – namely, mechanisms of participated management, monitoring and evaluation, during the phase of implementation (POC-ACE 2018, p.159; 2018 d, p.111). The POC recognizes the need of reinforcing institutional articulation.[63] Thus, it aims to: strengthen vertical and horizontal articulation, and create mechanisms of multilevel governance, e.g. by enhancing the coordination between the central and local administrations and the articulation between the POC and municipal spatial plans. The governance model proposed seeks to: reinforce the institutional, technical, and operational cooperation, increase the proactiveness and efficiency of public interventions, and ensure the regular systematic monitoring of the coastal zone (given its high vulnerability to coastal risks) to allow spatial planning to timely respond to the evolution of territorial threats and opportunities (POC-ACE 2018 d, p.111).

3.4.1. THE POC-ACE'S MODEL OF INTERVENTION / GOVERNANCE MODEL

The governance model of the POC is structured in 3 functions: management, follow-up, and monitoring (POC-ACE 2018, p.161; 2018 d, p.111):

- The function of management is under the responsibility of APA, which must steer the execution of the POC, namely the licencing and execution of actions of coastal protection and management of the hydric domain; regularly follow-up of the implementation of the POC by the diverse actors and ensure concertation between them; define (in articulation with other actors) the annual framework of interventions, the responsible entities and the amount of investment (based on the Program of Actions).
- The function of follow-up must guarantee the engagement of all entities with responsibility in the planning and development of the coastal zone, during the elaboration, implementation and follow-up of the POC. This function will be fulfilled through annual meetings promoted by APA to appreciate the socioeconomic evolution of the coastal zone, identify insufficiencies and obstacles to the POC's concretization and measures to overcome them, analyse the results of the monitoring of the POC and define new priorities of intervention.
- The function of monitoring will be ensured through a system of indicators and a process of collection, analysis, and presentation of results. It will involve various actors, under central responsibility of APA.

[62] The POC underlines that the definition of an 'operational model' is fundamental for the success of the Programme, given the exiguity of financial resources, and to ensure an effective harnessing of opportunities provided by the EU financial instruments (POC-ACE 2018, p.145).
[63] The need of reinforcing the institutional articulation and creating mechanisms of multilevel governance was one of the lessons of the POOCs. The 'Report of the Evaluation of the Implementation of POOCs' showed that it was imperative to ensure the concertation of actions of central and local administrations, and promote the compatibilization of the new POC with the municipal and regional plans (POC-ACE 2018, p.159).

3.4.2. The 'System of Monitoring and Evaluation' of the POC-ACE

According to the POC, monitoring involves the systematic observation and measurement of the physical, chemical, and biological systems, in order to assess their characteristics and changes over a period of time. The POC recognizes several reasons that may justify monitoring: it may be required by legislation, it may be needed as a warning mechanism that serves to register events and determine when a situation reaches a point that requires intervention, or it may be used as a research instrument (i.e. to compile a series of basic data for a wide range of investigations). For the POC, in the field of planning, monitoring has a fundamental role, as it can contribute to a greater effectiveness of the process itself, that is, to ensure greater adequacy of the planning instrument (i.e. the POC) to what is expected to be achieved with it. Moreover, environmental monitoring is essential for the implementation of any policy on sustainability (without the monitored information, it would be impossible to define targets and evaluate the impacts of the actions taken (POC-ACE 2018, p.164; 2018 d, p.114). The exercise of monitoring not only implies the collection of data and information, but also a regular and systematic evaluation over time (such evaluation differs from the assessment of alternatives due to the temporalities associated to such assessment). A duly structured monitoring programme must ensure a continuous cycle of interactions between its results and demonstrate positive and negative aspects (ibid).

The Strategic Model of the POC assumed as one of its objectives to ensure monitoring, evaluation and integrated management (POC-ACE 2018 d, p.111). As mentioned, the POC's governance model aims to promote *a strategic and proactive coastal management* supported in a four-year process of monitoring and evaluation of the Programme and of the coastal zone (POC-ACE 2018 a, p.12; 2018, p.160, 145). Such monitoring is essential '*to ensure a strategic, planned and adaptive management of the coastal zone*', and to allow the regular evaluation of the Program of Actions (POC-ACE 2018 a, p.12; 2018, p.160, 145). For the POC, on the one hand, '*the monitoring is fundamental to assess the results obtained with the implemented actions and the level of concretization of the actions and performance of the POC in the end of the first four years (the only period for which the POC presents estimates of financial investment), and, on the other, monitoring will allow readjusting priorities in function of the ongoing territorial dynamics and of the evolution of the economic-financial context and, consequently, define a feasible framework for action for the subsequent quadrennium*' (POC-ACE 2018 a, p.12; 2018, p.145, 160). In other words, the monitoring will allow the readjustment of priorities according to the territorial dynamics underway and the evolution of the economic conditions and their repercussions on the capacity of execution of the actors involved, and, consequently, the definition of an adequate financial frame for the next four years (POC-ACE 2018, p.160).

The POC, in the Norm NG1 (on coastal risks) highlights it is necessary to *'ensure the monitoring, assessment and integrated management of coastal risks* (…), which requires '*the regular and systematic monitoring of the sediment dynamics, evolution of the shoreline, and performance of the coastal protection / defence works'* (POC-ACE 2018 d, p.53). It also refers that it is necessary to *'regularly monitor the uses and occupations of the areas encompassed by the Strips of Safeguard, the extreme weather events and the mass movements, as well as the costs resultant from damages and destruction, with the aim of developing a proactive adaptive management of the settlements, which must ponder planned retreat supported by cost-benefit analyses'* (POC-ACE 2018 d, p.71).

The implementation of the monitoring system will involve a sequence of regular procedures / stages:

1) collection of basic information about the indicators (output indicators and outcome indicators).
2) treatment of information, namely about the outcome indicators.
3) presentation of a 4-year monitoring report based on quantitative data on the indicators and qualitative data collected during the annual follow-up meetings. Such reports will be the basis to support the evaluation of the Program of Actions (POC-ACE 2018, p.162; 2018 d, p.112).

The monitoring reports must be presented in the follow-up meetings, and support the final evaluation of the POC that precedes its review (POC-ACE 2018, p.162; 2018 d, p.112).

Regarding the outcome indicators, the system of information will be structured in a set of databases that integrates the diverse indicators in a vertical way, from the most general to the most specific. There will be a central database based on APA and organized per Strategic Objective, where all information about the outcome indicators must be inserted.
Regarding the output indicators, the information collected must be directly uploaded by the entities responsible for the execution of actions / projects, in model-fiches provided by APA (the entities must send the information to APA). The collection of information on the outcome indicators must occur with an annual periodicity and ensure: the collection from proper sources (some indicators are based on information already systematized by some entities, or result from the execution of coastal defence interventions and licencing processes of activities); a collection based on protocols with other entities. The outcome indicators must be periodically provided by the entities responsible for executing the projects defined in the Program of Actions. The information on outcome indicators must be systematized by APA, according to the contributions sent by the involved actors. Then, APA must present a central database (synthesis of all achievements) (POC-ACE 2018, p.162-163; 2018 d, p.113) (Note 360).

Based on the monitoring results, APA must, in the end of every four years, carry an evaluation of the Program of Actions. This exercise will involve an analysis of the obtained results (namely the level of concretization of the actions proposed, and of the general performance of the Program of Actions), and a revisitation of the priorities and actions proposed for the next four years, and, thus, it must readjust / redefine the actions to be carried (including their definition, scheduling, and financial sources). The reports of evaluation must be presented and analysed in follow-up meetings of the POC (POC-ACE 2018, p.163; 2018 d, p.113). Thus, the Program of Actions will be evaluated and re-programmed every four years. Such evaluation must consider the monitoring results and be discussed with all relevant entities, namely the Consulting Commission of the POC. The reprogramming involves the redefinition of the investments for the next four years (presented per year) (POC-ACE 2018, p.146,160; 2018 d, p.112).[64] Moreover, the Program of Actions will inform, every year, the 'Annual Plan for the Littoral' (Note 361).

Monitoring indicators

The POC's monitoring programme aims to keep track of the implementation of the POC and evaluate the effects associated to its concretization. It resorts to two types of indicators:

- **Output indicators**. These indicators serve to follow the execution of the POC at a strategic and operational level, namely evaluate the level of concretization of the Program of Actions and of the model of intervention and Territorial Model. These indicators were created based on the programmed actions and the Territorial Model, and include indicators to appreciate the evolution of the territorial vulnerability. These indicators are relevant for the entities responsible for the POC's implementation.
- **Outcome indicators**. These indicators serve to appreciate the level of achievement of the objectives. These indicators are revealed in thematic, spatial, and temporal terms, in line with the POC's objectives. Their function is to keep track of direct immediate effects in environmental, socioeconomic, territorial, and institutional terms (POC-ACE 2018, p.164; 2018 d, p.115).

The POC defined 36 output indicators and 36 outcome indicators, to monitor the execution of the Programme and the results achieved with its implementation (Table L and Table M).

[64] The POC-ACE will be implemented in three cycles of four years; each cycle will be preceded by a process of evaluation of the level of execution of the Program of Actions, which will include its review if necessary, and a redefinition of the framework of investment for the next four years (POC-ACE 2018 d, p.112).

Output indicators per strategic objective	Units	Periodicity	Target	Source (entity)
Coastal Risks				
Interventions of rehabilitation and maintenance of coastal defence works	nº; €	Four-year	9	APA
Interventions of re-establishment of the sediment balance	nº; €	Four-year	1	APA
Interventions of re-settlement of populations to sites / areas with lower susceptibility to risks	nº; €	Four-year	8	APA
Intervention of soft contention in zones of sandy littoral	nº; €	Four-year	2	APA
Interventions associated to the mitigation of risks in cliffs	nº; €	Four-year	23	APA
Natural Values				
Specific interventions of reinforcement and restoration of the dune chains	nº; €	Four-year	3	APA
Interventions of protection and valorisation of habitats (lagoon systems)	nº; €	Four-year	4	APA and CM
Interventions of protection and valorisation of marine habitats	nº; €	Four-year	4	CM
Interventions of preservation and recovery of priority ecosystems	nº; €	Four-year	6	INCF, CM and APA
Interventions of valorisation of coastal ecosystems	nº; €	Four-year	3	CM
Interventions of protection and valorisation of geomorphological formations and paleontological spaces	nº; €	Four-year	5	CM
Interventions of valorisation and interpretation of coastal landscapes	nº; €	Four-year	2	CM
Hydric Resources				
Requalified and valorised waterlines	nº; €	Four-year	2	APA and CM
Annually monitored bathing waters	nº; €	Annual	96	APA
Actions of investigation and supervision associated to discharges and definition of perimeters of protection around water catchment sites	nº; €	Four-year	15	APA + SMAS
Interventions of conservation and valorisation of margins (lagoon systems)	nº; €	Four-year	2	CM
Competitiveness				
Interventions in ports	nº; €	Four-year	6	DOCAPESCA
Facilities and infrastructures of support to local fishing	nº; €	Four-year	11	CM + DOCAPESCA
Interventions of promotion of bivalve in nursery farms	nº; €	Four-year	3	CM + DGRM
Interventions of monitoring of halieutic resources	nº; €	Four-year	1	CM
Intervention of cultural promotion and valorisation	nº; €	Four-year	10	CM
Infrastructures of support to nautical activities and wave sports	nº; €	Four-year	11	CM
Maritime beaches and bathing areas				
Interventions of urban valorisation and qualification in urban forefront	nº; €	Four-year	26	CM
Interventions of valorisation and qualification of the maritime beaches and bathing zones (areas to be requalified)	nº; €	Four-year	62	APA
Demolitions / reconstructions executed	nº; €	Four-year	18	APA
Interventions of improvement of the pedestrian accesses and car accesses to maritime beaches and bathing zones	nº; €	Four-year	73	APA
Interventions of improvement of the access and permanence of people with conditioned mobility	nº; €	Four-year	4	APA
Monitoring, evaluation, and integrated management				
Studies of evaluation & monitoring of pathways, dimension of sandy zone	nº; €	Annual	12	APA
Studies of evaluation and monitoring of the coastal defence structures	nº; €	Annual	3	APA
Studies of evaluation and monitoring of the areas and situations of risk	nº; €	Annual	3	APA
Studies regarding sedimentary dynamics and hydrodynamics	nº; €	Four-year	1	APA
Studies regarding innovative solutions (defence works)	nº; €	Four-year	1	APA
Creation of web tools for integrated coastal management	nº; €	Annual	1	APA
Municipal plans of adaptation to climate change (elaborated)	nº; €	Annual	15	APA
Actions of signalling of risk areas	nº; €	Annual	12	APA
Actions of awareness raising, communication on coastal risks+ climate ch.	nº; €	Annual	12	APA

Table L. Output indicators of the monitoring programme of the POC-ACE, organized per Strategic Objective, and indicating the periodicity of measurement and responsible entity. Source: POC-ACE 2018, p.165.

Outcome indicators per strategic objective	Units	Periodicity	Source (entity)
Coastal risks			
Occurrence / events of sea overtopping inundations	Nr	annual	CM / ANPC
Variation of the extension of soil in Strips of Safeguard in Littoral Cliff	ha; %	Four-year	APA
Variation of the extension of soil in Strips of Safeguard fr/ Coastal Erosion	ha; %	Four-year	APA
Variation of the extension of soil in Strips of Safeguard fr / Sea Overtopping Inundations and Coastal Floods	ha; %	Four-year	APA
Variation in the number and cost of emergency interventions of coastal defence	ha; Eur; %	Four-year	APA
Variation of the population living in Strips of Safeguard in the AI	%	2011-2021	INE
Variation in the number of houses in the Strips of Safeguard in the AI	%	2011-2021	INE
Variation in the number of licensed urbanistic operations in the Strips of Safeguard	nr; %	Four-year	CCDR / CM
Occurrence of instability and mass movements in cliffs	nr	annual	APA
Maximum local retreat, per stretch of cliffs	m	annual	APA
Borrow sites identified (characterization and inventory)	nr	Four-year	APA
Natural Values			
Area occupied by exotic invasive vegetal species	m^2	Four-year	ICNF
Area recovered per habitat	m^2	Four-year	ICNF
Variation in the number of species with an unfavourable status of protection	%	Four-year	ICNF
Visitors registered in the centres of interpretation or sites of observation of avifauna	nr	Annual	CM / ICNF
Hydric Resources			
Quality of bathing waters *	nr	Annual	APA
Ecological state of the coastal waters *	nr	Annual	APA
Ecological state of coastal waterlines *	nr	Annual	APA
Environmental state of the marine environment *	nr	Annual	APA
Competitiveness			
Facilities of beach support with functions of support to sports	nr	Annual	APA
International and regional championships of wave sports per year	nr	Annual	FPS, APK
Companies with maritime-touristic activities registered	nr	Annual	Turismo PT
Touristic facilities in the area of intervention	nr	Annual	Turismo PT
Number of beds in the area of intervention	nr	Annual	Turismo PT
Fishermen registered, per fishing segment	nr	Annual	DGRM
Evolution of the fish discharges (in the docks and points of sale)	%	Annual	DGRM
Maritime beaches and bathing zones			
Rate of coverage of the beach support facilities **	%	Four-year	APA
Rate of execution of the car parking areas **	%	Four-year	APA
Rate of execution of the actions of recovery of the dunes **	%	Four-year	APA
Extension of the pedestrian area in the urban seafront of settlements	km^2	Four-year	CM
Extension of the bicycle paths in the area of intervention	km^2	Four-year	CM
Monitoring, evaluation, and integrated management			
Rate of execution of the actions envisaged in the municipal plans of adaptation to climate change	%	Four-year	APA
Annual variation in the number of users of the web tools of integrated management	%	Four-year	APA
Beaches with updated signals of hazards in the beginning of the high season	%	Annual	APA
Occurrence of events of instability of cliffs identified in the monitoring and corrected before the beginning of each high season	%	Annual	APA
Level of actualness and improvement of the cartography and complementary information	%	Four-year	APA

Table M. Outcome indicators of the POC-ACE. Source: POC-ACE 2018, p.166. * evaluation of the parameters of sampling according to the legislation. ** envisaged in the Plans of Intervention on the Beaches and Bathing Zones.

3.5. Critiques and comments to the POC-ACE received during public consultations

This section sums up some of the main comments and critiques regarding the Strategic Environmental Assessment (and the POC-ACE), received during public consultations on the SEA, and with relevance for analysing the POC against the key-elements of an Adaptive Planning and Management approach.

- The **Municipality of Almada** underlined that '*adaptation and resilience to different scenarios of climatic evolution should be part of a Programme like a POC, and this should be considered a strategic issue, otherwise an important opportunity to address this issue in a consistent way would be lost*' (POC-ACE 2017, p.213). The Municipality argues that, given the multiplicity and complexity of the coastal issues in the area of intervention, the elaboration of evolutive scenarios should constitute an important prospective tool to grasp the possible hypotheses of evolution of the territory and the resulting conflicts, and to better substantiate the model of planning developed. Thus, 'adaptation to climate change' should have been one of the Strategic Issues (*Questões Estratégicas*) considered in the SEA (ibid, p.218, 223).

  According to this Municipality, the analysis of risks has focussed more on the urban settlements located in cliff littoral than in the identification of urban zones located in the strips of risk with other coastal profiles (e.g. dune, dune-cliffs, or areas adjacent to protection structures). This gap is particularly relevant in the coastal stretch between Cova do Vapor and Fonte da Telha. The Municipality claims that it should have been included a risk analysis for the coastal urban settlements of Almada (POC-ACE 2017, p.213). Moreover, the Municipality argues that it was important to include in the SEA a ponderation of the illegal occupations of the territory, with an analysis of the risks associated to their maintenance and an indication of options and alternative scenarios (POC-ACE 2017, p.213).

  Regarding the Strips of Safeguard that intersect urban areas, the Municipality advocates that both the POC and its SEA should integrate information already available on the impacts of extreme weather events and projected scenarios of climatic evolution, namely the information of the Detailed Plan of Fonte da Telha (*Plano Pormenor da Fonte da Telha* - PPFT). This information results from a modelling exercise carried by the Geology Centre of the Faculty of Sciences of the University of Lisbon in partnership with the Municipality of Almada, in the scope of the development of the Detailed Plan (which set risk strips and strips for protection in relation to the sea and the cliff). The width of the strips adopted in the PPFT is more conservative than the defined in the POOC Sintra-Sado (ibid, p.214).

  The Municipality also recommended reformulating the indicators listed in the SEA to allow a more detailed and targeted monitoring of the territorial resilience to current and future risks, of the evolution of the territory and of the concretization of the POC. It proposed adding the following indicators: areas susceptible to sea overtopping inundations and floods, projects that contemplate measures of adaptation at the level of biodiversity and ecosystems, areas susceptible to the risk of earthquakes and tsunamis, interventions that include measures to reinforce local resilience and / or adaptation to extreme weather events, solutions that favour the environmental services of ecosystems (ibid, p.217, 223, 224).

- Regarding the safeguard from coastal risks, the **Municipality of Cascais** highlighted that the Municipal Director Plan of Cascais has already produced risk maps (cartography) in line with the guidance provided by APA, and that the POC has produced new risk maps with a different methodology and at different spatial scales. The Municipality underlined that the classification of risk and the respective measures of prevention and minimization of risk are within the municipal competences[65], and raised doubts on the consonance between the POC's risk maps (in specific, of the Strips of Safeguard from Coastal Risks in Sandy Littoral and in Cliff Littoral) and the cartography of risks and susceptibility of

[65] In accordance with the article 13th of the RJIGT, the territorial plans delimit the hazard and risk areas, identify elements vulnerable to each risk and establish the rules and measures for the prevention and minimization of risks in function of the levels of hazardousness and in accordance with criteria established by the responsible entities.

the Municipal Director Plan (PDM), and about the POC's effects on the planning proposals of the PDM. Given this, for the Municipality, it was important to clarify the methodology and criteria used for delimiting the Strips of Safeguard from Coastal Risks (presented in the POC's report of Characterization and Prospective Diagnostic), and ensure the compatibilization of such strips with the cartography of risks and susceptibility of the PDM of Cascais (POC-ACE 2017, p.226).

The municipalities must transpose to their diverse spatial and strategic plans the guidelines and proposals of the POC-ACE. The Municipality of Cascais, drawing on the RJIGT, has raised the doubt of whether the proposals of the POC were not going beyond the legally establish competence of the POC. The article 13th of the RJIGT establishes that: 1) the programmes and territorial plans identify and delimit the hazard and risk areas, develop, and concretize them; 2) the territorial plans delimit the hazard and risk areas, identify the elements vulnerable to each risk and establish the rules and measures for the prevention and minimization of risks in function of the levels of hazardousness and in accordance with criteria established by the responsible entities (*in* POC-ACE 2017, p.228). This issue is relevant since the POC defines, for certain areas, the relocation of built assets to zones of lower susceptibility to risk, and this task is allocated to the Municipality. The Municipality of Cascais argues that this issue should be subjected to a juridical analysis, and that the POC may be exceeding what is enshrined in the RJIGT. For the Municipality, this issue should be treated at the municipal level, regardless of the constraints that this may represent to the territorial planning (POC-ACE 2017, p.228).

❖ The CCDR LVT (Commission of Coordination and Regional Development of Lisboa and Vale do Tejo) highlights that it was necessary to assess the situations in which the strategy contained in the Municipal Director Plans diverges from the strategy and principles envisaged in the POC-ACE.

Moreover, for the CCDR LVT, '*the actions proposed for the Critical Areas, which consider the risk associated but also the diverse expected impacts (social, economic, etc.), namely in the case of relocation / planned retreat, justify an approach with a greater level of detail*' (POC-ACE 2017, p.229).

In addition, the CCDR LVT underlines that there was no assessment of the effects resulting from the extraction of materials (sediments) from the borrow sites identified within the Cell 4, and considering the situations of sediment deficit known in this cell (POC-ACE 2017, p.230). While the SEA refers the risk of flooding due to tsunamis, it is unclear how this risk is addressed in terms of assessment criteria. Moreover, in the areas susceptible to coastal floods and sea overtopping inundations and in areas susceptible to the risk of earthquakes and inundation due to tsunamis, the 'artificialized areas' should be differentiated from 'non-artificialized areas' (POC-ACE 2017, p.230). Moreover, the SEA should have deepen the analysis of risks associated to extreme weather events (POC-ACE 2017, p.233).

CCDR LVT highlighted that it was important to assess whether the norms (for the contention of coastal risks) set for the Strips of Safeguard from Coastal Risks do not compromise some land uses or activities that should be boosted (POC-ACE 2017, p.231). For CCDR LVT, given the issues of territorial planning and territorial dynamics 'on the table', it would have been desirable to carry an assessment of the POC's proposals against the strategies enshrined in diverse spatial planning instruments, namely the municipal spatial plans. This would allow identifying situations of inadequacy between the current municipal strategies and the strategies defined by the POC, and those that require alterations.[66] Regarding the 'urban areas of illegal genesis' (AURI), the POC refers that it should be pondered the need of relocation and resettlement of population, in line with the respective municipal spatial plans in force, and this required an improved knowledge of each concrete situation and of the actuality (update) of the proposals

[66] The SEA was issued prior to the completion of the process of elaboration of the POC, in a moment at which the Norms (Directives) had not yet been produced, therefore, the assessment of the opportunities and threats (risks) associated to the implementation of the POC did not account for such Norms (but, on the contrary, the content of the SEA contributed to the definition of the Norms) (POC-ACE 2017, p.229).

of the municipal spatial plans. The current LBSOTU and the RJIGT constitute opportunities to concretize the strategy of the POC, namely in terms of classification of the soil (POC-ACE 2017, p.231).

CCDR LVT suggested that the SEA should have further clarified the articulation of the POC's proposal with other policies and spatial planning instruments applicable to the area of intervention, and further recognized potential conflicts in terms of utilization and occupation of the land, to anticipately plan adequate measures.[67] For example, the CCDR questioned whether promoting the planned adaptation of urban settlements (to coastal erosion, sea overtopping inundations and floods) could not be taken as an opportunity to articulate different strategies from different entities (POC-ACE 2017, p.232, 233).

- The **Municipality of Sintra** argued, that the POC-ACE, in several of its documents, namely in the Territorial Model, Directives, and SEA, has disregarded the existence of Detailed Plans in force, that had been recently published and which resulted from work carried in conjunction with APA (and in line with the prior POOCs) (POC-ACE 2017, p.234). For this Municipality, the process of the SEA has not considered the municipal spatial plans recently elaborated. Moreover, the SEA should have presented proposals for improving the documents of the POC (POC-ACE 2017, p.234).

In accordance with the legislation in force, the POC must be transposed to the PDM of the various municipalities, to ensure the conformity of the two plans in terms of regulation and plans (cartography). In the process of transposal, conflicts may arise, e.g. the POC may constrain the strategy of development defined by a municipality (POC-ACE 2017, p.148).[68] The need of ensuring the compatibilization of the various Municipal Director Plans (PDMs) with the POC was recognized in the SEA Report. Importantly, many of the municipalities in the area of intervention were reviewing their respective PDM when the POC was under elaboration, and which could have facilitated the integration of the POC's proposed in the municipal spatial planning (POC-ACE 2017, p.147).

During the elaboration of the POC-ACE, several meetings of concertation with the various entities involved in the ACE area were carried, namely with municipalities. The POC sought to minimize divergences between its strategies and Territorial Model and the model of development envisioned by the municipalities, especially with regard to the coastal urban settlements and their expansion in risk zones. The SEA highlights that the articulation between entities, and the congregation of strategies, are essential to promote a planned adaptation of urban settlements in the face of coastal erosion and expected increase in the occurrence and intensity of sea overtopping events and floods, under climate change (POC-ACE 2017, p.149).

[67] Regarding the promotion of economic competitiveness, the CCDR highlights that it should assessed how the normative content of the POC, namely the norms associated to the Strips of Safeguard, and the planned adaptation of coastal urban settlements, articulate with other strategies (e.g. sectoral strategies), and evaluate whether such norms constitute opportunities or risks (in case of divergence, lack of congruency, or articulation) (POC-ACE 2017, p.232).

[68] The POC, as a special programme, aims to establish 'regimes of safeguard of natural values and resources and a regime of management compatible with the sustainable utilization of the territory by defining actions allowed, conditioned or forbidden, in function of the respective objectives' (as stated in the Decree-Law *n.º 80/2015 de 14 de maio)* (in POC-ACE 2017, p.148).

4. Process of development of the POC-ACE: stages of development

The elaboration of the POC-ACE involved several phases: 1) Studies of Characterization and Prospective Diagnostic, 2) Proposal of Programme, 3) final public consultation and Strategic Environmental Assessment of the Proposal of POC; and 4) issuing of the final version of the POC-ACE.

In the first phase, occurred between January and May 2014, the POC-ACE Team developed the Studies of Characterization and Prospective Diagnostic, which were organized in four books: 1) Assessment of the implementation of the prior POOCs (Balanço de Implementação dos POOCs), 2) Characterization of the Coastal Environmental System, 3) Characterization of the Coastal Risks, and 4) Characterization of the Urban and Economic System (POC-ACE 2018, p.15).

The several phases of the process of development of the POC-ACE are described in Figure 41.

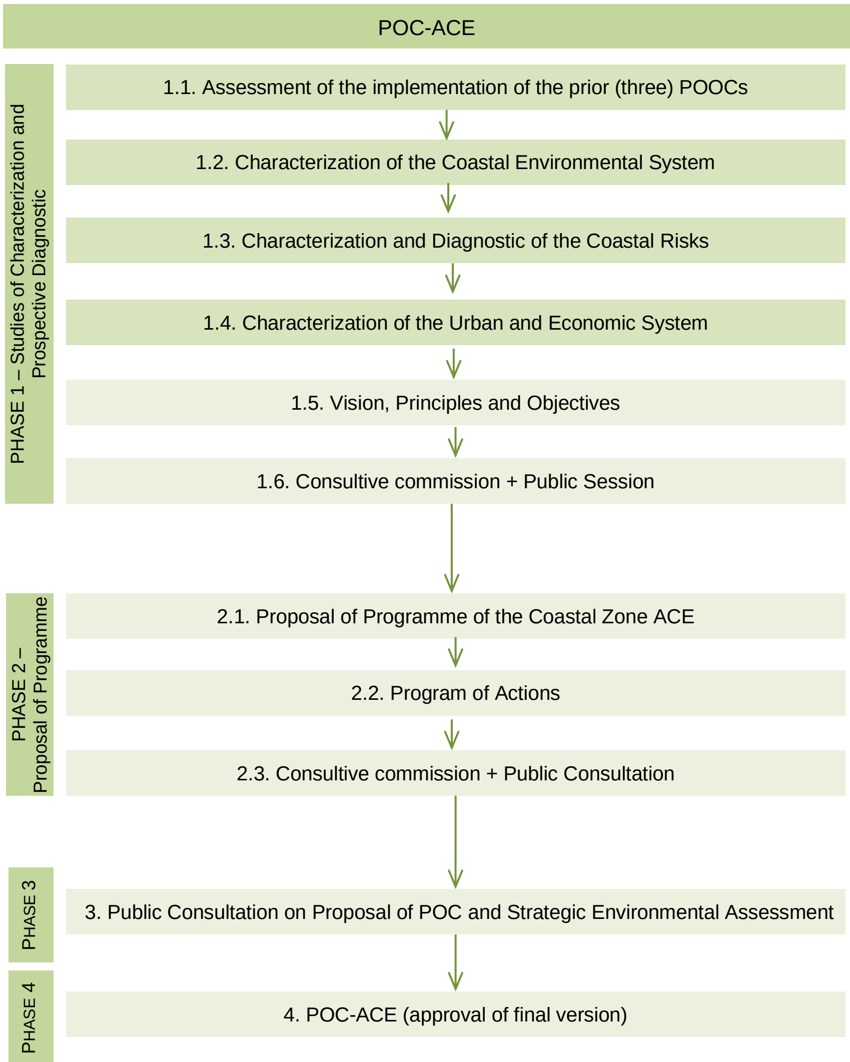


Figure 41. Main steps of the process of elaboration of the POC-ACE. Source: own elaboration, based on POC-ACE 2018, p.14-15; 2017, p.21.

The POC-ACE was approved in January 2019 (RCM nº66/2019).

4.1. Exploration of possible adaptation options – '*Scenarios of intervention*' – and Cost-benefit analyses, for the 'Critical Areas – Relocation'

The POC-ACE argues that, in addition to the strategy of sediment management that has been assumed for the area ACE, and the reduction of the exposure to coastal risks through the contention of uses and occupations of land in the Strips of Safeguard, it was indispensable to search for the most advantageous solutions for the situations that present greater hazardousness (POC-ACE 2018, p.90).[69]

In line with the recommendations of the GTL, the POC mentions that the choice of the adaptation response to address current problems and future vulnerabilities – i.e. *protection*, *accommodation*, or *planned retreat* – should be supported by cost-benefit and multi-criteria analyses that allowed a sustainable decision. In this context, for the POC-ACE, in the stretches that presented greater hazardousness (due to erosive processes and land use patterns, and risk of overtopping inundations), it was essential to envision and assess various forms of intervention, which implied the formulation of 'options' (proposals) to reduce risks – and this exercise was denominated '*scenarization*' (POC-ACE 2018, p.90). According to the POC, cost-benefit analysis is fundamental in the process of management of the coastal zone to equate the best forms of action and predict the costs and non-material benefits (the social cost of the analysis of benefits) of the diverse measures (alternatives) available (POC-ACE 2018, p.91).[70]

Exercise of 'scenarization' – development of '_Scenarios of Intervention_'

The POC-ACE explains that, in the field of spatial planning, the *exercises of scenarization* may be used in the phase of elaboration of Plans / Programmes, in three different situations which originate three different types of scenarios: 1) environmental scenarios; 2) 'scenarios of intervention' (also called 'response scenarios'); and 3) objective-scenarios. In the case of the POC-ACE, the *exercise of scenarization* involved the development of '*Scenarios of Intervention*' (also called *Response Scenarios*), which implied the formulation of various alternative solutions and the assessment of their costs and benefits. More specifically, considering a given problem, the Team sought to identify / devise various possible responses (namely in function of the level of priority that the community attributed to the minimization of the problem, or impacts that might occur, and of the financial resources that could be mobilized) (POC-ACE 2018, p.92).

For the POC, this *exercise of scenarization* was quite useful for the construction of the Model of Intervention (i.e. the *Program of Actions*), since it allowed an informed discussion on the choice of the diverse interventions that the POC should contain to adequately answer to the threats that might be faced in the problematic spaces (later called 'Critical Areas – Relocation') (POC-ACE 2018, p.92).

Moreover, this exercise of '*scenarization*' is deemed '*extremely pertinent for informing decisions and generate generalized consensus about the selectivity of options and the priority of interventions, and it*

[69] In the mid-term, it is expected that a significant number of residents in coastal settlements, and several built assets located in the coastal zone, will be affected by shoreline retreat, in low-lying sandy littoral and cliff littoral, and associated erosion processes, and by the increase in the intensity, frequency and dimension of sea overtopping inundations and coastal floods. The evolution of these phenomena will require interventions increasingly costly, regardless of the form of intervention used. The studies carried in the Phase of Characterization demonstrated that the exposure to coastal risks, and coastal erosion problems, have increased in the area of intervention, and will tend to aggravate due to the effects of climate change in weather and oceanographic conditions (POC-ACE 2018, p.90).

[70] The recommendations of diverse public policies at the European Union focused on investments on the coastal zone underline important aspects to support decision-making: improvement of knowledge about littoral dynamics (monitoring, mapping and risk assessment / analysis); ii) the incorporation of costs and existing risks in the development of planning and investment decisions (impact, cost, and human risk induced by coastal erosion); iii) the accountability for coastal management, iv) the reinforcement of the knowledge base about the management of coastal erosion and spatial planning (including cost-benefit analysis as the basis for assuming technical solutions financially viable) (POC-ACE 2018, p.90). The latter point is particularly relevant in the current context of strong restrictions to public investment and given the high dependence of Portugal on European Structural and Investment Funds (FEEI) to respond to this problem (POC-ACE 2018, p.91).

contributes to the assumption of volumes of investment that are realistic and proportionate to the effective capacity of the involved actors'. The existing budget context demands an increasing justification of the allocation of public resources. For these reasons, the cost-benefit analysis of interventions should be thoroughly developed and presented (POC-ACE 2018, p.92).

Above all, according to the Programme, these exercises of '*scenarization*' assume a great usefulness in spatial planning and management, '*as a tool to support decision-making in the short-term, as a model that ensures that the options taken in the present do not jeopardize future generations and the opportunities existent or emergent in the territory, and as an instrument of support to* ***a more adaptive planning*** *that is more adaptive to contextual changes (considering the variability of the phenomena and of the situations that the Programme will face)*' (POC-ACE 2018, p.92).

The methodology applied by the POC-ACE Team was developed based on other tools and methods used in Portugal in the last years[71]. It involved several sequenced steps (stages) in a structured rationale that allows, and leads to, the selection of the most advantageous option to be taken by the Programme / public entities in specific problem-spaces (Critical Areas – Relocation) (POC-ACE 2018, p.93):

- Step 1: description of the reference situation, including the identification of the problem under study, the definition of issues (departing questions) that frame the need of intervention, and an overview of the sensitivity and positioning of the main actors regarding the problem.
- Step 2: definition of 'base scenarios' that structure the response (or non-response), denominated '*Scenarios of Intervention*'. This implied indicating the main characteristics of each '*Scenario of Intervention*', namely the typology and extension of the interventions to be implemented and their estimated costs (including maintenance costs, assessed through an economic analysis).
- Step 3: assessment, of each of the '*Scenarios of Intervention*' envisioned, on three dimensions (economic, social, and environmental dimensions), through an analysis of benefits (against diverse descriptors that structure each of the three dimensions). This step also involved the attribution of a level of impact (positive in a scale between 1 and 5, or negative between -1 and -5). This allowed the calculation of the final score *per* dimension. The result was then pondered in function of the relevance of each dimension. These were the main elements of the analysis of benefits.
- Step 4: a new ponderation was carried based on the estimated costs and identified benefits, and on the calculation of the cost/benefit ratio for each '*Scenario of Intervention*'.

Exercise of Scenarization – development of Scenarios of Intervention	**Goal**	**Method**
	Identify responses to problems – i.e. various possible '*Scenarios of Intervention*' – and assess the possible consequences resultant from different responses, including their costs and benefits	Taking as a reference a '*Scenario of no intervention'*, compare the results of the analysis of the various alternative responses (i.e. of the various 'Scenarios of Intervention')

Table N. Method of identification and assessment of the '*Scenarios of Intervention*' for the problem-spaces. Source: extracted from POC-ACE 2018, p.92.

Importantly, in line with the recommendations of the GTL Report, the POC has sought to deliver an adaptation policy that encompassed *protection*, *accommodation*, and *planned retreat*. For the POC, the combination of these three strategies would be the most adequate solution since it allows a greater sustainability of the options in social, economic, and environmental terms. In the Directives, the three main coastal adaptation strategies are conceptualized in the following way:

[71] *Instituto de Hidráulica, Recursos Hídricos e Ambiente (IHRH / FEUP) e Sociedade Polis Litoral Norte, SA (2010) - Estudo de Vulnerabilidades e Riscos às Acções Directas e Indirectas do Mar sobre a Zona Costeira - 1ª Fase. Volume 6, Retirada Planeada.; Volume 3 Estudos de operações de alimentação artificial de praias e dunas com areias provenientes de fontes da plataforma continental e das operações de dragagem nas zonas portuárias. Avaliação de incidências ambientais. Análise custo / benefício versus eficácia como base de decisão sobre as opções de alimentação artificial de areias nas praias, com fontes offshore ou nas zonas portuárias e canais de navegação.*

- Protection. It serves to reduce the risk associated to the impacts of climate change, especially those resulting from SLR. It consists of maintaining or even advancing the line (the shoreline) by means of, for example, artificial sediment nourishments, reconstruction of dune system, construction of artificial dunes and their ecosystems, construction of hard structures such as groynes, detached breakwaters, seawalls (longitudinal adherent protection structures), etc.
- Accommodation. It aims at increasing the capacity of population to cope with such impacts and the respective risks, and it favours the alteration of human activities in the littoral and the flexible adaptation of infrastructures to reduce the risk of flooding.
- Planned retreat. It aims to reduce the risk of damaging events caused by climate change by limiting their potential effects. In terms of natural systems, planned retreat is a strategy of migration landwards, to make the coastal ecosystems less vulnerable to erosion and SLR (POC-ACE 2018 d, p.52).

Regarding *protection*, the POC has assumed, as a central measure / policy, the re-establishment of the sediment balance through operations of sediment nourishment with sediments obtained in the continental shelf, in the mouth of Tejo river, and from dredging works in the lagoons of Óbidos and Albufeira, as well as the harnessing of the potential of hydrographic basins for carrying sediments to the littoral (POC-ACE 2018 d, p.52).

For the 'problematic spaces' in sandy littoral, the POC has developed three '*Scenarios of Intervention*': Scenario A – non-intervention; Scenario B – stabilization of the shoreline through beach nourishments (and, eventually, maintenance and rehabilitation of hard defences); and Scenario C – planned retreat.

4.2. Cost-benefit analyses of the 'Scenarios of intervention' for 'Critical Areas – Relocation'

Figure 42 shows the conceptual model that substantiated the cost-benefit analyses carried by the POC-ACE Team (POC-ACE 2018, p.91). Based on this model, the Team developed a methodology to estimate, for each of the six problem-spaces (called 'Critical Areas – Relocation') defined in the Territorial Model, the costs and benefits associated to diverse alternatives of response – i.e. to assess each of the '*Scenarios of Intervention*' that had been devised in the '*exercise of* '*scenarization*'. This methodology was also applied in situations where *relocation* (planned retreat) was already enshrined in municipal spatial plans, as the case of the Parques de Campismo in Costa da Caparica, or envisaged by the respective municipality, as the case of Fonte da Telha (POC-ACE 2018, p.91).

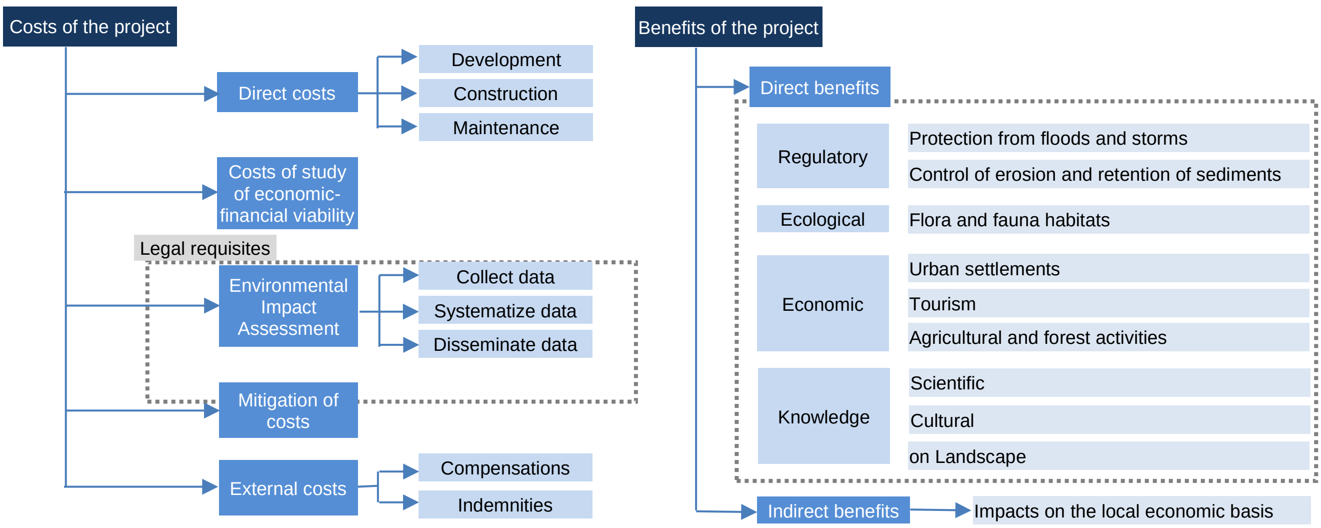


Figure 42. Conceptual model of cost-benefit analysis that served as a reference to the POC-ACE. It is based on diverse methodological approaches developed in the last years for similar cases in the Portuguese west coast. Source: POC-ACE 2018, p.91.

4.2.1. COST-BENEFIT ANALYSIS FOR THE 'CRITICAL AREA – RELOCATION' OF COVA DO VAPOR

Reference Situation
Problem
Cova do Vapor is a settlement of illegal occupation where precarious constructions prevail. It is located in an area vulnerable to natural risks (Zone Threatened by the Sea), namely coastal erosion and sea overtopping. It has an illegal genesis. There are several strategic options already defined in various spatial planning instruments, mostly focused on the re-naturalization of this territory. More specifically, the relocation and resettlement of population, followed by the re-naturalization, are envisaged in the local / municipal spatial plans approved and in force.
Departing issues / questions
1. What is the prediction of the physiographic evolution? This settlement is encompassed by the Strips of Safeguard from Coastal Risks in Low-lying Sandy Littoral (Coastal Erosion and Sea Overtopping Inundations and Coastal Floods). Climate change is expected to generate a greater persistence and frequency in storms, as well as SLR, and aggravate the hydrodynamic actions and the frequency and magnitude of overtopping events. **2. Are the built-up forefront and the shoreline to be maintained (hold-the-line)?** Hardly possible. The costs associated to successive interventions of artificial sediment nourishment and to the rehabilitation and reinforcement of adherent structures (seawalls and revetments) are too high. It is planned the relocation / resettlement of the population and the re-naturalization, in the municipal spatial plan approved and in force. **3. Are the residents and municipality aware of risk? How do they position regarding risk?** Yes. There have been frequent floods and sea overtopping inundations, and significant material damages have been reported. The municipality has manifested sensitiveness for the problem and agrees with the resettlement of population.

Figure 43 (left): Analysis of the 'reference situation' in the Critical Area – Relocation 'Cova do Vapor'. **Figure 43 (right):** the Critical Area – Relocation of Cova do Vapor. Source: POC-ACE 2018, p.106.

Scenarios of Intervention (Response Scenarios)		
Scenario A. Non intervention	**Scenario B. Stabilization of the shoreline**	**Scenario C. Planned retreat**
Aggravation of the problem (coastal erosion, floods and sea overtopping inundations): increase in number, frequency and magnitude of the floods and overtopping inundations.	Interventions of artificial sediment nourishment, rehabilitation of the groyne and reinforcement of the adherent defence structure (including their regular maintenance), to be carried by APA. The cost would be nearly 25 million Euros.	Demolition of the built assets, resettlement of the population, and re-naturalization of the space. The number of buildings to be demolished would be nearly 328 houses (including 80 common houses), and the number of people to be resettled would be around 183 residents. The area to be re-naturalized would have nearly 3,3ha, and 924m of perimeter. The cost of the intervention (including demolitions, resettlement, and re-naturalization) would be 10,5 million Euros.

Table P'. The *Scenarios of Intervention* ('*Response Scenarios*') considered for the Critical Area – Relocation 'Cova do Vapor'. Source: POC-ACE 2018, p.106.

Scenario of Intervention / Response Scenario A. Non-intervention					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Incapacity of adaptation of the community, given the expectable physiographic evolution (increase in the magnitude and frequency of floods and sea overtopping inundations), and complexity of the financial dimension of the solutions.		Incapacity of adaptation of the community (monitoring and permanent evaluation) to ensure a timely response and allow the safeguard of people and assets. Aggravation of the damages caused by floods and overtopping inundations, given the increase in their magnitude and frequency.		Incapacity of adaptation of the community (monitoring and permanent evaluation), to ensure a timely response and allow the safeguard of people and assets. Significant increase in damages given the aggravation of risk (regular floods and sea overtopping inundations, mainly in the Winter, with different intensities).	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	-2	Safety of population and beach users	-5	Maintenance of the shoreline (coastline)	-4
Activities of support (restaurants, etc.)	-2	Safety of built assets	-5	Coastal dynamics	-2
State revenue (taxes, levies, licences, etc.)	-1	Alterations in tourism and activities of support	-3	Dune system	-2
Municipal revenue (taxes, levies, licences, etc.)	-1	Opportunity of requalification of the territory	0	Values of flora	-2
Negotiating and juridic process (indemnities)	0	Negotiating and juridic process (indemnities)	0	Landscape	-3
Final score of the dimension	-6	Final score of the dimension	-13	Final score of the dimension	-13
Global value pondered (40%)	-2,4	Global value pondered (40%)	-5,2	Global value pondered (20%)	-2,6

Scenario of Intervention / Response Scenario B. Stabilization of the shoreline					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Concretization of specialized studies and attribution of budget; implementation of the Project (artificial sediment nourishment, rehabilitation of the groyne and reinforcement of the adherent defence structure).		New reality; adaptation of the community. Potential increase in the demand for beaches and fixation of residents.		The executed project stabilizes, and there is a regular monitoring of the physiographic evolution, regular maintenance of structures, and evaluation of the solutions.	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	3	Safety of population and beach users	4	Maintenance of the shoreline (coastline)	5
Activities of support (restaurants, etc.)	3	Safety of built assets	4	Coastal dynamics	4
State revenue (taxes, levies, licences, etc.)	2	Alterations in tourism and activities of support	2	Noise, traffic, garbage, during the interventions	1
Municipal revenue (taxes, levies, licences, etc.)	2	Opportunity of requalification of the territory	3	Values of flora	1
Negotiating and juridic process (indemnities)	0	Negotiating and juridic process (indemnities)	0	Landscape	1
Final score of the dimension	10	Final score of the dimension	13	Final score of the dimension	12
Global value pondered (40%)	4	Global value pondered (40%)	5,2	Global value pondered (20%)	2,4

Scenario of Intervention / Response Scenario C. Planned retreat					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Concretization of specialized studies and attribution of budget; implementation of the Project (demolition of the built assets and re-naturalization)		New reality; adaptation of the community (resettlement), and re-naturalization.		Monitoring of the physiographic evolution.	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	-1	Safety of population and beach users	0	Maintenance of the shoreline (coastline)	1
Activities of support (restaurants, etc.)	-1	Safety of built assets	0	Coastal dynamics	5
State revenue (taxes, levies, licences, etc.)	3	Alterations in tourism and activities of support	0	Fauna	1
Municipal revenue (taxes, levies, licences, etc.)	5	Opportunity of requalification of the territory	4	Values of flora	5
Negotiating and juridic process (indemnities)	-5	Negotiating and juridic process (indemnities)	3	Landscape	5
Final score of the dimension	1	Final score of the dimension	7	Final score of the dimension	17
Global value pondered (40%)	0,4	Global value pondered (40%)	2,8	Global value pondered (20%)	3,4

Table P''. Analysis of sensitivity for each *Scenario of Intervention* considered for the Critical Area – Relocation 'Cova do Vapor'. Source: POC-ACE 2018, p.107-109.

Global analysis for the Critical Area – Cova do Vapor							
Response scenarios / Scenario of Intervention	**Direct costs**		**Direct benefits (scores)**				**Benefit / cost ratio**
	Euros	**Score (60%)**	**Economic**	**Social**	**Environmental**	**Global (40%)**	
A. Non-intervention	300 000	0,12	-2,4	-5,2	-2,6	-10,2	-56,7
B. Stabiliza-tion of the shoreline	25 000 000	10,0	4,0	5,2	2,4	11,6	0,8
C. Planned retreat	10 500 000	4,2	0,4	2,8	3,4	6,6	1,0
Critical analysis of results	According to the analysis, and for the hypotheses and ponderations considered, the Response Scenario that is most favourable is 'C – Planned Retreat', as it obtained the most favourable global value (benefit / cost ratio). It is necessary to transmit information to the local population (raise awareness about risk) and proactively engage local authorities in the justification of this option.						

Table P'''. Global analysis of the *Scenarios of Intervention* considered for the Critical Area – Relocation 'Cova do Vapor'. Source: POC-ACE 2018, p.109.

4.2.2. Cost-benefit analysis for the ‘Critical Area – Relocation’ of Parques de Campismo (sul da Costa da Caparica)

Reference Situation
Problem
The winters of 2003, 2007, 2009 and 2010 were marked by extreme weather events and diverse events of sea overtopping with impacts in the camping sites (Parques de Campismo) of Costa da Caparica. Moreover, there is a current degradation of the accesses, an the dune systems in this stretch are damaged by the occupation with the camping sites (disappearance of dune morphologies and adaptive species). The Parques de Campismo at the south of Costa da Caparica are located in an area vulnerable to the coastal risks of erosion, sea overtopping inundations and floods (Zone Threatened by the Sea). The strategic options defined in the local spatial planning instruments – e.g. in a Detailed Plan (Plano Pormenor) – include the relocation of built structures and the re-naturalization of this territory through the reconstruction of the dune system. These options are envisaged in municipal spatial plans approved and in force. The surface susceptible to flooding encompasses almost the entire territory currently occupied by the camping sites (around 30ha).
Departing issues / questions
1. What is the prediction of the physiographic evolution? The camping sites are encompassed by the Strips of Safeguard from Coastal Risks in Low-lying Sandy Littoral (Coastal Erosion and Sea Overtopping Inundations and Coastal Floods). Climate change is expected to generate a greater persistence and frequency in storms, as well as SLR, and aggravate the hydrodynamic actions and the frequency and magnitude of sea overtopping events. Without interventions of artificial sediment nourishment, there will be a tendency for the aggravation of the sediment deficit in this coastal stretch. **2. Are the built-up forefront and the shoreline to be maintained (hold-the-line)?** Hardly possible. The costs associated to successive interventions of artificial sediment nourishment are too high (1230m of exposed forefront). It is planned the relocation of the camping sites, in the municipal spatial plan approved and in force. **3. Are the residents and municipality aware of risk? How do they position regarding risk?** Yes. There have been frequent floods and sea overtopping inundations, and significant material damages have been reported. The municipality has and the entities responsible for the management of the camping sites have manifested sensitiveness for the problem and agree with the resettlement of the camping sites.

Table 44 (left): Analysis of the ‘reference situation’ in the Critical Area – Relocation ‘Parques de Campismo a sul da Costa da Caparica’. **Figure 44 (right):** the Critical Area – Relocation of the Camping Sites of Costa da Caparica. Source: POC-ACE 2018, p.114.

Scenarios of Intervention (Response Scenarios)		
Scenario A. Non intervention	**Scenario B. Stabilization of the shoreline**	**Scenario C. Planned retreat**
Aggravation of the problem (coastal erosion, floods, and sea overtopping inundations): increase in number, frequency and magnitude of the floods and overtopping inundations.	Interventions of artificial sediment nourishment, to be carried by APA. The cost would be nearly 8 million Euros.	Demolition of the camping sites and re-naturalization of the space. The number of people to be resettled would be around 121 residents (who live permanently in the camping sites). The area to be re-naturalized would have nearly 37ha, and 3077m of perimeter. The cost of the intervention (including demolition of structures, relocation of the camping sites, and re-naturalization / recovery of the dune system) would be 2,5 million Euros.

Table Q’. The *scenarios of intervention* considered for the Critical Area – Relocation ‘Parques de Campismo at the south of Costa da Caparica’. Source: POC-ACE 2018, p.114.

Scenario of Intervention / Response Scenario A. Non-intervention					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Incapacity of adaptation of the community, given the expectable physiographic evolution (increase in the magnitude and frequency of floods and sea overtopping inundations), and complexity of the financial dimension of the solutions.		Incapacity of adaptation of the community (monitoring and permanent evaluation) to ensure a timely response and allow the safeguard of people and assets. Aggravation of the damages caused by floods and overtopping inundations, given the increase in their magnitude and frequency.		Incapacity of adaptation of the community (monitoring and permanent evaluation), to ensure a timely response and allow the safeguard of people and assets. Significant increase in damages given the aggravation of risk (regular floods and sea overtopping inundations, mainly in the Winter, with different intensities).	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	-5	Safety of population and beach users	-5	Maintenance of the shoreline (coastline)	-4
Activities of support (restaurants, etc.)	-2	Safety of built assets	-5	Coastal dynamics	-3
State revenue (taxes, levies, licences, etc.)	-1	Alterations in tourism and activities of support	-3	Dune system	-3
Municipal revenue (taxes, levies, licences, etc.)	-1	Opportunity of requalification of the territory	0	Values of flora	-2
Negotiating and juridic process (indemnities)	0	Negotiating and juridic process (indemnities)	0	Landscape	-3
Final score of the dimension	-9	Final score of the dimension	-13	Final score of the dimension	-15
Global value pondered (40%)	-3,6	Global value pondered (40%)	-5,2	Global value pondered (20%)	-3,0

Scenario of Intervention / Response Scenario B. Stabilization of the shoreline					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Concretization of specialized studies and attribution of budget; implementation of the Project (artificial sediment nourishment).		New reality; adaptation of the community. Potential increase in the demand for beaches.		The executed project stabilizes, and there is a regular monitoring of the physiographic evolution, and evaluation of the solutions of sediment nourishment and soft adaptation.	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	3	Safety of population and beach users	4	Maintenance of the shoreline (coastline)	5
Activities of support (restaurants, etc.)	3	Safety of built assets	4	Coastal dynamics	4
State revenue (taxes, levies, licences, etc.)	2	Alterations in tourism and activities of support	2	Noise, traffic and garbage, during the interventions	1
Municipal revenue (taxes, levies, licences, etc.)	2	Opportunity of requalification of the territory	-1	Values of flora	1
Negotiating and juridic process (indemnities)	0	Negotiating and juridic process (indemnities)	0	Landscape	1
Final score of the dimension	10	Final score of the dimension	9	Final score of the dimension	12
Global value pondered (40%)	4	Global value pondered (40%)	3,6	Global value pondered (20%)	2,4

Scenario of Intervention / Response Scenario C. Planned retreat					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Concretization of specialized studies and attribution of budget; implementation of the Project (demolition of the built assets and re-naturalization)		New reality; adaptation of the community (resettlement), and re-naturalization.		Monitoring of the physiographic evolution.	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	-3	Safety of population and beach users	3	Maintenance of the shoreline (coastline)	1
Activities of support (restaurants, etc.)	-3	Safety of built assets	5	Coastal dynamics	5
State revenue (taxes, levies, licences, etc.)	1	Alterations in tourism and activities of support	2	Fauna	1
Municipal revenue (taxes, levies, licences, etc.)	1	Opportunity of requalification of the territory	5	Values of flora	5
Negotiating and juridic process (indemnities)	-1	Negotiating and juridic process (indemnities)	1	Landscape	5
Final score of the dimension	5	Final score of the dimension	16	Final score of the dimension	17
Global value pondered (40%)	2,4	Global value pondered (40%)	6,4	Global value pondered (20%)	3,4

Table Q''. Analysis of sensitivity for each Scenario of Intervention (Response Scenario) considered for the Critical Area – Relocation 'Parques de Campismo at the south of Costa da Caparica'. Source: POC-ACE 2018, p.115-117.

Global analysis for the Critical Area – Parques de Campismo (south of Costa da Caparica)							
Response scenarios / Scenarios of Intervention	**Direct costs**		**Direct benefits (scores)**				**Benefit / cost ratio**
	Euros	**Score (60%)**	**Economic**	**Social**	**Environmental**	**Global (40%)**	
A. Non-intervention	100 000	0,13	-2,4	-5,2	-3,0	-10,6	-54,4
B. Stabilization of the shoreline	8 000 000	10,0	4,0	3,6	2,4	10,0	0,7
C. Planned retreat	2 500 000	3,1	2,4	6,4	3,4	12,2	2,6
Critical analysis of results	According to the analysis, and for the hypotheses and ponderations considered, the Response Scenario that is most favourable is 'C – Planned Retreat', as it obtained the most favourable global value (benefit / cost ratio). It is necessary to transmit information to the local population (raise awareness about risk) and proactively engage local authorities in the justification of this option.						

Table Q'''. Global analysis of the Scenarios of Intervention considered for the Critical Area – Relocation 'Parques de Campismo at the south of Costa da Caparica'. Source: POC-ACE 2018, p.117.

4.2.3. Cost-benefit analysis for the 'Critical Area – Relocation' of Fonte da Telha

Reference Situation
Problem
Fonte da Telha is settlement that originated as a local fishing community, and which has witnessed to illegal occupations (including fishermen houses and second holiday houses, some of them demolished in the late 1980's). This settlement is highly exposed to the advancement of the sea (extreme potential damage with nearly 2037m of urban forefront and 150 families in the seafront). It is located in an area vulnerable to natural risks (Zone Threatened by the Sea), namely coastal erosion and floods and overtopping inundations. The local spatial planning instruments already envisage several options for this area, namely the ecological restoration of this territory and the relocation / resettlement of population (to ensure the safeguard of people and assets), and the re-naturalization of the area. These options are envisaged in a Special Plan and in a proposal of Detailed Plan (proposta de Plano Pormenor).
Departing issues / questions
1. What is the prediction of the physiographic evolution? This settlement is encompassed by the Strips of Safeguard from Coastal Risks in Low-lying Sandy Littoral (Coastal Erosion and Sea Overtopping Inundations and Coastal Floods). Climate change is expected to generate a greater persistence and frequency in storms, as well as SLR, and aggravate the hydrodynamic actions and the frequency and magnitude of sea overtopping events. Without interventions of artificial sediment nourishment, there will be a tendency for the aggravation of the sediment deficit in this coastal stretch. **2. Are the built-up forefront and the shoreline to be maintained (hold-the-line)?** Hardly possible. The costs associated to successive interventions of artificial sediment nourishment are too high. It is planned the relocation / resettlement of the population and the ecological restoration, in a Special Plan and in a proposal of municipal Spatial Plan. **3. Are the residents and municipality aware of risk? How do they position regarding risk?** Yes. There have been frequent floods and sea overtopping inundations, and significant material damages have been reported. The municipality has manifested sensitiveness for the problem and agrees with the resettlement of the fishing community. There is a generalized agreement on the need of vacating the areas surrounding the urban perimeter, and re-naturalizing them, and creating conditions for the fruition of beaches.

Figure 45 (left): Analysis of the 'reference situation' in the Critical Area – Relocation 'Fonte da Telha'. **Figure 45 (right):** the Critical Area – Relocation of Fonte da Telha. Source: POC-ACE 2018, p.110.

Scenarios of Intervention (Response Scenarios)		
Scenario A. Non intervention	**Scenario B. Stabilization of the shoreline**	**Scenario C. Planned retreat**
Aggravation of the problem (coastal erosion, floods and sea overtopping inundations): increase in number, frequency and magnitude of the floods and overtopping inundations.	Interventions of artificial sediment nourishment, to be carried by APA. The cost would be nearly 15 million Euros.	Demolition of built assets (buildings and structures), resettlement of the population, and re-naturalization of the space. The number of people to be resettled would be around 361 residents (namely 80 families in regular houses). The area to be re-naturalized would have nearly 17,2ha, and 5281m of perimeter. The cost of the intervention (including demolitions, resettlement, and re-naturalization) would be 13,3 million Euros.

Table R'. The *scenarios of intervention* considered for the Critical Area – Relocation 'Fonte da Telha'. Source: POC-ACE 2018, p.110

Scenario of Intervention / Response Scenario A. Non-intervention					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Incapacity of adaptation of the community, given the expectable physiographic evolution (increase in the magnitude and frequency of floods and sea overtopping inundations), and complexity of the financial dimension of the solutions.		Incapacity of adaptation of the community (monitoring and permanent evaluation) to ensure a timely response and allow the safeguard of people and assets. Aggravation of the damages caused by floods and overtopping inundations, given the increase in their magnitude and frequency.		Incapacity of adaptation of the community (monitoring and permanent evaluation), to ensure a timely response and allow the safeguard of people and assets. Significant increase in damages given the aggravation of risk (regular floods and sea overtopping inundations, mainly in the Winter, with different intensities).	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	-2	Safety of population and beach users	-5	Maintenance of the shoreline (coastline)	-3
Activities of support (restaurants, etc.)	-2	Safety of built assets	-5	Coastal dynamics	-1
State revenue (taxes, levies, licences, etc.)	-1	Alterations in tourism and activities of support	-3	Dune system	-2
Municipal revenue (taxes, levies, licences, etc.)	-1	Opportunity of requalification of the territory	0	Values of flora	-2
Negotiating and juridic process (indemnities)	0	Negotiating and juridic process (indemnities)	0	Landscape	-3
Final score of the dimension	-6	Final score of the dimension	-13	Final score of the dimension	-11
Global value pondered (40%)	-2,4	Global value pondered (40%)	-5,2	Global value pondered (20%)	-2,2

Scenario of Intervention / Response Scenario B. Stabilization of the shoreline					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Concretization of specialized studies and attribution of budget; implementation of the Project (artificial sediment nourishment).		New reality; adaptation of the community. Potential increase in the demand for beaches.		The executed project stabilizes, and there is a regular monitoring of the physiographic evolution, and evaluation of the solutions of sediment nourishment and soft adaptation.	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	3	Safety of population and beach users	4	Maintenance of the shoreline (coastline)	5
Activities of support (restaurants, etc.)	3	Safety of built assets	4	Coastal dynamics	4
State revenue (taxes, levies, licences, etc.)	2	Alterations in tourism and activities of support	2	Noise, traffic, garbage, during the interventions	1
Municipal revenue (taxes, levies, licences, etc.)	2	Opportunity of requalification of the territory	3	Values of flora	1
Negotiating and juridic process (indemnities)	0	Negotiating and juridic process (indemnities)	0	Landscape	1
Final score of the dimension	10	Final score of the dimension	13	Final score of the dimension	12
Global value pondered (40%)	4	Global value pondered (40%)	5,2	Global value pondered (20%)	2,4

Scenario of Intervention / Response Scenario C. Planned retreat					
Short-term (0-4 years)		**Mid-term (5-12 years)**		**Long-term (12-50 years)**	
Concretization of specialized studies and attribution of budget; implementation of the Project (demolition of the built assets and re-naturalization)		New reality; adaptation of the community (resettlement), and re-naturalization.		Monitoring of the physiographic evolution.	
Analysis of sensitivity (from -5 up to 5)					
Economic		**Social**		**Environmental**	
Descriptor	**Level of impact**	**Descriptor**	**Level of impact**	**Descriptor**	**Level of impact**
Touristic Activity (touristic housing)	1	Safety of population and beach users	0	Maintenance of the shoreline (coastline)	1
Activities of support (restaurants, etc.)	1	Safety of built assets	5	Coastal dynamics	5
State revenue (taxes, levies, licences, etc.)	4	Alterations in tourism and activities of support	2	Fauna	2
Municipal revenue (taxes, levies, licences, etc.)	5	Opportunity of requalification of the territory	4	Values of flora	5
Negotiating and juridic process (indemnities)	-2	Negotiating and juridic process (indemnities)	2	Landscape	5
Final score of the dimension	9	Final score of the dimension	13	Final score of the dimension	18
Global value pondered (40%)	3,6	Global value pondered (40%)	5,2	Global value pondered (20%)	3,6

Table R''. Analysis of sensitivity for each Scenario of Intervention (Response Scenario) considered for the Critical Area – Relocation 'Fonte da Telha'. Source: POC-ACE 2018, p.111-113.

Global analysis for the Critical Area – Fonte da Telha							
Response scenarios / Scenarios of Intervention	**Direct costs**		**Direct benefits (scores)**				**Benefit / cost ratio**
	Euros	**Score (60%)**	**Economic**	**Social**	**Environmental**	**Global (40%)**	
A. Non-intervention	200 000	0,13	-2,4	-5,2	-2,2	-9,8	-50,3
B. Stabiliza-tion of the shoreline	18 000 000	10,0	4,0	5,2	2,4	11,6	0,8
C. Planned retreat	13 300 000	7,4	3,6	5,2	3,6	12,4	1,1
Critical analysis of results	According to the analysis, and for the hypotheses and ponderations considered, the Response Scenario that is most favourable is 'C – Planned Retreat', as it obtained the most favourable global value (benefit / cost ratio). It is necessary to transmit information to the local population (raise awareness about risk) and proactively engage local authorities in the justification of this option.						

Table R'''. Global analysis of the Scenarios of Intervention considered for the Critical Area – Relocation 'Fonte da Telha'. Source: POC-ACE 2018, p.113.

For more on the cost-benefit analyses for other 'Critical Areas – Relocation', see Note 362.

5. Analysis of the POC-ACE against the key-elements of an Adaptive Planning and Management approach

This section analyses whether and how the five key-elements of an Adaptive Planning and Management approach were applied in the POC-ACE case. Here, the research work focused on searching for ingredients to develop an *adaptive plan* in the POC-ACE, and on examining how these were applied. The POC's content is discussed against each of the five key-elements identified in Part A as essential to produce a *dynamic adaptive plan*. Table 12 of Part A summed up the main elements of an Adaptive Planning and Management approach that are essential to develop a *dynamic adaptive plan*, which were derived from the analysis of the reference cases (TE2100 and DP 2014) and related literature.

5.1. Key-element 1: considering and working with a wide range of plausible future scenarios

As the main risks / hazards in low-lying sandy littoral, the POC-ACE identifies coastal erosion and related retreat of the shoreline, and sea overtopping inundations and coastal floods. It recognizes the uncertainty that surrounds the future projection of the variables relevant for the calculation of the risks of erosion and sea overtopping inundations and floods. In the generation of scenarios for these coastal risks (i.e. coastal erosion and associated retreat of the shoreline, and spatial extension of sea overtopping inundations and coastal floods) for 2050 and 2100, the POC Team assumed a value of SLR of +0,30m (for 2050) and +1,50m (for 2100). These values were considered in the estimation of the future shoreline retreat and the of maximum height of sea overtopping inundations and floods (POC-ACE 2017, p.73).

As seen, the *Strip of Safeguard from Coastal Erosion* consists of the area that might be potentially affected by coastal erosion and the associated retreat (regression) of the shoreline, in the time-horizons of 2050 (Level I) and 2100 (Level II). This Strip was calculated and delimited based on the extrapolation, for the projection-years 2050 and 2100, of the evolutive tendencies observed in the recent past (POC-ACE 2018, p.86; 2018 d, p.39). In the delimitation of this 'risk zone' in terms of retreat (regression) of the shoreline, the Team the took into consideration the average past evolution of each coastal stretch (POC-ACE 2017, p.73), as well as the above-mentioned values of SLR. Thus, the POC only developed a single future *scenario* (projection) for the plausible future retreat of the shoreline induced by erosion with two time-horizons (i.e. for each projection-year considered), and, in this, it assumed a continuation of the past recent trend (to which a single value of SLR could be added). This led to the representation of a single Strip (a single projection) for each of the projection-years considered. It is not mentioned whether and which other developments / parameters, in addition to the past tendency of erosion (and associated shoreline retreat) and SLR, were considered in the generation of this projection, namely climatic-related parameters (like storm patterns) and socioeconomic developments.

The *Strip of Safeguard from Coastal Floods and Sea Overtopping Inundations* corresponds to the area that will be potentially affected by sea overtopping inundations and coastal floods, which was estimated for the time-horizons of 2050 (Level I) and 2100 (Level II). This Strip was determined and delineated based on the calculation of the combined effect of: the medium sea level, the elevation (rise) induced by astronomic tide, the level induced by a storm surge, and the extension of water / wave overtopping, and this calculation could also include SLR induced by climate change (POC-ACE 2018, p.85-86; 2018 d, p.39). In this case, the POC considered several parameters / variables that may influence the spatial extension of overtopping inundations and floods, however, it only assumed a single value for each of them, which, again, led to the representation of a single Strip (for each time-horizon considered).

In both cases (*Strip of Safeguard from Coastal Erosion* and *Strip of Safeguard from Sea Overtopping Inundations and Coastal Floods*), the POC only generated a single scenario (projection), which resulted in the representation of a single 'band / strip' for each of the time-horizons (projection-years) considered. If other projections (scenarios) had been generated, this would have led to the representation of other bands / lines, which could be, ultimately, encompassed by an 'uncertainty margin' (a buffer to absorb potential uncertainties about the line of shoreline retreat and the line that delimits the future spatial extension / coverage of coastal floods and overtopping inundations).

Importantly, the Strips of Safeguard from Coastal Risks in Low-lying Sandy Littoral were used as a reference in the delimitation of the 'Critical Areas – Relocation' in sandy littoral (among other factors). Thus, the limits set for the Critical Areas were influenced by the spatial limits of the Strips of Safeguard. The Critical Areas would likely have other / different spatial limits if other projections (other Strips of Safeguard) had been developed, and, eventually, the spatial coverage of the measures proposed (and the measures themselves) would be different in function of the scenario considered.

BOX 12. Importantly, the POC contains several Norms that mention the need of working with climate scenarios:

- the NG1 (on coastal risks) calls for the consideration of *'scenarios of climate change for time-horizons of mid- and long-term, in a rationale of preventive action that accounts for the vulnerabilities and opportunities of the coastal zone and its environmental values'*. It also calls for '*a vision of local development the considers the principle of precaution*' and for a '*definition of land uses and occupations (…) that pays due attention to the future vulnerabilities and threats associated to erosive processes and expected SLR, supported by climatic scenarios'* (POC-ACE 2018 d, p.53).
- the NG14 mentions the need to '*ensure that the urban planning considers the vulnerabilities stemming from climatic scenarios of mid- and long-term, and responds to the current needs and future challenges, by not allowing the aggravation of the exposure to risks* (POC-ACE 2018 d, p.70).
- the NG5 (on hydric resources) highlights that *'climatic scenarios must be considered in the modelling and occupation of the public space and in the dimensioning of new infrastructures or rehabilitation of existing ones, namely in what concerns alterations in precipitation patters, in superficial drainage and SLR, by ensuring the integration of innovative technical solutions, e.g. the increase in the flood storage capacity and the dissipation of water energy, non-occupation of the most sensitive urban forefronts, and re-directing overtopping floods to less sensitive zones'* (POC-ACE 2018 d, p.60).

The SEA Report highlights the importance of working with various plausible future scenarios, however, the POC did not use diverse future scenarios. The SEA explains that *scenarios* offer a series of narrative plausible futures that help to grasp and adapt to changes in the current environment, and, as *plausible futures*, allow making strategic decisions that are safe under all plausible futures. This clearly relates with the development of robust strategies (as set in Key-element 3). Moreover, the SEA, drawing on the guide '*Guia de boas práticas para Avaliação Ambiental Estratégica*' (APA 2007), refers that scenarios allow grasping the evolution of the Plan under each scenario, its potential effects, and identifying options that might be taken to reduce negative effects and meet the objectives. Such Guide mentions that it is important to use various plausible scenarios, but also to consider options and alternatives to achieve the proposed objectives (e.g. in the SEA and, here, use the scenarios developed in the planning of the Plan, if they exist). Nevertheless, in the elaboration of the POC, the Team did not consider various scenarios. Despite this, the SEA carried an analysis of diverse scenarios (POC-ACE 2017, p.72) (Note 363).[72]

The POC, in several of its documents (namely in its Directives), calls for the use of various climatic scenarios with a mid- and long-term time-horizon to grasp the potential future vulnerabilities, threats, and needs, and, in accordance, prepare adequate responses / actions to tackle them, however, the POC itself only considered and worked with a single *scenario* (projection) of the plausible future shoreline retreat (associated to coastal erosion) and a single scenario of the plausible future extension of the floodable area (area subjected to sea overtopping inundations and coastal floods). It can be concluded that the POC-ACE did not consider, nor prepare for, a wide range of plausible future scenarios.

[72] The SEA Team carried a comparative analysis of plausible future scenarios. First, it identified the main drivers of uncertainty that should be considered in future projections: a) dynamics of land use and transformation; b) capacity of adaptation to climate change; and c) dynamics of development of the sea economy. Then, the Team developed and assessed different scenarios associated to these drivers, namely scenarios that stem from the evolution of recent trends and more disruptive scenarios (Note 363). The SEA analysis cannot substitute the plausible future scenarios that should have been generated in the POC's planning process. The SEA sought to assess the expectable performance of the POC, predict tendencies and limit-situations, identify risks and opportunities associated to the POC's implementation, prevent weaknesses, and ensure the POC's efficacy, under different scenarios (POC-ACE 2017, p.72).

5.2. Key-element 2: identifying critical thresholds / tipping-points

The POC-ACE identified the main vulnerabilities / threats associated to coastal risks that might emerge in the future. The main vulnerabilities / threats identified for the mid- and long-term are associated to the risk of coastal erosion and to the risk of sea overtopping inundations and coastal floods:

- risk of coastal erosion: the associated retreat of the shoreline (and consequent loss of territory, damages on built assets and infrastructures). Without intervention, it is expected a tendency for the aggravation of the sediment deficit in several coastal stretches.
- risk of sea overtopping inundations and floods – it is expected increase in the frequency and intensity (magnitude and dimension) of sea overtopping inundations and floods (with consequent damages and destruction on built-up areas) (POC-ACE 2018, p.90, 110). With climate change effects, it is expected a greater frequency (persistence) of storms, and SLR is expected to aggravate the frequency and magnitude of sea overtopping events (POC-ACE 2018, p.110).

Based on a single projection (*scenario*) of the future shoreline retreat associated to erosion, the Team delimited (set the limit of) the *Strip of Safeguard from Coastal Erosion* for 2050 (Level I) and 2100 (Level II). Similarly, based on a single projection (*scenario*) of the future possible floodable area (generated based on a calculation that included several parameters, with a single value for each parameter), the Team delimited the *Strip of Safeguard from Sea Overtopping Inundations and Coastal Floods* for 2050 (Level I) and 2100 (Level II).

Thus, the analysis of potential future vulnerabilities (threats) associated to the risks of coastal erosion and flooding was based on, and only took into consideration, a *single scenario* for the plausible future retreat of the shoreline, and a *single scenario* for the plausible future extension of overtopping inundations / floods. The analysis of risks, vulnerabilities and potential impacts did not involve an examination of thresholds / tipping-points that may be reached over time under diverse and changing *scenarios* (i.e. different *transient scenarios* of the plausible future shoreline retreat and of the plausible floodable area), nor under different scenarios of climate change and socioeconomic development.

While the POC advocates the adoption of a preventive precautionary approach (*principle of prevention and precaution*) that considers the potential vulnerabilities / threats and opportunities that may emerge now and in the future, namely vulnerabilities / threats associated to erosion processes and overtopping inundations / floods (POC-ACE 2018 d, p.53), the need to cope with such potential vulnerabilities did not lead to an analysis / specification of ATPs or thresholds by the POC itself. The POC did not identify critical thresholds in the existing system of coastal defence structures, neither potential tipping-points for the current or proposed measures.

The rationale underlying the identification of ATPs / thresholds (conditions under which a given measure – existent or proposed – ceases to be effective or acceptable, and a new measure is needed) was not explored in the POC, in part, because the analysis of vulnerabilities / threats that may emerge in the future only took into account a *single future scenario* (a single projection for the future shoreline retreat, and a single projection for the spatial extension of overtopping inundations and floods), and because the risks of coastal erosion and inundation/flooding are implicitly understood as 'stationary'.

The POC recognizes the need of considering, in spatial planning, the current and future vulnerabilities, and the need of limiting the exposure to risks (e.g. Norm NG14) (POC-ACE 2018 d, p.70), however, it has focused mainly on its implementation period (2017-2028) and has proposed actions with such time-horizon in mind: it selected the measures that presented the highest cost-benefit ratio and that lasted in time as long as possible. The critical points (conditions) under which it might be necessary to switch from a given measure to another (i.e. switch of, change, or add measures) were not explored, neither alternative measures that might be used in the future, namely in the mid- and long-term.

In sum, while the POC calls for the analysis, in spatial planning, of current and potential future vulnerabilities/ threats (associated to the main coastal risks identified) that might emerge under diverse scenarios of climate change, especially in the mid- and long-term, the Programme itself did not carry such analysis in-depth. The Programme could have examined what potential limits / thresholds might be reached over time (in terms of vulnerability and exposure), which levels of risk would be acceptable until new / additional measures are needed, and their timing (moment) – all this, under different *plausible future scenarios* (that consider parameters like climate change effects and socioeconomic development).

5.3. Key-element 3: developing a '*robust* and *flexible* set of measures' to deal with uncertain future changes, by using the 'Adaptation Pathways approach'

According to the POC-ACE, in areas of high hazardousness, it was essential to search for and identify the most advantageous solutions. For the critical stretches that presented greater hazardousness in terms of risk of coastal erosion, sea overtopping inundations and floods, or cliff instability (later called 'Critical Areas – Relocation'), the POC Team has formulated three main options – called 'Scenarios of Intervention' (or 'Response Scenarios'). The development of these 'Scenarios of Intervention' required the exploration of adequate solutions to reduce risks, followed by their assessment through cost-benefit analyses. This exercise was denominated '*scenarization*' (POC-ACE 2018, p.90).

In specific, the exercise of *scenarization* consisted of the development of '*Scenarios of Intervention*' (i.e. the exploration various possible response solutions) and the assessment of their costs and benefits (POC-ACE 2018, p.92). To develop and select the most advantageous option for each specific 'problem space' ('Critical Area – Relocation'), the Team followed several steps:

1) Formulation of *Scenarios of Intervention*, which involved equating the best forms of action / intervention for each situation ('problem space') (POC-ACE 2018, p.90).[73] The definition of *Scenarios of Intervention* required describing the main characteristics of each *Scenario*, namely the typology and extension of the interventions involved, and estimated costs (POC-ACE 2018, p.93). Three *Scenarios of Intervention* were formulated: scenario A (non-intervention); scenario B (stabilization of the shoreline through protection measures); scenario C (planned retreat).[74]
2) cost-benefit analysis of each *Scenario of Intervention* and comparative assessment of the three *Scenarios* (assessing the costs and benefits of each alternative and comparing them) (ibid).[75]

The three *Scenarios of Intervention* developed by the POC can be deemed three alternative adaptation strategies – three broad options – that were devised and then assessed in each 'problem space' (later called 'Critical Area – Relocation'), and among which the POC Team would choose one (based on the comparison of their cost-benefit ratio). Nevertheless, the development of these three *Scenarios of Intervention* does not fully correspond to the 3rd Key-element of an Adaptive Planning approach – i.e. developing (preparing) a *robust and flexible* set(s) of measures to deal with uncertain future changes, by using the method of 'Adaptation Pathways' (APs) (designing *robust flexible strategies* with the APs).

The *Scenarios of Intervention* developed by the POC do not deliver the *robustness* and *flexibility* that is required in an '*dynamic adaptive plan / strategy*' that contains alternative pathways / options, which, in their whole, provide a '*robust and flexible set (or sets) of actions*' (i.e. *robust flexible strategies*) to cope

[73] Given a particular problem and its implications, the Team formulated various possible responses, in function of the level of priority that the community attributed to the minimization of problems / impacts that might occur and financial resources available (POC-ACE 2018, p.92).
[74] In the case of 'Critical Areas – Relocation' located in Cliff Littoral, the scenario of intervention B corresponds to the stabilization and consolidation of the cliff (through diverse interventions of stabilization of the cliffs and slopes, e.g. structural reinforcements and maintenance).
[75] The POC Team developed a methodology of cost-benefit analysis for the assessment of the three main 'scenarios of intervention' formulated in each Critical Area. This methodology was applied in all 'Critical Areas – Relocation', even in cases where 'planned retreat' was already enshrined in municipal spatial plans (POC-ACE 2018, p.91).

with uncertain future changes over time. The main aspects that explain why these *Scenarios of Intervention* do not provide a '*robust flexible set of measures*' (or sets of measures), and do not consist of adaptation pathways, are outlined next, in comparison to sub-elements of Key-element 3 that confer *robustness* and *flexibility* to the pathways and the general Plan / Strategy (summarized in the left boxes).

The APs method allows switching between different options in the future. It identifies possible options for switching and remaining flexible.

No adaptation pathways were developed: The POC Team did not apply the 'APs approach' to develop the *Scenarios of Intervention* proposed for each 'problem space'. In the APs approach, each pathway is composed of a set of sequenced measures that are implemented over time to cope with changing levels of risk (where a new measure is activated once its predecessor ceases to be effective or acceptable), and several pathways (options) are usually devised and designed (between which it is possible to switch). Hence, each pathway (and the diverse pathways) it itself a '*flexible and robust set of actions*'. However, in the POC, each *Scenario of Intervention* was not conceived as a pathway (i.e. a set of various measures sequenced and implemented over time, where it is possible to change of measure, or pathway, depending on evolving risks); and the three *Scenarios of Intervention* do not consist of alternative pathways between which it would be possible to switch if developments require so. Overall, in the POC, the *Scenarios of Intervention* were not devised as different possible pathways available: in each *Scenario*, it was not ensured the possibility of switching of measures over time (it is not possible to switch to a new measure, change, or add additional measures), and it was also not contemplated the eventual need of shifting to a different '*Scenario of Intervention*' to deal with uncertain future changes.

APs: short-term decisions are coupled with long-term options. The APs' approach involves envisioning options and possibilities for switching between them, through adaptation pathways.

Moreover, in the POC-ACE, each *Scenario of Intervention* was not designed as a pathway in which diverse measures are envisioned (each pathway usually contains more than one measure to manage risk, namely changing levels of risk, over time), and in which the measures proposed for the short-term are logically linked to (chained with) possible alternative measures (options) for the mid- and long-term. Instead, the three *Scenarios of Intervention* consist of three possible options (alternative solutions) mainly focused on solving problems now (during the period of implementation of the POC) and assuming a single plausible future (a single projection of the future shoreline retreat associated to erosion, and a single future projection of the future floodable).

Whereas the APs' approach involves envisioning diverse options and possibilities for switching between them – which contributes to the *dynamic robustness* / *flexibility*, and *adaptability* of the general Plan – this aspect was not ensured in the *Scenarios of Intervention* of the POC (in each of them, neither in their range). As described in the POC, the three *Scenarios of Intervention* have different lifespans (*sell-by dates*) – i.e. not all the *Scenarios* will remain effective and cost-beneficial under the plausible future assumed by the POC. The POC did not safeguard the possibility of switching from a given measure to a new one in order to increase the shelf-life of a certain *Scenario*. Hence, the three *Scenarios of Intervention* do not consist of three possible options viable in the long-term (only one of three *Scenarios of Intervention* will be cost-beneficial in the *plausible future* assumed by the POC, and that was the *Scenario* chosen), and the POC did not safeguard the possibility of switching from a *Scenario* to another.

In the POC, each *Scenario of Intervention*, rather than containing various measures to manage changing risk over time, contains a single broad adaptation measure that is expected to last until a certain point in time (except *Scenario B* – which, in some areas, may involve *soft* and *hard* protection). The POC describes the expected evolution of each *Scenario* in the short-, mid- and long-term (including the interventions required). Despite that, it does not mention *when*, or, more precisely, *under what conditions* a given *Scenario* will become ineffective or cease to perform acceptably (and a new measure will be needed), nor which measures might be applied then. The interventions described in each *Scenario* form part of the overall response to the problem identified, and all interventions must be applied more-or-less in the same period (first 4 years, with some maintenance and monitoring actions in the long-term). As mentioned, the *Scenarios of Intervention* were not devised as pathways – i.e. concatenations of measures to manage evolving risks over time, in which a new measure is needed if its predecessor ceases to perform well, and where alternative measures and pathways are usually left open for the future. Each of the *Scenarios of Intervention* does not provide other possible measures for the mid-/ long-term (to cope with changing risks, and other *plausible future scenarios*) – i.e. the POC did not provide diverse possible options for the mid/ long-term, the measures proposed in each *Scenario* are not coupled with possible alternatives/options for the mid- and long-term, nor presented in a timeframe/ map that allows grasping their *robustness* under diverse *plausible transient futures*. As the POC has only considered a single *plausible future*, it implicitly assumed that the best *Scenario of Intervention* would be the one that provided a 'response' for once and for the next decades, with no need of changing, adding, or switching, measures.

A pathway is a set of measures sequenced and implemented over time to manage changing risk. Each pathway is flexible (e.g. it is possible to move from a measure to another), and it is also possible to move from a pathway to another.

The possibility of switching from a given measure, and / or option (pathway), to a new one, is not ensured. The POC did not contemplate the eventual need of switching of measure (within a given *Scenario of Intervention*), neither the eventual need of shifting of *Scenario*, as conditions change or new knowledge arises. Although three *Scenarios of Intervention* were formulated, the POC did not address nor safeguard the possibility of switching of, changing, or adding new measures (if a measure becomes ineffective/ unacceptable), neither the possibility of switching from a *Scenario of Intervention* (option) to another. Overall, the Programme did not envision the possibility of changing of measure, or *Scenario of Intervention*, if new developments or changes demand so, which undermines the *dynamic robustness* / *flexibility* and *adaptability* of the general strategy envisioned for each Critical Area.

The APs' map clearly identifies ATPs / critical thresholds defining when (under what conditions) to switch from an action to another (greater flexibility).

No critical thresholds / tipping-points (ATPs) were identified: In the analysis of potential future vulnerabilities / threats and problems, the POC did not apply the method of ATPs, which involves analysing and identifying conditions (e.g. specific levels in a certain variable) under which the current or a given measure ceases to perform well and a new measure is needed to meet the objectives. The identification of ATPs leads to the generation of pathways: once an ATP is in sight (the point / condition under which a measure ceases to be effective), a new measure is needed, and, in this way, a pathway emerges. The POC briefly mentions until when each *Scenario of Intervention* is expected to perform well, by describing its performance in the short-, mid- and long-term. However, the POC Team did not examine in-depth under what concrete conditions each *Scenario* will become ineffective or unacceptable (regardless of the plausible future assumed), nor when this might happen under different plausible futures.

APs: measures are applied iteratively over time to keep risk below target levels, while keeping open options to manage future risk.

Each of the *Scenarios of Intervention* of the POC was not planned (nor programmed) as a sequence of measures that are applied over time to keep risk below a desired level, and there was no explicit intention of *keeping open options* (alternatives) to manage changing risks throughout time and under other plausible future transient scenarios. To a certain extent, this is explained by the fact that the POC only worked with a single plausible future scenario of shoreline retreat (erosion) and a single plausible future scenario for the floodable area, and, thus, it developed the '*Scenarios of Intervention*' with such single future in mind. The Team did not plan possible measures to tackle changing (levels of) risk over time, nor different possible options (diverse *Scenarios of Intervention*) viable under various plausible futures.

The APs' map shows short-term actions linked to (chained with) long-term options.

Although the POC briefly describes the evolution of the performance of each *Scenario of Intervention* in each 'Critical Area – Relocation' in three time-periods, including, in some cases, interventions required in the long-term (e.g. in *Scenario B – stabilization of the shoreline through artificial sediment nourishments*, it may be necessary to carry maintenance works and monitoring in the long-term), no further details were provided. The POC did not explore nor specify possible options for the mid- and long-term: the measures proposed for the near-future were not linked to possible alternative measures in the mid- and long-term future, namely additional or other different measures (e.g. increasing frequency or volume of sediment nourishments, or a single large nourishment operation to create a sandy area).

Responses do not foreclose future options or unnecessarily constrain future choices. Flexibility involves '*keeping open options*'.

In a '*dynamic adaptive plan*', *dynamic robustness* and *flexibility* are also related with '*keeping options open*' to manage future risks, which implies having alternative measures 'at hand' (available for the case they become necessary) and avoiding foreclosing possible future measures unnecessarily. The APs' approach helps to ensure this: the various pathways provide alternative options and measures for the future, and each pathway usually contains diverse measures to manage changing levels of risk over time (linking measures in the short-term to possible options in the long-term, and allowing logical shifts from a measure to another measure).

Decisions in the near-future on specific actions do not foreclose future options to act differently (switch or add actions) if climate or societal changes ask for it; and developments in near-future do not foreclose future options.

The POC highlights that its exercise of *scenarization* (development and assessment of *Scenarios of Intervention*) was quite useful '*as a tool to support decision-making in the short-term, as a model that ensures that the options taken in the present do not jeopardize future generations and opportunities existent or emergent in the territory, and as an instrument of support to a planning more adaptive to contextual changes*' (*in* POC-ACE 2018, p.92). Nevertheless, the POC does not explain how it will ensure that the decisions and options (measures) taken now do not jeopardize future generations and opportunities that might arise over time, namely under different plausible futures. The Team only worked with a single plausible future, and the *Scenarios of Intervention* were not presented in a temporal frame that allowed grasping the lifespan of each *Scenario*. It is unclear whether the interventions envisaged for the short-term could be logically linked to other alternatives / options in the mid- and long-term (or, conversely, whether they could not be linked to any alternative and, thus, foreclose future options). This may give the false idea that the *Scenario of Intervention* chosen is *adaptive* (*robust* and *flexible / adaptable*) to the contextual changes that may occur. However, to guarantee that the option taken now does not hinder potential future options and opportunities, and to operationalize an Adaptive Planning, it is essential to plan 'ahead' diverse possible options for the mid- / long-term and assess

Plan's flexibility is increased if the APs' map contains multiple pathways (allows switching between different options), and if measures can be implemented stepwise, or if there is the possibility of switching to other measures.

their performance under various plausible futures. In the POC, the idea of keeping open options to manage future risk was not fully ensured. The availability of alternative measures and pathways for the future, and the possibility of shifting to other possible measures or strategies / pathways (i.e. having various possible pathways / routes ahead), were not explored. The POC provides a single solution for the problem: although it envisioned three *Scenarios of Intervention*, only one *Scenario* (*Scenario C – planned retreat*) remains viable (effective and cost-beneficial) under the plausible future assumed (*Scenario A* and *Scenario B* were not cost-beneficial in the mid- and long-term).

Stepwise / phased implementation of various actions or small projects (but, in some cases, a single larger investment is more cost-effective). Short-term decisions are part of a phased longer-term plan.

The POC did not envision a phased implementation of various actions over time within each of the *Scenarios of Intervention*. In each *Scenario of Intervention*, the POC identifies the main interventions to be carried in the short-term (first 4 years), describes their probable behaviour in the mid-term (year 5 to 11) and long-term (year 12 to 50) and, in some cases, it indicates interventions required in the long-term (like maintenance works or monitoring). Despite this, each *Scenario of Intervention* does not consist of a pathway in which measures are implemented in a phased / stepwise way over time to tackle evolving risks. The POC does not mention the possibility of switching from a measure to a new one, or adding measures, in an incremental way (which could have been considered, e.g. in *Scenario B* regarding beach nourishments).

Diversity of measures (soft, hard, structural, non-structural, at different scales, across different sectors, or actors).

The POC proposes diverse coastal adaptation measures, and at different spatial scales, e.g.: integrated sediment management (re-establishment of sediment balance) at a regional scale (sediment cells), the regimes of safeguard defined for the Strips of Safeguard from Coastal Risks (in low-lying sandy littoral and in cliff littoral), but also localized measures like *planned retreat* in the 'Critical Areas – Relocation', as well as *soft protection* measures (beach nourishments, dune reinforcements), *hard protection* measures (maintenance or rehabilitation of existing hard defences), and *accommodation* measures (in the Program of Actions, the POC defines measures of *soft* and *hard protection* and *accommodation*). Some measures proposed aim to reduce the vulnerability and exposure to coastal risks, while others aim to reduce the probability of coastal erosion and / or floods – which contributes to increase the diversity of measures. Despite this, no georeferenced map is provided containing the various measures proposed per location. In addition, for each 'Critical Area – Relocation', the POC Team selected a single *Scenario of Intervention* (option) – i.e. *Scenario C – planned retreat* (removal or relocation of built assets, resettlement of people, and re-naturalization of the space). The POC enumerates such interventions, however, it could have further detailed their timing / scheduling, and the potential sites for re-settling people and built assets. Moreover, no alternative options (other *Scenarios of Intervention*) were left open for the future (as feasible strategies under the plausible future assumed by the POC and under other plausible future scenarios). The POC could have explored other possible (viable) measures and strategies, namely under other transient scenarios of climate change and socioeconomic development, and including actions for the short-, mid-, and long-term.

At each 'Critical Area – Relocation', the choice of the best / most advantageous *Scenario of Intervention* was based on the assessment through cost-benefit analyses of the three *Scenarios* formulated. Such decision was not explicitly and directly based on the criteria like *robustness*, *flexibility*, and *adaptability* in the face uncertain future

No- / low-regret actions (actions w/ properties like robustness, flexi-bility, reversibility).

Flexible strategies or measures: can be adapted if the future unfolds differently than foreseen.

changes, but mainly on the cost / benefit ratio and effectiveness. In all 'Critical Areas–Relocation', planned retreat is presented as the *Scenario* that will be more effective and cost-beneficial over the next 50 years (meaning that it is the one that better performs in the plausible future assumed). The criteria *dynamic robustness* (satisfactory performance under a wide range of plausible transient futures) and *no-/low-regret* (regardless of how the future unfolds) were not considered; but the criteria of *flexibility* (to be adapted to changing conditions) was slightly addressed. The POC recognizes the importance of using flexible measures: it refers that one of its challenges is '*to promote an increasing flexibility in the forms of occupation of the hydric domain, by favouring the creation of soft, movable, and modular structures that are better adapted to extreme weather events*' (POC-ACE 2018, p.69). Some measures were chosen because, among other reasons, they are inherently *flexible*, e.g. re-establishing the sediment balance (following the GTL advice for cell 4, the POC assumes that the re-establishment of the sediment cycle equivalent to the littoral drift would have the advantages of minimizing the loss of territory, be easily reversible, favour the permanence of sand, maintain landscape values, and be more similar to the natural situation) (POC-ACE 2018 d, p.179). In this line of though, the POC proposes (in the Program of Actions) sediment nourishments as a flexible measure at local scale. However, it could have further detailed it, by specifying sources of sediments, volumes required to address changing levels of risk, periodicity of nourishments, and deposition sites (which could be represented in a geo-referenced cartography).

Furthermore, the POC advocates that it is indispensable to integrate into the planning of coastal urban settlements *'key principles of adaptability' namely: flexibility, to follow the annual climatic cycle; reversibility, by anticipating the development of the littoral in the long-term and envisaging anticipated hypotheses of relocation; sobriety, by grasping the limitations of responses in the face of the dimension of the challenges brought by the coastal geo-system; innovation / ingenuity to incorporate into urban development the rationale of adaptation of natural systems*' (POC-ACE 2018 d, p.69). The Norm NG14 also refers that is necessary to '*integrate the principle of precaution in urban planning, by distancing, as far as possible, built assets from the shoreline, from areas adjacent to the crest of cliffs and from areas subjected to sea overtopping inundations and floods, and by promoting the reduction of the intensity of use and occupation of vulnerable zones and progressively relocating the existing constructions and structures to areas outside the Strips of Safeguard* (POC-ACE 2018 d, p.70). It is worth mentioning that, although the POC did not pursuit *robustness* and *low-/no-regret* in the choice of measures, the establishment of setback lines and *non-aedificandi* zones (as set through the Strips of Safeguard from Coastal Risks), and the option of 'planned retreat' for some 'problem spaces', correspond to measures that may be '*robust*' and '*low-/no-regret*' under multiple plausible futures.

<u>In sum, in general, there was an insufficient or weak planning of possible measures and options to deal with uncertain future conditions and changes, namely of other options viable in the mid- and long-term</u>. As the Team did not work with various plausible future scenarios, namely with various scenarios / projections of the future retreat (regression) of the shoreline and of the future floodable area, the exploration of possible measures that might be used in the future was limited, and mostly focused on interventions to be implemented during the next decade and to last throughout the next 50 years (i.e. the limit of the period of long-term' considered in the Critical Areas – Relocation). Besides this, the Program of Actions only presents a scheduling of the projects and actions for the period 2017-2028; from 2028

onwards, it is does not provide any scheme of the measures potentially required until 2050 and, especially, until 2100 (such task is left for future reviews of the POC). It can be concluded that the POC-ACE did not develop a '*robust flexible set of measures*' – including diverse measures that might be needed if conditions change, or new information or scenarios emerge, risks aggravate/ accelerate, unexpected changes occur, or if measures (applied or planned) become ineffective. This has limited the *dynamic robustness* and the *adaptability* of the POC as a *long-term sustainable adaptive plan*.

Importantly, the POC-ACE has largely followed the advice of the GTL Report. The GTL recommended the elaboration of studies on adaptation, including integrated assessments of adaptation measures (protection, accommodation and relocation) under scenarios of climate change, and considering the costs associated to '*different adaptation pathways*' up to time-horizons in the long-term (e.g. 2100) (POC-ACE 2018, p.179).[76] Notwithstanding, the POC did not develop such adaptation pathways. The *Scenarios of Intervention* considered for each 'problem space' ('Critical Area – Relocation') consist of three different options, which were devised to solve problems mainly in the near-future, and from which the Team could choose one (based on a comparative assessment of such *Scenarios* through cost-benefit analyses). Moreover, while the GTL and the ENGIZC recommend both cost-benefit and multi-criteria analyses, the POC only carried cost-benefit analyses to assess the *Scenarios of Intervention*.

In addition, the *Scenarios of Intervention* drawn up for each 'Critical Area – Relocation' were not devised to ensure *dynamic robustness*, *flexibility*, and *adaptability* – which are characteristic features of a *dynamic adaptive plan / strategy* that could have been achieved by using the APs approach. Overall, in the 'Critical Areas – Relocation', the POC does not truly provide '*robust flexible* set(s) of measures (*robust flexible strategies*) to deal with uncertain future changes' (as required by the Key-element 3).

For each 'Critical Area – Relocation', the POC-ACE has decided that the strategy of adaptation to be implemented is 'planned retreat' (relocation), and described the main interventions required in such strategy. For other locations / zones, the POC proposed other measures – e.g. measures of *soft protection* (beach nourishments and dune reinforcements), *hard protection* (maintenance and repair works in existing hard defences), and *accommodation*. However, no georeferenced map with all the proposed strategies is provided, which strongly hampers the comprehension of the range of adaptation measures proposed and their spatial coverage. In the Program of Actions, the adaptation actions / projects are not organized per geographical location, but per 'Strategic Line'. Thus, it is difficult to understand, when looking at the area of intervention, or sub-parts of it, which concrete actions (of adaptation / coastal risk management) were defined, what is their specific location, timing of implementation, inter-relation, and expected lifespan (under the plausible future assumed). Besides this, for the 'Critical Areas – Relocation', and for other areas where other measures than planned retreat were proposed, the POC has not explored options (alternative measures and strategies) for the mid-term (2050) and long-term (2100).

BOX 13. For each 'Critical Area – Relocation' located in Low-Lying Sandy Littoral, the POC has formulated 3 *scenarios of intervention*: A) non-intervention; B) stabilization of the shoreline, through sediment nourishments (and, occasionally, rehabilitation of some hard defences); and C – planned retreat (relocation or removal of built assets, resettlement of populations, and re-naturalization of the space). Then, the Team carried a comparative assessment of the three *scenarios* through a cost-benefit analysis of each *scenario*, and based on this, it decided that the *scenario of intervention* to be implemented in each Critical Area was C. In this way, the POC has defined the strategy of adaptation to be followed in these Critical Areas, and it describes the main interventions required to fulfil the strategy of planned retreat.

[76] The GTL Report also recommended a strategy of planned retreat for the coastal zones where there is a high risk of sea overtopping inundations, coastal floods, erosion, or cliff instability (relocation as a priority response); and it suggested the development of prospective studies on relocation based on cost-benefit analyses that include the mid- and long-term. Moreover, the GTL advises that 'sediment management' should assume a primary role in the strategies of intervention and mitigation of the erosive process in the coastal stretch ACE, namely in Costa da Caparica. According to the GTL, it is possible to reduce or annul the sediment deficit, through nourishments with sediments extracted from borrow sites outside the outer estuary of Tejo (POC-ACE 2018 d, p.179).

Suggestions

The POC-ACE would benefit from the consideration of more than one plausible future scenario (namely of diverse scenarios of climate change but also diverse scenarios of socioeconomic development), as well as from the development of several adaptation pathways that provided various possible options (including measures for the short-, mid-, and long-term). The 'APs approach' would contribute to enhance the *adaptability* and *long-term sustainability* of the Programme in general, and, in particular, of the strategies envisaged for the 'Critical Areas – Relocation' and for other spaces (for which the POC proposes different adaptation measures), at diverse geographical scales.

The Team could have further explored other alternative actions (or groups of actions) for the next century and analysed their performance until 2100, and, in this process, consider diverse scenarios (more than one projection) of the future shoreline regression and flood extension. These actions (or groups of actions) could then be sequenced according to thresholds / ATPs that might be reached over time. In this way, diverse pathways could be developed.

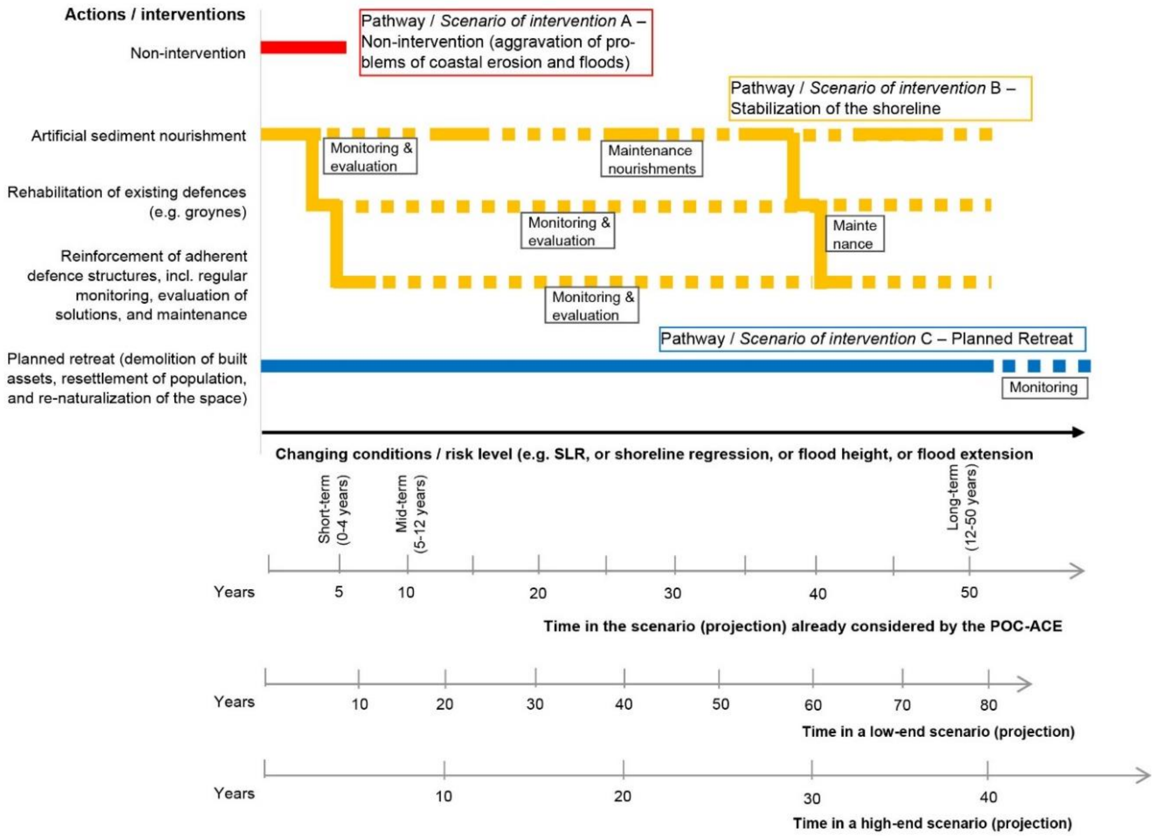
By using the APs' approach, the POC could develop more than three '*Scenarios of Intervention*' (i.e. more than one option / strategy of adaptation throughout the century), namely strategies that combine adaptation measures from the three main typologies, i.e. *hard* and *soft protection*, *accommodation*, and *planned retreat*. Moreover, the POC could further define the following aspects: the timing and the sequencing of measures within each '*Scenario of Intervention*', by specifying which measures can be applied to cope with different levels of risk in a given area. The measures to be applied at the same time (within a given Critical Area, in the same or diverse places of such area) could be grouped in boxes, for example. The sequencing of various boxes would generate a pathway, and, in this way, several pathways could be designed in a map of pathways. Such APs' map would resemble the maps of *adaptation paths* generated in the DP 2014 for the coastal zone. Other possible way of assembling various pathways would be to present the diverse adaptation measures available in the Y axis of the APs' map (in a logical order, e.g. grouped per typology), and seek to design several viable pathways to tackle changing levels of coastal risks until the mid- and long-term (Figures 46, 47 and 48).

In this process, it will be important to examine the 'sell-by-date' (i.e. the moment when a tipping-point is reached) of each of the measures envisioned in each *Scenario of Intervention* under diverse plausible futures scenarios. As mentioned, the *Scenarios of Intervention A*, *B* and *C* do not have the same 'shelf-life' and cost-effectiveness over time, under the 'plausible future' assumed in the POC.

To assess and compare the three *Scenarios of Intervention* in each 'Critical Area – Relocation', the POC Team carried a cost-benefit analysis and scored each *Scenario* against several economic, social, and environmental criteria (descriptors). The graphical representation of the scores of each *Scenario* could be improved by designing a 'scorecard', as proposed by Haasnoot et al. (2013). Such scorecard shows the scores attributed to each of the pathways, in terms of costs, effectiveness, and side-benefits, in a simple way, which can be quickly understood when presented with the APs' map (Figure 46).

In the Program of Actions, the adaptation actions proposed are organized per Strategic Line. Despite this, for each given location / zone, the POC often proposes more than one action (e.g. for Fonte da Telha, the POC proposes planned retreat for the 'Critical Area – Relocation of Fonte da Telha', as well as interventions of sediment nourishment and ecological restoration of the dune system, as mentioned in the *Plan of Intervention on the Beach*). The set of measures proposed for a given area / zone could be represented in an APs' map; such map should show all the possible proposed measures and pathways over time (including information about ATPs). Moreover, it would be useful to map out in a georeferenced map each *Scenario of Intervention* (i.e. each strategy / pathway) devised for a given critical zone, in a similar way to what was done in the TE2100 case. Each georeferenced map should contain all actions of coastal adaptation / coastal risk management foreseen for each critical zone within a given '*Scenario of Intervention*', the specific location of each action, and its timing (thus, a georeferenced map should be produced for each *Scenario of Intervention* that was devised). This would provide a clearer picture of the possible solutions available and their spatial (physical) implications, and confer to the alternative '*Scenarios of Intervention*' a more realistic character as options (pathways) that may be adopted in the future, and which are possible under different plausible futures.

EXAMPLE OF A POSSIBLE MAP OF ADAPTATION PATHWAYS FOR THE 'CRITICAL AREA – COVA DO VAPOR'



'Scenario of intervention' / pathway	Direct costs (Eur)	Effectiveness (target effects)
A	300 000	
B	25 000 000	
C	10 500 000	

Direct benefits and Co-benefits	A	B	C
Economic			
Touristic activity	-2	3	-1
Activities of support (restaurants)	-2	3	-1
State revenue	-1	2	3
Municipal revenue	-1	2	5
Juridic and negotiation process	0	0	-5
Social			
Safety of population and users	-5	4	0
Safety of built assets	-5	4	0
Alterations in tourism and activities of support	-3	2	0
Opportunities of requalification of the territory	0	3	4
Juridic and negotiation process	0	0	3
Environmental			
Maintenance of the shoreline (coastline)	-4	5	1
Coastal dynamics	-2	4	5
Dune system / Fauna / Noise, traffic and garbage	-2	1	1
Values of flora	-2	1	5
Landscape	-3	1	5
Total	**-10,2**	**11,6**	**6,6**
Cost-benefit ratio	**-56,7**	**0,8**	**1,0**

Figure 46. Example of a possible map of adaptation pathways for the case of the Critical Area – Relocation of Cova do Vapor, and the respective scorecard. Source: own elaboration.

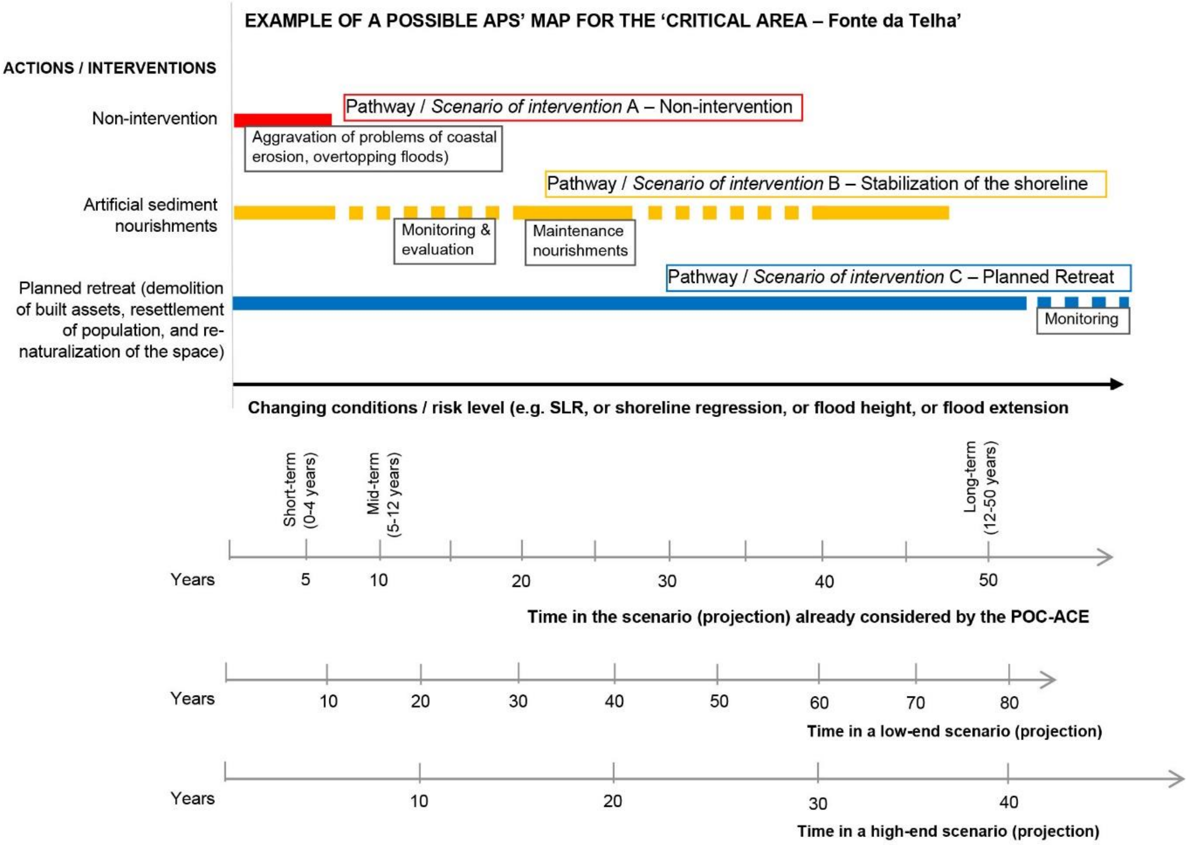


Figure 47. Example of a possible map of adaptation pathways for the case of the Critical Area – Relocation of Fonte da Telha, where it would be beneficial to add other adaptation measures and 'scenarios of intervention' viable in the long-term period. Source: own elaboration.

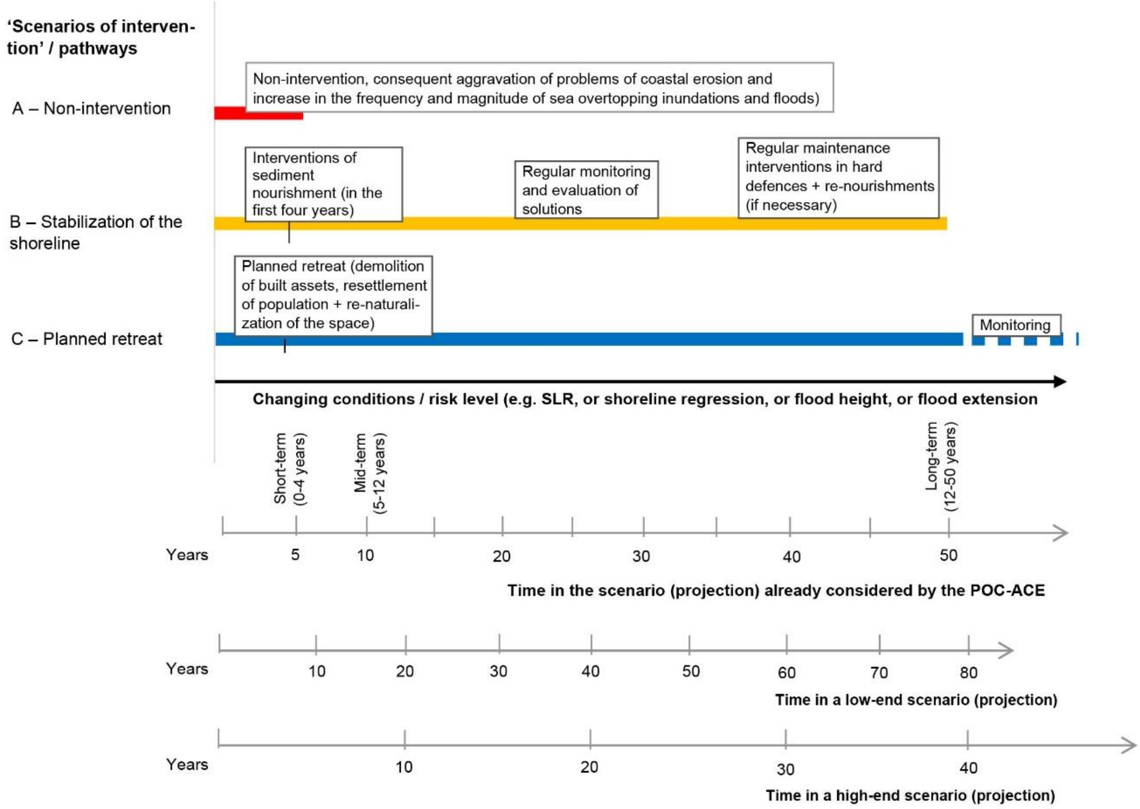


Figure 48. Other example of a possible map of APs for the case of the Critical Area – Relocation of Fonte da Telha, where it would be beneficial to add other 'scenarios of intervention' viable in the long-term period. Source: own elaboration.

5.4. Key-element 4: monitoring, evaluation and review / adjustment of the Plan

The elaboration of the POC included the definition of a system of monitoring and evaluation of the POC itself and of the coastal zone. It is expected to allow the regular re-evaluation of the POC, namely of its Program of Actions, and, if necessary, its review (alteration or modification).

The POC underlines that monitoring is essential '*to ensure a strategic, planned and adaptive management of the coastal zone*', and to allow the regular evaluation of the Program of Actions (POC-ACE 2018 a, p.12; 2018, p.160, 145). Monitoring is deemed '*fundamental to assess the results obtained with the implemented actions and the level of concretization of the actions and performance of the POC in the end of the first four years (...)*', and to *'allow readjusting priorities in function of the ongoing territorial dynamics and of the evolution of the economic-financial context and, consequently, define a feasible framework for action for the subsequent quadrennium*' (POC-ACE 2018 a, p.12; 2018, p.145, 160). However, the POC does not explain how the monitoring system will allow the readjustment of priorities (according to the dynamics underway and evolving conditions) and the redefinition the Program of Actions for the next four years. The POC provides no example of how its priorities might be readjusted and its action framework redefined, e.g. it is not mentioned whether it will be possible to change the order of actions envisaged in the Program of Actions, in time, or to include new actions that were not envisaged during the elaboration of the POC.

Monitoring is deemed crucial to ensure the effectiveness and adequacy of the planning instrument (POC) to what is expected to be achieved with it (POC-ACE 2018, p.164; 2018 d, p.114). The POC also recognizes that monitoring is necessary to assess changes in the coastal biophysical systems over time, and as a warning mechanism that serves to determine when a situation reaches a point that requires intervention, and to set targets and evaluate the impacts of the actions taken (POC-ACE 2018, p.164; 2018 d, p.114). Notwithstanding, the POC did not define critical levels / values that indicate when a situation reaches a point that requires action, i.e. no trigger-values were defined, neither concrete targets (measurable levels of certain variables) to help assess the effects of the actions taken. Whereas the POC intends to ensure the regular monitoring of the coastal zone to allow spatial planning to timely respond to the evolution of physical threats and opportunities (POC-ACE 2018 d, p.111), it does not explain how it will ensure such timely response: no decision-points and trigger-values were defined (that could be used to indicate the need to take a decision or action), and few indicators were defined to monitor the evolution of threats and vulnerabilities.

Based on the monitoring results, APA will carry, in the end of every four years, an evaluation of the Program of Actions. This exercise will imply evaluating the obtained results (namely the level of concretization of the actions proposed and of the performance of the Program of Actions), and revisiting the priorities and actions planned for the next four years, and, thus, readjusting the actions to be taken (including their definition, scheduling, and financial sources) (POC-ACE 2018, p.163; 2018 d, p.113). Thus, the Program of Actions will be evaluated and reprogrammed every four years (including the redefinition of the investments for the next 4 years) (POC-ACE 2018, p.146,160; 2018 d, p.112).

Although the POC provides a monitoring and re-evaluation programme, such programme presents several shortcomings (in relation to the main characteristics of the Key-element 4):

- The POC's monitoring and re-evaluation system specifies indicators to be monitored, but such indicators do not cover relevant changes and new information that might emerge over time, namely new / updated future scenarios of climate change and socioeconomic development, possible changes in relevant parameters like SLR, storm patterns, socioeconomic changes, etc. Monitoring should ensure a targeted observation of important changes in variables related with the effects of climate change and urban development, and the regular re-assessment of future scenarios. The monitoring of local changes and global changes is required to analyse whether decisions or actions must be anticipated or delayed in time, or if other actions must be carried.

- The POC mentions that the Program of Actions may be reviewed and adjusted over time, but it does not clearly explain how such reviews and adjustments can be carried. While the Program of Actions – its actions, their timing, the entities responsible, and the investment required – may be altered, if necessary, in function of monitoring results, the POC did not specify whether and what alternative actions may be included in the Program of Actions, nor in which conditions. As the POC did not anticipately plan nor provide alternative actions, neither identify ATPs, it will be difficult to devise which action(s) may be used (in alternative to an implemented or planned action) and when it will be necessary to implement it. Moreover, the adjustment of the Program of Actions will not necessarily imply an adjustment of the POC itself. Besides this, the review of the Program of Actions will be based on the monitoring outputs, and, as referred above, some important aspects about external conditions, and new information and updated scenarios, were not considered as indicators to be monitored. Moreover, some relevant changes in variables may not be detectable in the timescales of the monitoring and evaluation system (e.g. SLR cannot be detected in 4 years). All these factors may lead to an underestimation of the real need of adjusting the Program of Actions and the POC itself. Thus, despite the definition of the monitoring and evaluation system, the possibility of adjusting the POC, its measures, or their timing, is not completely safeguarded.
- As the Team did not define critical thresholds / ATPs, it will be more difficult to reassess the choices, strategies, and measures, planned (proposed) or implemented, in terms of effectiveness, and to identify the adequate timing for new actions (under different future scenarios). Moreover, the monitoring and re-evaluation system of the POC did not specify 'trigger-points' or 'decision-points' (e.g. in the TE2100, the decision-points serve to trigger a decision on the measure(s) to be implemented and its subsequent implementation, based on the observation of the indicators and on critical thresholds previously defined for certain variables, e.g. water level). As such, in the case of the POC-ACE, if a change is detected in a given indicator, it will still be difficult to determine if the Program of Actions must be altered (e.g. whether an action must be anticipated / postponed, or whether a new action is necessary, and which action can be used). It will remain difficult to understand what is the right timing to (cost-effectively and timely) implement an action.

The 4th key-element of an Adaptive Planning approach involves the capacity to adapt (adjust) the Plan (its policies, measures, or their timing), as new information arises or as changes occur. However, in the POC-ACE, this was not fully ensured. The system of monitoring and evaluation could have further explained how it will serve to regularly reassess of the POC itself, and review (adapt) it. In addition to the monitoring of relevant changes in external conditions, of the level of concretization of the POC, and of the effects of the actions implemented, the Programme must be regularly revaluated, and such monitoring and revaluation must allow that its policies (e.g. Directives), strategies / options, and measures (namely the *Scenarios of Intervention* envisaged for the Critical Areas, but also the actions listed in the Program of Actions), are adequately reassessed and adjusted / adapted, if necessary.

BOX 14. The SEA recommends the regular and systematic evaluation, monitoring and integrated management of coastal risks at different scales and considering scenarios of climate change at large time-horizons, in a logic of preventive action aimed at the prevention and mitigation of coastal risks. According to it, the monitoring of the sedimentary dynamics, evolution of the shoreline, and performance of coastal protection works, should be prioritized (POC-ACE 2017, p.83). It also recommends a regular follow-up of the evolution of the situations of risk for people and assets, and studies on the susceptibilities of the coast to climate change (intensifying the monitoring and evaluation of situations of risks and deepening knowledge of threats) (POC-ACE 2017, p.133, 169). It proposes measures like: elaborating risk maps of floodable areas and management plans; developing monitoring programmes of the situations of risk; revaluating and reconfiguring the priorities of intervention in function of monitoring results (POC-ACE 2017, p.158, 153). APA, with other actors, should monitor and evaluate the alterations in the coastal zone, identify insufficiencies and obstacles to the concretization of the Directives and projects / actions, and measures to overcome them. Moreover, it should regularly analyse the monitoring results and define new priorities of intervention, and this implies annually examining the state of play of the coastal defence interventions, updating the register of expenses with adaptation, and cost-benefit and multi-criteria analyses (POC-ACE 2017, p.161). The coastal zone is a very complex system marked by uncertainties and unpredictability, which make their management complex. The improvement of coastal management implies implementing a monitoring system that produces data that serves as a reference to evaluate the applied policies, however, in Portugal there are still great insufficiencies regarding monitoring, namely shortcomings related with the coastal risks associated to the evolution of the shoreline and sedimentary dynamics (POC-ACE 2017, p.149).

5.5. Key-element 5: ongoing cycle of planning, monitoring and adaptation

The 5th key-element of an 'Adaptive Planning and Management' approach concerns the ongoing process of development, implementation and reassessment of a *dynamic adaptive plan / programme* and its associated cycle of iterative risk management. This process involves several steps which are essential to design an *adaptive plan*, implement it, and monitor and (re)evaluate the plan itself and relevant changes in external conditions, and, in this way, to ensure the Plan's *adaptability* under uncertain future conditions and changes over time. It is a continual and learning-oriented process, where the various steps (individually and in their whole) are crucial for concretizing an *adaptive planning and management*.

The analysis of the documents that constitute the POC-ACE showed that the process of elaboration of the Programme followed several phases, but, in each of these phases, the key-elements of an 'Adaptive Planning and Management' approach were little explored or not addressed. In the phase of analysis of potential future vulnerabilities and threats associated to the coastal risks of erosion, sea overtopping inundations and floods, and cliff instability, the Team could have considered other plausible future scenarios (projections of the shoreline retreat induced by erosion, and of the extension of the floodable area, for the time-horizons of 2050 and 2100). Moreover, in this phase, the Team could have identified critical thresholds / ATPs that might be disruptive for the existing or proposed measures. In the phase of exploration of adaptation options, and particularly, in the development of possible *scenarios of intervention* for the 'problem spaces' (in terms of coastal risks), the Team could have worked with the method of APs, and could have considered *dynamic robustness* and *flexibility* as key criteria for assessing and selecting options (in addition to cost-benefits and effectiveness). Finally, the definition of the monitoring and evaluation system could have included the specification of decision-moments or triggers (trigger values in the indicators monitored), and the re-evaluation of new / updated scenarios. Moreover, the POC could have provided examples of how the Program of Actions, and the POC itself, might be adapted / adjusted and when this might be required (under what conditions will be necessary to review actions applied or planned, how this will be done, will it be possible to include other measures, e.g. measures not envisaged during the POC's elaboration, will it be possible to alter the timing of an action, etc.).

The POC-ACE was approved in 2019, hence, its implementation and the concretization of its monitoring and evaluation system still need to be evaluated. It will be essential to examine how the monitoring and re-evaluation system will inform the implementation of the POC and its possible reviews in the future. The first three key-elements of an 'Adaptive Planning and Management approach' were scarcely considered in the POC's elaboration, and a great emphasis has been put on the monitoring and evaluation system as the main (and, almost unique) ingredient to ensure an adaptive coastal planning and management[77], thus, it will be important to analyse whether such system will be sufficient (*per se*) to deliver and fulfil an approach of 'Adaptive Planning and Management' (even when the other four key-elements have been largely disregarded).

[77] The SEA underlines that, to develop an '*adaptive management in the face of the territorial dynamics*' and meet the proposed objectives, it will be necessary to enhance the articulation between the various actors involved in the coastal zone (POC-ACE 2017, p.153). The concretization of the Objective 1 (*prevent and reduce the coastal risks and the vulnerability to climate change*) will require building a governance model that ensures the coordination among actors (namely municipalities) and knowledge share in the phase of implementation of the POC. According to the SEA, '*to boost an adaptive management in the face of dynamics of the territory*', it will be necessary '*to promote the continual and formal articulation between the various actors involved in the coastal zone*', provide training and human resources on the implementation of measures, and improve the institutional involvement in the implementation process (POC-ACE 2017, p.158).

5.6. Comparison: Key-elements of an Adaptive Planning and Management *versus* the POC-ACE

Table F' compares the key-elements of an 'Adaptive Planning and Management approach' (APM) that are essential to develop a *dynamic adaptive plan* (left column) to the POC-ACE case by synthesizing whether and how these key-elements were applied in the POC-ACE case (right column).

Key-elements of APM, based on reference cases	POC-ACE case
Key-element 1: To consider a wide range of *plausible future scenarios* (different climatic, physical, and socioeconomic scenarios), rather than a single probabilistic projection of the future, and use them namely to assess measures and strategies on their effectiveness. This key-element consists of the consideration of a wide range of plausible future scenarios, and their use in the assessment of measures and strategies (pathways) regarding their effectiveness. It is necessary to consider various plausible futures to assess what measures can be used to achieve the objectives regardless of how the future unfolds. The scenarios should represent the main uncertainties about future conditions and changes.	The Team generated a single scenario (projection) of the future shoreline retreat (regression) with two time-horizons (2050 and 2100), and a single scenario (projection) of the future floodable zone with two time-horizons (2050 and 2100). These two projections were used to delineate two risk zones in low-lying sandy littoral: the Strips of Safeguard from Coastal Erosion (Level I - 2050 and Level II - 2100), and the Strips of Safeguard from Coastal Floods and Sea Overtopping Inundations (Level I - 2050 and Level II - 2100). In the generation of both projections, it was considered a single scenario of SLR (which was aggregated to other components to calculate the projections): +0,30 m in 2050 and +1,50m in 2100. No scenarios were considered for other climate change-related parameters / variables (e.g. changes in storm patterns, or in wave climate, river discharges, etc.), neither for socioeconomic and urban development. The Strips of Safeguard from Coastal Erosion and the Strips of Safeguard from Coastal Floods and Sea Overtopping Inundations were then considered in delimitation of 'problem spaces' (in terms of high susceptibility to coastal risks, and which were latter called 'Critical Areas – Relocation'), and in the exploration of possible responses for such 'problem spaces'– i.e. in the formulation of the possible '*Scenarios of Intervention*' for critical areas. Thus, both Strips (single projections) were used for planning purposes, namely for exploring and assessing possible adaptation options.
Key-element 2: To identify critical thresholds / ATPs (conditions under which the current or a given measure ceases to be effective / acceptable, and a new measure is needed.	**Not addressed.** Although the Team carried an analysis of potential future threats and vulnerabilities associated to coastal risks and climate change effects, it did not identify critical thresholds (limit-values) or ATPs.
Key-element 3: To develop a *robust and flexible* set of measures, to deal with uncertain future changes, through the 'Adaptation Pathways approach' (APs). I.e. to design a '*robust and flexible* set of actions', to respond to uncertain change. This element involves designing *robust flexible strategies* with the APs approach, a strategy can be itself a set of sequenced measures, a pathway. In an Adaptive Planning approach, measures must be *robust*, *flexible*, and '*low/ no-regrets'* as much as possible. The development a *robust and flexible* set of measures requires incorporating *robustness* and *flexibility* and low-regrets properties in the choice of measures and design of strategies. The design of *robust flexible strategies* can be done by using the 'APs approach'. The APs is a methodological approach for '*exploring and sequencing a set of possible actions* (or sets) *based on alternative external developments over time*' (Haasnoot et al. 2012, p.485). In the APs, a planner envisions short-term measures chained with long-term possible alternatives (options), and envisages possibilities for switching between them, through pathways. In the APs, measures are implemented iteratively over time to keep risk below target	The POC Team developed three *Scenarios of Intervention* for the 'problem spaces' (later called 'Critical Areas - Relocation'): *Scenario A* (non-intervention); *Scenario B* (stabilization of the shoreline or cliff, mainly through *soft protection measures* like beach nourishment); *Scenario C* (planned retreat). These *Scenarios* consist of three possible options (alternatives) for the critical areas. Each *Scenario* is mainly based on a single type of adaptation measure (*non-action*, *soft protection*, or *planned retreat*). Although the POC describes the likely evolution of each *Scenario of Intervention* in the short-, mid-, and long-term, each *Scenario* does not consist of a pathway (i.e. a set of measures sequenced and implemented over time). The Team did not work with the APs method to develop the '*Scenarios of Intervention*', and the three *Scenarios* were not elaborated with the aim of ensuring the *dynamic robustness* and *adaptability* of the Programme (which are required to develop a *dynamic adaptive plan*). The POC does not mention the possibility of switching of measures, or from a given *Scenario of Intervention* to another *Scenario*. It was not considered nor planned a phased implementation of several measures over time to tackle changing levels of risk. The *Scenarios of Intervention* were devised with a single plausible future in mind and were only assessed under such future (the Team chose the *Scenario* that presented the highest cost-benefit ratio under such plausible future). Only three *Scenarios* were developed, and it was not ensured the possibility of switching to other measures, or to other *Scenarios of Intervention*. It is not ensured the possibility of switching to a new measure, or to other *Scenario of Intervention*, as changes occur. The Team did not analyse under what conditions a given *Scenario* (and its measures) will cease to be effective or acceptable (it did not identify ATPs that require switching of measure, changing, or adding new measures). Each *Scenario* was not devised as a pathway, in which a new measure is needed once its predecessor become ineffective or unacceptable.

levels, and, at the same time, keeping open options to manage future risk. A pathway is a '*package*' of measures sequenced and applied over time. Each pathway contains a set of measures (individual or in groups) that are implemented in sequence to manage risk over time. Each pathway is *flexible* (it is possible to move from a measure to another), and it is possible to switch from a pathway to another. In the APs, a plan / strategy is '*designed to be adjusted over time as more is learnt about the future*' or as changes occur. The timing for new measures, and measures themselves, can be modified (changed) over time. The APs leads to an *adaptive plan* that is: *dynamically robust* to uncertain future change and *adaptable* to change (the pathways can be adapted as climatic, socioeconomic, or physical changes occur).	The Team did not anticipately plan alternative measures / options for the mid- and long-term, and the measures envisioned for the short-term were not linked with possible future options (viable in the long-term). Thus, the flexibility of *keeping open options* for the future (having measures 'on hand' to manage future risk) was not guaranteed. There was no anticipatory planning of possible measures for the mid- and long-term. Moreover, it was not envisioned a potential stepwise / phased implementation of measures within each *Scenario*. Apparently, the POC provides a wide diversity of coastal adaptation measures, but when looking at the scale of each 'Critical Area – Relocation', the POC offers few alternatives: it assessed the same three *Scenarios of intervention* in all 'Critical Areas – Relocation', and in all of them, it prescribed *planned retreat* (which was the most cost-beneficial solution under the plausible future assumed by the POC). The POC describes each *Scenario of Intervention* and its evolution in three time-periods (0-4 years, 5-12 years, and 12-50 years), but no alternatives for the mid- and long-term were envisaged or programmed. The POC Team did not use the criteria of *dynamic robustness* and '*low-regrets*' to support the development and selection of the *Scenarios of Intervention*. In its turn, *flexibility* was recognized as an important feature in some measures chosen (e.g. sediment nourishments).
Key-element 4: To continuously monitor relevant changes and new information, reassess / review the Plan, and adjust it accordingly. This requires: the targeted monitoring of relevant changes (in external conditions, effects of measures), the continual evaluation of new information (e.g. updated scenarios); and the regular reassessment / review of the Plan, and, if necessary, its adjustment (by redefining or modifying measures, pathways, or action plans, according to monitoring results). Important changes are continuously observed and foreseen through monitoring, and future scenarios are reassessed; the Plan is regularly revaluated, and, if necessary, its measures or pathways are adapted. The monitoring of local and global changes is necessary to examine if decisions should be anticipated / postponed, reviewed or altered. The monitoring and revaluation system must be accounted in the Plan.	The POC-ACE has defined a monitoring and evaluation system of the Programme and of the coastal zone. Such system is deemed essential to operationalize an *adaptive management* and ensure eventual adjustments of the Program of Actions. The POC describes its Monitoring and Evaluation System, including output and outcome indictors to be monitored. Although the monitoring system considers important drivers of change and risk in the list of the indicators, it does not include indicators / variables that are relevant for detecting trends regarding climate change effects, such as SLR, changes in storm patterns, as well as indicators regarding socioeconomic and urban development (that induce to changes in risk levels). The POC does not specify decision-points neither trigger-values in variables that may indicate the need to take a decision / action. The monitoring system does not refer that it is necessary to monitor progresses in scientific knowledge and new / updated climate scenarios that might emerge. The monitoring and evaluation programme refers to the eventual need of adjusting the Program of Actions in function of the monitoring results, but it does not explain how it will ensure that the Program of Actions, and more broadly, the POC and its contents – e.g. actions proposed for the Critical Areas – can be adjusted / adapted, if the monitoring results, or if developments over time, demand such adjustment.
Key-element 5: ongoing process of planning and adaptation / iterative risk management, with its several steps: definition of objectives, analysis of risks and potential impacts now and in the future; identification of ATPs; exploration of possible measures; development of pathways and their assessment under various scenarios; selection of preferred pathway (decision) as input for designing an 'action plan'; implementation, monitoring of external changes and regular reassessment of the Plan and, if necessary, the adjust (correct or alter) it, its measures or their timing. This process safeguards the adaptability of the Plan over time, so it can deal with uncertain future change.	The POC-ACE has put a strong emphasis on the role of the monitoring and evaluation programme as the main (and, almost, single) ingredient necessary to ensure an *adaptive planning and management*. Although the POC is already in force, there is still little experience and few analyses of the steps of implementation and of monitoring and evaluation. It is necessary to analyse how monitoring has been used to inform the implementation and adaptation of the actions proposed over time. The POC-ACE sought to adopt an approach of *adaptive planning and management*, but such approach is mainly substantiated in the 4th Key-element. The POC tends to disregard the importance of following the various steps that are required to ensure an ongoing process of 'Adaptive Planning and Management', and, in these, applying the other four key-elements that underlie the approaches of the paradigm of Adaptive Planning.

Table F'. Comparison of the key-elements of an *Adaptive Planning and Management approach* identified in Part A with the POC-ACE case. Source: own elaboration.

5.6.1. Sub-elements of Key-element 3: is the POC-ACE an *adaptive programme*?

Table G' provides a comparison between the main sub-elements of the Key-element 3 – and whether and how they were addressed in the POC-ACE case.

Sub-elements of K3: how the robustness and flexibility are safeguarded in the 'set of measures (actions)' of a dynamic adaptive Plan, based on the reference cases (and the Plan is adaptable and how it can be adapted) versus the POC-ACE case	
Reference cases	**POC-ACE**
The 'APs approach' allows switching between different options in the future. Each pathway contains a set of measures sequenced and implemented to manage risk over time. Each pathway is itself flexible (e.g. is possible to switch from a measure to another), and it is also possible to switch (move) from a pathway to another. (Possibility of switching to other measures; switching between measures / options)	**Not addressed. No pathways were designed.** The POC-ACE Team has formulated three 'scenarios of intervention' for the 'problem spaces' (critical areas in terms of susceptibility to the risks of coastal erosion, or sea overtopping inundations and coastal floods, or cliff instability). However, the POC does mention the possibility of switching from a measure to another within a given 'scenario of intervention' (i.e. the possibility of shifting of, changing or adding measures), neither the possibility of switching from a 'scenario of intervention' to another one, if future developments require so. Moreover, the three *scenarios of intervention* have different lifespans (not all the three scenarios will remain effective and viable under the plausible future assumed by the POC), therefore, they do not offer possible alternatives / options (viable in the long-term). The POC has not left open alternatives for the mid- and long-term, neither linked the measures envisaged for the near future to such options.
It is possible to switch (move) from a pathway to another. (Possibility of switching to other pathways)	**Not addressed.** The POC does not refer the possibility of moving from an 'scenario of intervention' to another, as conditions change or new knowledge arises. The three 'scenarios of intervention' different lifespans, and not all of them would be cost-effective in the plausible future assumed in the POC, therefore, they do not constitute alternative options (to manage flood risk) throughout the future. The Team only considered a single plausible future, and with such future in mind, it selected the best 'scenario of intervention' for each critical area. The Team did not consider 'worse' scenarios for climatic parameters, nor assessed the robustness of the proposed 'scenarios' under such scenarios. Furthermore, no ATPs or critical thresholds were identified, thus, it is not shown under what conditions a given measure (or *scenario of intervention*) will cease to be effective and a new measure will be needed.
Having various measures (availability of alternative measures) + Having various pathways available (the APs' map presents several possible pathways).	**Not addressed**. Three 'scenarios of intervention' were devised, but each of them has a different lifespan, and not all the three constitute viable options in the plausible future. Each scenario is mainly based on a type of adaptation measure (non-intervention, soft protection through beach nourishments, or planned retreat). It is not fully clarified until when such 'scenarios of intervention' are expected to be useful to manage risk, neither which levels of SLR or shoreline retreat, or other parameters, such 'scenarios of intervention' are expected to cope with. The Programme does not identify critical thresholds at which another measure or 'scenario of intervention' will be required. The POC does not provide a range of alternative options (diverse 'scenarios of intervention') viable and possible in the future (especially in the mid- and long-term).
Stepwise / phased implementation of various measures	The POC did not plan a phased implementation of several measures over time, in a stepwise or sequenced way. However, it briefly describes the likely evolution of the three main scenarios of intervention in three periods (short-, mid- and long-term). For the Critical Areas – Relocation, the adaptation option chosen (i.e. the scenario of intervention selected) was 'C – planned retreat'. The POC describes the interventions required in this 'scenario of intervention' (demolition of built assets, relocation of buildings, re-settlement of populations, and re-naturalization of the space).
Keeping open options (alternatives); not foreclosing future options. Decisions in the near-future on concrete actions should not foreclose future options to act differently (and switch or add actions if climate or societal changes ask for it); responses should not unnecessarily constrain future choices.	The POC-ACE aims to ensure that '*the options taken in the present do not jeopardize future generations and the opportunities existent or emergent in the territory*', however, it does not mention how it will ensure this. The POC did not devise options for the mid- and long-term, i.e. it did not kept options open for the future. The diverse *scenarios of intervention* were not logically coupled with possible alternative measures (new or additional measures) that may be used in the future. The three *scenarios* were not presented in a timeframe that allows grasping their effectiveness over time.
Possibility of changing (altering) the timing of new measures (bringing forward or postponing)	**Partially addressed.** The POC mentions that, based on the results of the monitoring and evaluation system, it will be possible to change the timing of the actions programmed in the Program of Action and their 'definition'. It is not specifically mentioned the possibility of anticipating or postponing the timing for a measure, as changes are observed or as new climate scenarios arise over time. No references to what should be done if conditions change faster or slower than currently expected (i.e. under the plausible future assumed), or if unexpected changes occur.
Possibility of adjusting / adapting the Plan (its pathways, measures, or their timing), over time; (allowing the adjustment of the Plan /	**Partially addressed.** The POC-ACE mentions the possibility of changing its Program of Actions over time, according to monitoring results (namely the programmed actions, their timing, and financial sources). However, it provides no specific information about how the POC itself and its contents – e.g. the Directives, the 'scenarios of intervention', and other

Strategy devised, based on the results of the monitoring and revaluation system). The Plan can be adapted to changes over time: it is possible to adjust the timing of new measures, or shift from a measure to a new measure (or from a pathway to another). The Plan can be adapted in the following ways: by adjusting the timing for a new measure (decision point and implementation point); by switching to a new measure or to another pathway; or modifying a measure (within a pathway). Flexibility to be adapted to changing conditions over time Possibility of changing of measure or pathway. Possibility of postponing or advancing the timing for an action.	actions proposed (in the Program of Actions) might be adjusted / adapted (no references to the possibility of switching of 'scenario of intervention' or measure in the Critical Areas). It is not clear how the POC itself will be *adaptable to change* (e.g. to changing climatic and socioeconomic conditions and evolving risks that may develop until 2100), and how the Program of Actions will be adapted in function of changes observed in the indicators. It is not ensured the possibility of altering the timing of new measures; nor the possibility of switching of actions / measures, or shifting from a 'scenario of intervention' to a new one. Moreover, the POC does not explain how it will address changes as these are monitored and identified, or each time the POC is reassessed. The POC will carry a re-evaluation (review) of the Program of Actions every four years, which must be informed by the monitoring results. However, the POC did not specify relevant values in the indicators that could act as triggers or that might require the anticipation or postponing of a measure, nor important decision-points. In addition, the POC does not provide alternative measures (options) for the future (it does not provide possible alternative actions that might be used in alternative to a proposed measure or to substitute or modify an implemented measure). The POC recognizes that its monitoring and revaluation system will be crucial to allow the adjustment of the Program of Actions, but provides little details on how this will be done. The Program of Actions focusses on the period 2018-2028, without any schematic program of possible measures for the mid- and long-term. It is not referred the need of monitoring / assessing new climate projections as these arise. The POC might not be adaptive enough to deal with accelerating / decelerating effects of climate change and socioeconomic changes (different than the current projection) and with unexpected/ unforeseen conditions (e.g. other projections than the one assumed).
Diversity / variety of measures. Diversity of measures (w/ different purposes, including measures to reduce probability of hazard, measures to exposure, and measures to reduce vulnerability); hard and soft measures, structural / non-struct. Measures across different actors, sectors)	**Partially addressed.** The Team considered differentiated adaptation measures (including measures of soft and hard protection, accommodation and planned retreat). To reduce the risks of coastal erosion and coastal flooding and the vulnerability associated, it proposes diverse measures, namely: sand nourishments; dune reinforcements; rehabilitation of existing hard defences, relocation / planned retreat, accommodation measures (for integration in spatial planning instruments at municipal level), and regimes of safeguard for the Strips of Safeguard, integrated sediment management and re-establishment of the sediment cycle (in sediment cells). Regarding the prevention and reduction of coastal risks and vulnerability to climate change, the POC proposes actions to avoid the retreat (regression) of the shoreline, and actions to reduce the probability of occurrence of coastal floods and overtopping inundations (e.g. the preservation of existing natural defences, maintenance and rehabilitation of coastal defence structures, strengthening of dune chains, and sediment nourishments on beaches), and actions to contain (limit) the exposure of the coastal zone to the risks of coastal erosion and sea overtopping inundations and coastal floods (through the establishment of the Strips of Safeguard from Coastal Risks and their respective regimes of safeguard).
Use of no- / low-regrets measures (and earlier in time); and win-win measures	**Partially addressed.** Measures were not selected with criteria like dynamic robustness or low-/no-regrets properties (reversibility and adaptability) in mind. For example, measures were not selected because they perform well under a wide range of plausible futures (robustness), or because they reduce risk immediately and cost-efficiently under a wide range of climate scenarios (i.e. they are low-/ no-regret) or provide benefits regardless of the scenario that unfolds. However, the POC has (intentionally) proposed some measures are inherently flexible or more easily reversible (e.g. sediment nourishments, and re-establishment of the sediment cycle). The main criteria upon which the selection of the 'scenarios of intervention' was based was the cost-benefit ratio of each 'scenario', and its effectiveness over time (lifespan) under the plausible future assumed by the POC.
Robust measures + flexible measures Robust measures: e.g. create a robust system that can better cope with extreme events; or increase a system's resilience; or incorporate large safety margins (increase a system's resistance); incorporate engineered/structural flexibility, adapting engineered structures. Flexible measures: e.g. can be adapted if the future unfolds differently than foreseen; cope with uncertain change; remain flexible under uncertain future changes.	**Partially addressed**. The POC-CE did not intentionally take into consideration criteria such as *dynamic robustness* and *flexibility* in the exploration, identification, and assessment of possible 'scenarios of intervention' for the 'problem spaces', and of adaptation measures / strategies for other zones or locations. However, some of the measures proposed correspond to flexible measures, e.g. beach nourishments. The POC defines measures of maintenance and rehabilitation for some existing defence structures or, and mentions that such maintenance or rehabilitation works must take into account possible future scenarios of climate change.
Safeguarding land for future adaptation measures	**Partially addressed.** The POC-ACE defines the Strips of Safeguard from Coastal Risks as areas that are mainly *non-aedificandi*, to limit the exposure to risks.
Integration of climate adaptation into new infra-structure projects (*mainstreaming*); Integrating FRM with other investments and agendas	**Partially addressed.** Integration of climate adaptation into coastal spatial planning and management. The POC could have further explained whether and how it will be possible to seize opportunities that might arise; search for win-win options.

Table G'. Comparison of the main ways through which the Reference Cases delivered an *adaptable plan / programme* with the case of POC-ACE. Source: own elaboration, based on Part A of this Thesis and on the analysis of the POC-ACE.

6. Barriers to the adoption and operationalization of an Adaptive Planning and Management approach in the POC-ACE case

The variety of strategies envisioned in the POC may lead to problems of operationalization, and some proposals will involve multiple actors (private and public actors at several levels, who may face difficulties in integrating proposals and principles set at a higher institutional level), and there may be proposals that overlap (as noted in POC-ACE 2017, p.148). The articulation between the various entities with competences in the coastal zone is essential to ensure that the process of implementation of the POC is effective and its final product coherent. In the process of transposal of the POC's proposals to the various PDMs, some conflicts may arise, e.g. the POC may constrain the strategy of development defined by a municipality, and there may be problems in conforming / ensuring the compatibilization of the regulations and plans (cartography) of the two plans. Though the POC sought to minimize the divergences between its strategies and Territorial Model and the model of development envisioned by the municipalities, especially regarding urban settlements and their expansion in risk zones, it will be necessary to enhance the articulation among entities, and the congregation of strategies, to truly ensure a planned adaptation of coastal urban settlements (POC-ACE 2017, p.148-149).

Some important aspects that can constitute barriers to the adoption and application of an approach of Adaptive Planning and Management are:

- the existence of a wide range of entities with different objectives and priorities in the area of intervention of the POC-ACE. There are several entities with interest on the territory, and with objectives and priorities that are contradictory (POC-ACE 2017, p.150).
- The existence of a multiplicity of strategies envisioned for the area ACE. The operationalization of a wide range of strategies defined in various reference documents may raise several problems.
- The reduced concertation (harmonization) between the entities responsible for knowledge production and scientific research (e.g. universities, research centres) and the Central Administration; existence of low levels of information share between the centres of knowledge production and the political system involved in coastal planning and management (POC-ACE 2017, p.150).
- Difficulties in integrating the principles defined at a higher (institutional) level by the various actors involved in coastal planning and management (POC-ACE 2017, p.150).
- Inexistence of monitoring systems in fields / areas essential for an effective management of the coastal zone (e.g. monitoring of the evolution of the shoreline) (POC-ACE 2017, p.150).
- The concentration of competences in a single entity may lead to a reduced diversity of responses (in relation to the variety of responses that would stem from a polycentric system of co-management / shared management) (POC-ACE 2017, p.150) (see also Note 364).

- Overreliance on the monitoring and reassessment system as the main and, almost, unique ingredient necessary to ensure an adaptive planning and management. Even though, there other four key-elements are essential to ensure a truly APM. Moreover, there may be changes and developments not detectable within the temporal scales of the monitoring system.
- Resistance to change and tendency for the status quo. The first POOCs have waited almost 20 years to be reviewed (they were expected to be reviewed every 10 years). Weak perception of coastal risk management and coastal climate adaptation as an ongoing process (iterative risk management cycle) where the plan / programme must be more regularly reviewed and adapted in accordance.
- Lack of understanding of the advantages of using an APM approach. Moreover, often the involved entities use the excuse of lack of time to absorb and apply new methods, which apparently are more complex and sophisticated, while in fact, such methods could simplify the planning process and make the plan more robust and adaptable to change and uncertain future conditions and risks.

III. SYNTHESIS FROM BOTH CASE-STUDIES

This section provides a synthesis of the main findings of Chapter II (Part B of the Thesis).

Table F'' compares the key-elements of an 'Adaptive Planning and Management approach' (APM) that are essential to develop a *dynamic adaptive plan* (left column) to the Study-cases (POC-CE and POC-ACE). It describes whether and how these key-elements were applied in the cases of the POC-CE and POC-ACE (right columns).

Table G'' shows the comparative analysis of both study cases with the main sub-elements of the Key-element 3 that contribute to develop a '*robust flexible set of actions*' (and an *adaptive plan*). Table H'' compares the main ways through which a plan is *adaptable* to uncertain future conditions and change – which mostly consist of important sub-elements of the key-elements 3 – and whether and how they were addressed in the case of the POC-CE and in the case of the POC-ACE.

Table E' answers to the main questions that concern the steps of a process of Adaptive Planning and Management, in each of the study cases.

Table S sums up some of the main topics analysed regarding the POCs.

Key-elements of APM	POC-CE case	POC-ACE case
K1: To consider a wide range of *plausible future scenarios* (different climatic, physical, and socioeconomic scenarios), rather than a single probabilistic projection of the future, and use them namely to assess measures and strategies on their effectiveness.	The Team generated: • a single scenario (projection) of the future shoreline retreat (regression) with two time-horizons (2050 and 2100). • a single scenario (projection) of the future floodable zone, for two time-horizons (2050 and 2100). With these two projections, the Team delineated two different risk zones – i.e. the Strips for Safeguarding from Coastal Erosion (Level I and II), and the Strips for Safeguarding from Coastal Floods (Level I and II), respectively. In the generation of both projections (Strips), it was only considered a single scenario of SLR, which was aggregated to other components to calculate the projections. The Team considered a single scenario for SLR: +0,35m in 2050 and +1,50m in 2100. No scenarios were considered for other parameters / variables, e.g.: storminess / changes in storm patterns (storm surges), wave climate, river discharges, socioeconomic development. The Strip for Safeguarding from Coastal Erosion (Level I – 2050) and the Strip for Safeguarding from Coastal Floods (Level I -2050) were then used (as environmental scenarios) in the assessment of four main possible Adaptation Scenarios / Strategies, for critical areas. As such, both Strips (single projections) were used for planning purposes – i.e. for exploring and assessing possible strategies.	The Team generated a single scenario (projection) of the future shoreline retreat (regression) with two time-horizons (2050 and 2100), and a single scenario (projection) of the future floodable zone with two time-horizons (2050 and 2100). These two projections were used to delineate two risk zones in low-lying sandy littoral: the Strips of Safeguard from Coastal Erosion (Level I - 2050 and Level II - 2100), and the Strips of Safeguard from Coastal Floods and Sea Overtopping Inundations (Level I - 2050 and Level II - 2100). In the generation of both projections, it was considered a single scenario of SLR (which was aggregated to other components to calculate the projections): +0,30 m in 2050 and +1,50m in 2100. No scenarios were considered for other climatic parameters / variables (e.g. changes in storm patterns (storminess), or in wave climate, river discharges, etc.) neither for socioeconomic and urban development. The Strip of Safeguard from Coastal Erosion (Level I) and the Strip of Safeguard from Coastal Floods and Sea Overtopping Inundations (Level I) were then considered in delimitation of 'problem spaces' (given their high hazardousness and susceptibility to coastal risks, and which were latter called 'Critical Areas – Relocation'), and in the exploration of possible responses for such 'problem spaces'– i.e. in the formulation of the possible '*scenarios of intervention*' for critical areas. Thus, both Strips (single projections) were used for planning purposes, namely for exploring and assessing possible adaptation options.
K2: To identify critical thresholds and ATPs	**Not addressed.** The Team did not identify critical thresholds (limit-values) or adaptation tipping-points.	**Not addressed.** Although the Team carried an analysis of potential future threats and vulnerabilities associated to coastal risks and climate change effects, it did not identify critical thresholds (limit-values) or ATPs.
K3: To develop and use a *robust and flexible* set of measures, to deal with uncertain future changes, through the 'Adaptation Pathways approach' (APs). I.e. to design a '*robust and flexible*' set of actions (containing *robust* and / or *flexible* measures), to respond to uncertain change. This element involves designing *robust flexible strategies* with the APs approach, a strategy can be itself a set of sequenced measures, a pathway.	The POC Team developed Four '*Adaptation Scenarios / Strategies*'. Each *Adaptation Scenario / Strategy* may contain several 'type-interventions' (measures). These *Adaptation Scenarios / Strategies* consist of four alternatives available for critical areas, in the near future. Each *Adaptation Scenario / Strategy* does not consist of a pathway. The Team did not design adaptation pathways. The four '*Adaptation Scenarios / Strategies*' do not provide alternative adaptation pathways, and they do not fully ensure the *dynamic robustness* and *adaptability* required in an 'adaptive plan / programme'. The POC does not explain if the type-interventions considered within each *Adaptation Scenario / Strategy* should be implemented at the same time, or whether they constitute alternatives that may be chosen (or not), and whether the interventions should be implemented in a sequence over time. It is not mentioned the possibility of a phased / stepwise implementation of the interventions. It is not explained if it would be possible to switch from an intervention to another within a given *Adaptation Scenario / Strategy*. The same applies to the four *Adaptation Scenarios / Strategies*: it is not mentioned whether it is possible to shift from a *Scenario* to another one, over time. The Team did not analyse under what conditions the type-interventions within each *Adaptation Scenario / Strategy* will cease to be effective (i.e. it did not identify ATPs that would require the implementation of new interventions). Thus, each *Adaptation Scenario / Strategy* was not devised as a pathway (where a measure is implemented when its predecessor ceases to be effective or acceptable). The Team did not anticipately plan alternative measures (options) for the mid- and long-term. As such, measures envisaged for the short-term are not linked to (chained with) possible options for the long-term. The POC mentions the intention of not foreclosing future options, by stating that the current strategies and measures should not preclude future strategies, however, it does not explain how it will ensure this. The *flexibility* of having options available for the future (i.e. *keeping open options* to manage future risk) is not fully guaranteed, as there was no anticipatory planning of possible measures for the mid- and long-term. Moreover, no information is given on a stepwise/phased implementation of interventions within each *Adaptation Scenario / Strategy* (which would provide a pathway). Apparently, the POC provides a wide variety of coastal adaptation measures (including measures to reduce different components of risk (probability of hazard, exposure, and vulnerability). However, when looking at each Critical Area, the POC offers few alternatives: it usually prescribes a *strategy of adaptation* based on one or two type-interventions, with little specifications on *what* concrete measures should be implemented, *when*, *where*, and *how*. It provides no alternatives beyond the prescribed strategy and its interventions. The POC Team did not use criteria of *robustness*, *flexibility*, or '*no-regrets*', to support the selection of a certain *Adaptation Scenario / Strategy* (decision-making). In the development and assessment of the four *Adaptation Scenarios / Strategies*, the Team considered a single projection of the future shoreline evolution (for 2050) and a single projection of the future floodable area (for 2050). As such, if these projections fail, the *Strategies* chosen might fail too.	The POC developed three *Scenarios of Intervention* for the 'problem spaces' (critical areas in terms of susceptibility to coastal erosion, or coastal flooding and overtopping inundations, or cliff instability): *Scenario A* (non-intervention); *Scenario B* (stabilization of the shoreline or cliff, through soft protection measures like beach nourishment); *Scenario C* (planned retreat). These *Scenarios* consist of three possible options (alternatives) for the 'Critical Areas – Relocation'. Each of these *Scenarios* is mainly based on single type of adaptation measure (*non-action*, *soft protection*, or *planned retreat*). Although the POC describes the likely evolution of each *Scenario* in the short-, mid-, and long-term, each *Scenario* does not consist of a pathway (a set of measures sequenced and implemented over time). It is not ensured the possibility of switching to a new measure, or to a new *Scenario of Intervention*, as changes occur. The Team did not work with the APs method to develop the '*Scenarios of Intervention*', and the three *Scenarios* were not elaborated with the aim ensuring the *dynamic robustness* and *flexibility* of the Programme, or the *adaptability* required in a 'dynamic adaptive plan'. The POC does not safeguard the possibility of switching of measures, or from a given '*Scenario of Intervention*' to another. It was not planned a phased implementation of several measures over time to tackle changing levels of risk. The *Scenarios of Intervention* were devised with a single plausible future in mind and were only assessed under such future (the *Scenario* chosen was the one that was most cost-beneficial under the plausible future assumed by the POC). Only three *Scenarios* were developed, and it was not ensured the possibility of switching to other measures, or to a new *Scenario of Intervention*, as conditions change. The Team did not analyse under what conditions a given *Scenario of Intervention* (and its measures) will cease to be effective or acceptable (it did not identify ATPs that require switching of measure, changing, or adding measures), thus, each *Scenario* was not devised as a pathway in which a new measure is needed once its predecessor ceases to perform satisfactorily. The Team did not anticipately plan alternative measures / options for the mid- and long-term, thus, the measures envisioned for the short-term were not linked with possible future options (viable in the long-term). The *flexibility* of keeping open options for the future (having measures 'at hand' to manage future risk) was not guaranteed. Moreover, it was not envisioned a potential stepwise / phased implementation of measures within a given *Scenario of Intervention*. Apparently, the POC provides a wide diversity of coastal adaptation measures, but when looking at the scale of each 'Critical Area – Relocation', it offers few alternatives: it assessed the same three *Scenarios of intervention* in all problem-spaces, and in all of them, it prescribed *Scenario C – planned retreat* (i.e. the most cost-beneficial solution over the next 50 years, under the plausible future assumed). The POC describes each *Scenario of Intervention* and its evolution in three time-periods (0-4 years, 5-12 years, and 12-50 years), but no alternatives for the mid- and long-term were envisaged or programmed. The POC did not use the criteria of *robustness* and 'low-regrets, to support the development of the 'scenarios of intervention, and the selection of the 'scenario' to be applied. Flexibility is recognized as an important feature in some measures chosen (sand nourishment).
K4: To continuously monitor relevant changes and new information, reassess / review the Plan, and adjust it accordingly.	The need of creating a monitoring and evaluation system is explicitly mentioned in the Programme, and it is recognized as a key requisite for ensuring an adaptive management approach / model, and for ensuring potential adjustments of the POC and its contents. The POC proposes the creation of a monitoring and evaluation system of the coastal zone and of the POC itself. It defines such Monitoring and Evaluation System and how it will work, including output and outcome indictors that must be monitored. The main drivers of change and risk are addressed in the indicators. However, it has not identified some variables that are relevant for detecting trends regarding climate change effects (SLR, changes in storm patterns). No information is given about triggers (i.e. trigger-values in variables) that may indicate the need to take a new decision / action. No information is given on decision-points or implementation-points. The monitoring system does not refer that is it necessary to monitor progresses in scientific knowledge and new climate projections that might emerge. The monitoring and evaluation system does not explain how it will ensure that the Programme and its contents – e.g. the measures planned for the Critical Areas – will be adjusted / adapted, if the monitoring results require so.	The POC-ACE has defined a monitoring and evaluation system of the Programme and of the coastal zone. Such system is deemed essential to operationalize an adaptive management and ensure eventual adjustments of the Program of Actions. The POC describes its Monitoring and Evaluation System, including output and outcome indictors to be monitored. Although the monitoring system considers important drivers of change and risk in the list of the indicators, it does not include indicators / variables that are relevant for detecting trends regarding climate change effects, such as SLR, changes in storm patterns, as well as indicators regarding socioeconomic and urban development (that induce to changes in risk levels). The POC-ACE does not specify decision-points nor trigger-values in variables that may indicate the need to take a decision / action. The monitoring system does not refer that is it necessary to monitor progresses in scientific knowledge and new / updated climate scenarios that might emerge. The monitoring and evaluation programme refers to the eventual need of adjusting the Program of Actions in function of the monitoring results, but it does not explain how it will ensure that the Program of Actions, and more broadly, the POC and its contents – e.g. actions proposed for the Critical Areas – can be adjusted / adapted, if the monitoring results, or if developments over time, demand such adjustment.
K5: ongoing process of planning and adaptation, and iterative risk management, with its several steps	The model of adaptive management proposed by the POC resembles the Adaptive Management approach proposed by Holling (1978), which puts greater emphasis on the role of monitoring. The new POC-CE is still waiting for approval. There is still no experience on the steps of implementation and monitoring. It will be necessary to analyse how monitoring will be used to implement and adapt strategies. The POC sought to adopt an approach of adaptive management, but this remains more an 'intention' than a reality upon which the Programme was elaborated.	The POC-ACE has put a strong emphasis on the role of the monitoring and evaluation programme as the main (and, almost, single) ingredient necessary to ensure an adaptive planning and management. Though the POC is already in force, there is still little experience in the phases of implementation and of monitoring and evaluation. It is necessary to analyse how monitoring has been used to inform the implementation and adaptation of the actions proposed over time. The POC sought to adopt an approach of *adaptive planning and management* which is mainly substantiated in the 4th key-element. It disregarded the importance of following the steps of the process of APM, and, in these, applying the other key-elements of APM.

Table F''. Comparison of the key-elements of an *Adaptive Planning and Management approach* identified in Part A, with the cases of POC-CE and POC-ACE. Source: own elaboration.

Table G''. Sub-elements of Key-element 3: Do the study-cases provide Adaptive Programmes?

Table G''. Sub-elements of Key-element 3: how are *robustness* and *flexibility* safeguarded in the 'set(s) of actions' of a 'dynamic adaptive plan / strategy', based on the Reference Cases; how a Plan / Programme / Strategy is *adaptable*: ways through which the Plan can be adapted		
Reference cases	**POC-CE**	**POC-ACE**
The 'APs approach' allows switching between different options in the future. Each pathway contains a set of measures sequenced and implemented to manage risk over time. Each pathway is itself flexible (e.g. is possible to switch from a measure to another), and it is also possible to switch (move) from a pathway to another. (Possibility of switching to other measures; switching between measures / options)	**Not addressed. No pathways were designed.** Although each '*Adaptation Scenario / Strategy*' contains several measures (interventions), it is not mentioned whether it will be possible to switch from a measure to another in a given *Adaptation Scenario / Strategy*. No tipping-points or critical thresholds were identified. As such, it is not shown under what conditions a given measure will cease to be effective and a new measure will be needed. Each Adaptation Scenario / Strategy main contain package of several measures (to be applied more or less at the same time), and four possible Adaptation Scenarios / Strategies were developed, and comparatively assessed, in the case of the Critical Areas.	**Not addressed. No pathways were designed.** The POC-ACE Team has formulated three 'Scenarios of Intervention' for the 'problem spaces' (critical areas in terms of susceptibility to the risks of coastal erosion, or sea overtopping inundations and coastal floods, or cliff instability). However, the POC does mention the possibility of switching from a measure to another within a given '*Scenario of Intervention*' (i.e. the possibility of shifting of, changing or adding measures), neither the possibility of switching from a '*Scenario of Intervention*' to another one, if future developments require so. Moreover, the three *scenarios of intervention* have different lifespans (not all the three scenarios will remain effective and viable under the plausible future assumed by the POC), therefore, they do not offer possible alternatives / options (viable in the long-term). The POC has not left open alternatives for the mid- and long-term, neither linked the measures envisaged for the near future to such options.
It is possible to switch (move) from a pathway to another. (Possibility of switching to other pathways; possibility of switching between pathways)	**Not addressed.** The POC-CE does not refer the possibility of moving from an '*Adaptation Scenario / Strategy*' to another one, according to the rate of change that is observed, as conditions change or as new knowledge arises. The Team did not consider 'higher / worse' scenarios for climatic parameters, neither assessed the robustness of the proposed Adaptation Scenarios / Strategies' under such scenarios.	**Not addressed.** The POC does not refer the possibility of moving from a 'Scenario of Intervention' to another, as conditions change or new knowledge arises. The three 'scenarios of intervention' different lifespans, and not all of them would be cost-effective in the plausible future assumed in the POC, therefore, they do not constitute alternative options (to manage flood risk) throughout the future. The Team only considered a single plausible future, and with such future in mind, it selected the best 'scenario of intervention' for each critical area. The Team did not consider 'worse' scenarios for climatic parameters, nor assessed the robustness of the proposed 'scenarios' under such scenarios. Furthermore, no ATPs or critical thresholds were identified, thus, it is not shown under what conditions a given measure (or *Scenario of Intervention*) will cease to be effective and a new measure will be needed.
Having various pathways available. The APs' map presents several different pathways available. + Having various measures (availability of alternative measures).	**Partially addressed**. More than one *Adaptation Scenario / Strategy* is available to manage flood risk (four Adaptation Strategies were developed). It is not explained until when such Strategies are expected to be useful to manage risk. Similarly, it is not mentioned with which levels of SLR or shoreline retreat, or other parameters, such Strategies are expected to cope with. The Programme does not identify critical thresholds at which another Strategy will be required.	**Not addressed**. Three '*Scenarios of Intervention*' were devised, but each of them has a different lifespan, and not all the three constitute viable options in the plausible future. Each scenario is mainly based on a type of adaptation measure (non-intervention, soft protection through beach nourishments, or planned retreat). It is not fully clarified until when such 'scenarios of intervention' are expected to be useful to manage risk, neither which levels of SLR or shoreline retreat, or other parameters, such 'scenarios of intervention' are expected to cope with. The Programme does not identify critical thresholds at which another measure or 'scenario of intervention' will be required. The POC does not provide a range of alternative options (diverse 'scenarios of intervention') viable and possible in the future (especially in the mid- and long-term).
Stepwise / phased implementation of various measures	**Not addressed**. It is not mentioned whether the interventions within each *Adaptation Scenario / Strategy* can be applied over time, in a phased and sequenced way. For the Critical Areas, the POC-CE proposes the 'strategic principle of planning', i.e. a strategy of adaptation that must be followed, with no detailed planning of measures in space and in time. The detailed planning of adaptation measures is allocated to municipal level, which must follow the 'strategy' prescribed.	**Not addressed.** The POC did not plan a phased implementation of several measures over time, in a stepwise or sequenced way. However, it briefly describes the likely evolution of the three main *Scenarios of Intervention* in three periods (short-, mid-, and long-term). For the Critical Areas – Relocation, the *Scenario* selected was 'C – planned retreat'. The POC describes the interventions required in this *Scenario* (demolition and relocation of buildings, re-settlement of populations, and re-naturalization of the space).
Keeping open options (alternatives); not foreclosing future options. Not foreclosing future options to act differently (and switch or add actions if climate or societal changes ask for it); responses should not unnecessarily constrain future choices.	The POC-CE intends to ensure that the adaptation strategies and measures that are taken today do not preclude future strategies, however, it does not mention how this will be done. In a certain way, the POC Team did not design measures and strategies for the mid- and long-term, to avoid the 'risk' of committing to a certain measure or strategy in a context of high uncertainty about future SRL and erosion conditions. There was no envisioning of alternative measures or pathways for the mid- or long-term. It is implicitly assumed that this will be done in the future revisions of the Programme.	The POC-ACE aims to ensure that '*the options taken in the present do not jeopardize future generations and the opportunities existent or emergent in the territory*', however, it does not mention how it will ensure this. The POC did not devise options for the mid- and long-term, i.e. it did not kept options open for the future. The diverse *Scenarios of Intervention* were not logically coupled with possible alternative measures (new or additional measures) that may be used in the future. The three *Scenarios* were not presented in a timeframe that allows grasping their effectiveness over time.
Possibility of changing (altering) the timing of new measures (bringing forward or postponing)	**Not addressed.** No reference to the possibility of postponing or advancing the timing of implementation of a measure, as changes are observed, as new climate scenarios arise over time. No references to what should be done if conditions change faster or slower than currently expected.	**Partially addressed.** The POC mentions that, based on the results of the monitoring and evaluation system, it will be possible to change the timing of the actions programmed in the Program of Action and their 'definition'. It is not specifically mentioned the possibility of anticipating or postponing the timing for a measure, as changes are observed or as new climate scenarios arise over time. No references to what should be done if conditions change faster or slower than currently expected (i.e. under the plausible future assumed), or if unexpected changes occur.
Possibility of adjusting / adapting the Plan (its pathways, measures, or their timing), over time; (allowing the adjustment of the Plan / Strategy devised, based on the results of the monitoring and revaluation system). The Plan can be adapted to changes over time: it is possible to adjust the timing of new measures, or shift from a measure to a new measure (or from a pathway to another). The Plan can be adapted in the following ways: by adjusting the timing for a new measure (decision point and implementation point); by switching to a new measure or to another pathway; or modifying a measure (within a pathway). • Flexibility to be adapted to changing conditions over time • Possibility of changing of measure or pathway. • Possibility of postponing or advancing the timing for an action.	**Partially addressed.** The POC-CE mentions the possibility of changing the Programme over time, namely the possibility of adjusting the Program of Actions, Directives, limits of the Critical Areas, over time. However, it provides no specific information about how such contents might be adjusted / adapted (no references to the possibility of switching of measure (within a Strategy) or shifting Strategy in the Critical Areas). It is not mentioned whether and how the Programme will be *adaptable to change* (e.g. to changing climatic and socioeconomic conditions that may develop until 2100), namely how the Program of Actions can be adapted to changes observed in the indicators. It is not safeguarded the possibility of adjusting (altering) the timing for new measures; neither the possibility of switching from an intervention to another intervention, or from an Adaptation Scenario / Strategy to another one. The Programme does not explain how it will address and respond to changes as these are monitored and identified, or each time the Programme is reviewed or updated. The POC intends to conduct a re-appraisal (review) of the Program of Actions every three years, which must be informed by the monitoring results. However, the POC did not specify: relevant values in the indicators that could act as triggers of measures and require the anticipation or postponing of a measure (i.e. triggers-values); or important decision-points; in addition, the POC does not provide alternative measures (options) for the future. It is mentioned that the monitoring and revaluation system will be crucial to allow the adjustment of the Programme, but it is not explained how. The Plan might not be adaptable and *flexible* enough to deal with accelerating / decelerating effects of climate change in relation to current projections. The Program of Actions focusses on the next decade. It is not referred the need of monitoring and assessing new climate projections and scenarios that might arise.	**Partially addressed.** The POC-ACE mentions the possibility of changing its Program of Actions over time, according to monitoring results (namely the programmed actions, their timing, and financial sources). However, it provides no specific information about how the POC itself and its contents – e.g. the Directives, the 'scenarios of intervention', and other actions proposed (in the Program of Actions) might be adjusted / adapted (no references to the possibility of switching of 'scenario of intervention' or measure in the Critical Areas). It is not clear how the POC itself will be *adaptable to change* (e.g. to changing climatic and socioeconomic conditions and evolving risks that may develop until 2100), and how the Program of Actions will be adapted in function of changes observed in the indicators. It is not ensured the possibility of altering the timing of new measures; nor the possibility of switching of actions / measures, or shifting from a 'scenario of intervention' to a new one. Moreover, the POC does not explain how it will address changes as these are monitored and identified, or each time the POC is reassessed. The POC will carry a re-evaluation (review) of the Program of Actions every four years, which must be informed by the monitoring results. However, the POC did not specify relevant values in the indicators that could act as triggers or that might require the anticipation or postponing of a measure, nor important decision-points. In addition, the POC does not provide alternative measures (options) for the future (it does not provide possible alternative actions that might be used in alternative to a proposed measure or to substitute or modify an implemented measure). The POC recognizes that its monitoring and revaluation system will be crucial to allow the adjustment of the Program of Actions, but provides little details on how this will be done. The Program of Actions focusses on the period 2018-2028, without any schematic program of possible measures for the mid- and long-term. It is not referred the need of monitoring / assessing new climate projections as these arise. The POC might not be adaptive enough to deal with accelerating / decelerating effects of climate change and socioeconomic changes (different than the current projection) and with unexpected/ unforeseen conditions (e.g. other projections than the one assumed).
Diversity / variety of measures. Diversity of measures (w/ different purposes, including measures to reduce probability of hazard, measures to exposure, and measures to reduce vulnerability); hard and soft measures, structural / non-struct. Measures across different actors, sectors).	**Yes / partially addressed.** The Team considered differentiated adaptation measures (including soft and hard protection measures, accommodation measures and planned retreat measures). Moreover, the POC proposes a strategy of integrated sediment management and re-establishment of the sediment cycle. Consideration of the integration of accommodation measures within spatial planning instruments at intermunicipal and municipal levels. The Programme seeks to reduce erosion risk and flood risk through diverse measures, for example: measures to adapt the existing flood defence system, improving existing flood defences; construction of new defences; sand nourishments; dune reconstructions; accommodation measures for the built assets and built environments (resilience-building measures for new and existent urban development), flood warning systems and forecasting, emergency preparedness. The Plan contains measures to reduce the probability of flooding (e.g. protection measures), but also measures to reduce the potential impacts of an eventual flood on spatial development. The POC proposes actions to avoid the retreat of the shoreline, and actions to reduce the occurrence of coastal floods and inundations (e.g. preservation of existing natural defences, maintenance and rehabilitation of coastal defence structures, sediment nourishments).	**Partially addressed.** The Team considered differentiated adaptation measures (including measures of soft and hard protection, accommodation, and planned retreat). To reduce the risks of coastal erosion and coastal flooding and the vulnerability associated, it proposes diverse measures, namely: sand nourishments; dune reinforcements; rehabilitation of existing hard defences, relocation / planned retreat, accommodation measures (for integration in spatial planning instruments at municipal level), and regimes of safeguard for the Strips of Safeguard, integrated sediment management and re-establishment of the sediment cycle (in sediment cells). Regarding the prevention and reduction of coastal risks and vulnerability to climate change, the POC proposes actions to avoid the retreat (regression) of the shoreline, and actions to reduce the probability of occurrence of coastal floods and overtopping inundations (e.g. the preservation of existing natural defences, maintenance and rehabilitation of coastal defence structures, strengthening of dune chains, and sediment nourishments on beaches), and actions to contain (limit) the exposure of the coastal zone to the risks of coastal erosion and sea overtopping inundations and coastal floods (through the establishment of the Strips of Safeguard from Coastal Risks and their respective regimes of safeguard).

Use of no- / low-regrets measures (and earlier in time); and win-win measures	**Partially addressed.** Measures were not selected with criteria like flexibility or low-/no-regrets properties (reversibility and adaptability) in mind. For example, measures were not selected because they reduce risk immediately and cost-efficiently under a wide range of climate scenarios (i.e. they are low-/ no-regret) or because they provide multiple benefits (regardless of the scenario that unfolds). However, the POC has (intuitively) proposed some measures are inherently flexible or reversible (e.g. sediment nourishments, which can be easily increased in volume and frequency).	**Partially addressed.** Measures were not selected with criteria like dynamic robustness or low-/no-regrets properties (reversibility and adaptability) in mind. However, the POC has (intentionally) proposed some measures are inherently flexible or more easily reversible (e.g. sediment nourishments, and re-establishment of the sediment cycle). The main criteria upon which the selection of the 'scenarios of intervention' was based was the cost-benefit ratio of each 'scenario', and its effectiveness over time (lifespan) under the plausible future assumed by the POC.
Use of robust measures + flexible measures Robust measures: create a robust system that may better cope with extreme events. E.g. increase a system's resilience (capacity to cope with and recover from uncertain future flood risk) or incorporate large safety margins (increase a system's resistance). Flexible measures or strategies: can be adapted if the future unfolds differently than foreseen; ability to cope with uncertain futures; actions are chosen to remain flexible in the face of uncertain future changes. E.g. incorporating engineered / structural flexibi-lity, and adaptation of engineered structures.	**Not fully addressed**. The POC-CE did not intentionally take into consideration criteria such as dynamic robustness and flexibility in the exploration, identification and assessment of possible Adaptation Scenarios / Strategies and their type-interventions. However, some of the actions and interventions proposed correspond to robust measures and flexible measures. The POC defines measures of maintenance and repair works for some existing defence structures or coastal engineering works. However, it provides little information how these defence structures can be updated / adjusted, in a way that accounts for future climate change effects, namely SLR. No information is given on how the new project for the extension of the breakwater of the Leixões Port should take into account the effects of climate change in its design (whether it should consider a structure that might be modified in the future, or construct larger foundations to withstand higher flood water loadings, or designing larger 'safety margins' (over-engineering structures to cope with greater change than predicted). The POC-CE mentions the intention of ensuring that the new large-scale engineering structures or coastal engineering works, such as port defence works, are designed in a way that accounts for future climate change effects, namely SLR.	**Partially addressed**. The POC-CE did not intentionally take into consideration criteria such as *dynamic robustness* and *flexibility* in the exploration, identification, and assessment of possible 'scenarios of intervention' for the 'problem spaces', and of adaptation measures / strategies for other zones or locations. However, some of the measures proposed correspond to flexible measures, e.g. beach nourishments. The POC defines measures of maintenance and rehabilitation for some existing defence structures or, and mentions that such maintenance or rehabilitation works must take into account possible future scenarios of climate change.
Safeguarding land for future adaptation measures	**Partially addressed.** The POC-CE defines the Strips for Safeguarding from Coastal Risks as areas that are mostly non-aedificandi, to limit the exposure to risks. It defines the actions allowed, conditioned and forbidden in such Strips.	**Partially addressed.** The POC-ACE defines the Strips of Safeguard from Coastal Risks as areas that are mainly *non-aedificandi*, to limit the exposure to risks.
Integration of climate adaptation into new infrastructure projects (*mainstreaming*); Integration of FRM / adaptation measures with other investments / agendas	**Partially addressed.** The POC could have further explained whether and how it will be possible to seize opportunities that might arise; search for win-win options, for example, opportunities to integrate adaptation / risk management measures into large-scale investments that are planned to occur (e.g. the extension of the breakwater of the Leixões Port).	**Not addressed.** The POC could have explained whether and how it will be possible to seize opportunities that might arise; search for win-win options.

Table G''. Comparison of the main ways through which an adaptive plan / programme (as the one developed in the Reference Cases) delivers an adaptable plan / programme, with the cases of the POC-CE and POC-ACE. Table H provides a comparison between the main sub-elements of the Key-element 3 – and whether and how they were addressed in the study cases. Source: own elaboration, based on Part A of this Thesis and on the analysis of the POC-CE and POC-ACE

Table E'. Answering the questions presented in Table E regarding the main steps of a process of Adaptive Planning and Management

Step		Question	POC-CE	POC-ACE
Step 1	Scenarios	Which developments / changes / parameters are considered in the scenarios used? (climate, socioeconomic, SLR, river discharge, storm patterns, etc.)	To delineate the Strips for Safeguarding from Coastal Erosion, the POC-CE Team generated a single projection of the future retreat (regression / landward migration) of the shoreline. To develop this projection (i.e. to calculate the plausible future shoreline retreat), the Team considered three components: erosion (shoreline retreat) extrapolated from past observations of the shoreline migration; 2) erosion (shoreline retreat) induced by an extreme storm; and 3) erosion (shoreline retreat) induced by SLR. Regarding the parameter SLR, the Team only considered a single plausible scenario (0,35m for 2050 and 1,50m for 2100), and regarding the parameter 'extreme storms', the Team only considered one possible extreme storm. The final projection of the future shoreline retreat results from the sum (addition) of these three components. The projected future shorelines (for 2050 and 2100) correspond to the inward limit of the Strips for Safeguarding from Coastal Erosion (2050 and 2100, respectively). To delimitate Strips for Safeguarding from Coastal Floods and Overtopping Inundations, the Team applied a different methodology. Such methodology served to estimate the maximum flood height, for 2050 and 2100, which was calculated as the sum of four different components – i.e. sea level determined by the astronomical tide, the level induced by a storm surge, and the run-up, which includes the wave set-up and the extension of the waves. Then, the flood heights were overlapped to an altimetric model (LIDAR), which allowed the identification of zones vulnerable to coastal flooding. In this calculation, again the Team considered a single projection of SLR (0,35m in 2050 and 1,50m in 2100). Thus, the POC-CE Team only generated a single projection (scenario) of the plausible future shoreline retreat for two time-horizons (2050 and 2100), and a single projection (scenario) of the plausible future floodable area for two time-horizons (2050 and 2100). In the generation of both projections, the Team only considered a single scenario of plausible future SLR.	The Team delimited the *Strips of Safeguard from Coastal Erosion* as the areas potentially affected by the retreat (regression) of the shoreline (associated to coastal erosion) in the time-horizons of 2050 (Level I) and 2100 (Level II). These Strips were determined based on the extrapolation for the year 2050 and 2100 of the evolutive tendencies observed in the recent past. The POC does not mention which parameters and developments, in addition to the past tendency of erosion (and related retreat of the shoreline) and SLR, were considered in the generation of this scenario (projection), e.g. climatic-related parameters such as changes in storm patterns, wave climate, etc. No scenarios of socioeconomic or urban developments were considered. This led to the representation of a single Strip of Safeguard (a single projection) for two time-horizons. The *Strips of Safeguard from Sea Overtopping Inundations and Coastal Floods*, which represent the areas potentially affected by sea overtopping inundations and coastal floods in the time-horizons of 2050 (Level I) and 2100 (Level II), were delineated based on the calculation of the combined effect of the medium sea level, the elevation (raise) induced by astronomic tide, the level induced by a storm surge, and the extension of water / wave overtopping, and they may also include SLR induced by climate change. Although the Team considered several parameters / variables that influence the spatial extension of coastal floods and overtopping inundations, it only considered a single value for each of them, which led to the representation of a single Strip (one for 2050 and one for 2100).
		What type of scenarios were used and how many? (predictive scenarios / projections and / or explorative scenarios)	The projection of the future retreat of the shoreline provides a single plausible future scenario (a predictive scenario, that is, a single projection of the future mobility and location of the shoreline for two different projection years – 2050 and 2100). This projection served to delineate the inward limit of the Strips for Safeguarding from Coastal Erosion Level I and Level II (for 2050 and 2100, respectively). The projection of the future floodable zones also offers a single plausible future scenario (also a predictive scenario, that is a single projection of the future area that might be affected by coastal floods and sea overtopping inundations, for the same two projections years). This projection served to delimit the Strips for Safeguarding from Coastal Floods and Overtopping Inundations (2050 and 2100). Thus, **only a single projection / plausible future scenario was generated** for each of the coastal hazards / risks considered by the POC.	The POC-ACE Team developed a single projection of the future retreat of the shoreline induced by coastal erosion (a predictive scenario) for to projection-years, which was used to delineate the *Strip of Safeguard from Coastal Erosion* (Level I – 2050 and Level II – 2100). It also developed a single projection of the future plausible floodable zones (associated to phenomena of sea overtopping inundations and coastal flooding), for the same two projection-years, which was used to delineate the *Strip of Safeguard from Sea Overtopping Inundations and Coastal Floods* (Level I – 2050 and Level II – 2100). In both Strips of Safeguard from Risks, the Team **only generated a single plausible scenario**, which led to the representation of a single 'strip' for each of the time-horizons / projection-years considered by the POC (2050 and 2100). If other projections (scenarios) have been generated and considered, this would have led to the representation of other strips, which could be encompassed in an uncertainty margin / band'.
		What is the temporal scale addressed in such scenarios (projection years, time-horizons, continuous / discon-tinuous trends)	The POC-CE considered two projection-years (called time-horizons) in the generation of the projections of the future shoreline retreat and of the future floodable area: 2050 and 2100. These projection-years were also considered in delineating the Strips for Safeguarding from Coastal Risks. In these projections, the Team implicitly assumed a continuation of the recent past tendencies, to which it added a single value for SLR.	The time-horizons considered in both the *Strip of Safeguard from Coastal Erosion* and in the *Strip of Safeguard from Sea Overtopping Inundations and Coastal Floods* are 2050 and 2100. In the Strip of Safeguard from Coastal Erosion, it was assumed a continuation of the recent past tendencies, to which the Team added SLR.
Step 2	Risk / impact assessment	What are the main vulnerabilities (threats) and opportunities identified (based on the analysis of such scenarios)?	The main vulnerabilities and threats identified by the POC-ACE are associated to the coastal risks of erosion, sea overtopping inundations and coastal floods, and translate into the retreat (regression) of the shoreline and flood events and associated damages in built assets and infrastructures. The Strips for Safeguarding from Coastal Risks served to assess and express the potential future spatial extension of such risks / hazards.	The main vulnerabilities (threats) identified by the POC-ACE in the mid- and long-term are related with the risks of coastal erosion and sea overtopping inundations and coastal floods, and, in the case of cliff littoral, instability of the cliffs and mass movements: • risk of coastal erosion: the associated retreat (regression) of the shoreline, and consequent loss of territory, damages on built assets and infrastructures. Without intervention, it is expected a tendency for the aggravation of the sediment deficit in several coastal stretches. • risk of sea overtopping inundations and floods – it is expected increase in the frequency and intensity (magnitude and dimension) of sea overtopping inundations and floods (with consequent damages and destruction on built-up areas) (POC-ACE 2018, p.90, 110). With climate change effects, it is expected a greater persistence of storms, and SLR is expected to aggravate the frequency and magnitude of sea overtopping events (ibid).
		How are risks / impacts assessed?	The Team did not carry an in-depth analysis of coastal risks (where risk is understood as a product of the multiplication of the probability of occurrence, vulnerability, and exposure). However, it sought to assess the potential future extension (spatial coverage) of the main coastal risks (erosion and flooding) – i.e. it assessed what might be the plausible future retreat of the shoreline (and the location of the shoreline) in 2050 and 2100, and what might be the floodable area in 2050 and 2100.	Based on a single projection (scenario) of the future shoreline retreat induced by erosion (generated based on the extrapolation for the future of past tendencies), the Team delimited the *Strip of Safeguard from Coastal Erosion* for 2050 (Level I) and 2100 (Level II). Similarly, based on a single projection (scenario) of the future possible extension of the floodable area (generated based on a calculation with several parameters, each of them with a single value), the Team delimited the *Strip of Safeguard from Sea Overtopping Inundations and Coastal Floods* for 2050 and 2100.
		Were critical thresholds / tipping-points identified?	No, the POC-CE did not carry an in-depth analysis of risks that involved the identification of critical thresholds or levels that might be disruptive for the existing / current coastal protection system, for example. The Team did not examine nor specify conditions or points under which a measure or a system ceases to perform well or becomes unacceptable. It was implicitly assumed that the measures proposed will perform well and be effective under the single 'plausible future' assumed.	No. The POC-ACE identified the main threats (risks, vulnerabilities and potential impacts) that might occur in the future under a single 'plausible future scenario', for the time-horizons of 2050 and 2100. Then, measures were explored and defined with such scenario in mind. The Team did not explore under what conditions a given measure (e.g. a certain *scenario of intervention*) might fail. The Team did not consider changing levels of risk over time, neither under various 'plausible futures'.
Steps 3-4	Strategy development	What (type of) measures were identified?	The Team developed four '*Adaptation Scenarios or Strategies*' for the critical areas: *Scenario 0 – Strategy of Emergency Protection*; *Scenario 1 – Strategy of Relocation / Planned Retreat*; *Scenario 2 – Strategy of Protection / planned maintenance*; *Scenario 3 – Strategy of Mixed Protection / planned anticipation*. Each of these Adaptation Scenarios / Strategies contains several *type-interventions* (adaptation measures) except Strategy 1 which has a single type-intervention (planned retreat). Based on the comparative assessment of these four *Adaptation Scenario / Strategies*, through a cost-benefit analysis, the Team could choose one *Scenario / Strategy* for each Critical Area. Despite this, these *Adaptation Scenarios / Strategies* do not offer a '*robust and flexible set of measures to deal with uncertain future changes*' (as key-element 4 implies). These *Adaptation Scenarios / Strategies* do not fully ensure the *robustness* and *flexibility* required in an 'dynamic adaptive plan' (containing a '*robust and flexible* set of actions').	For the 'problem spaces' (in terms of coastal risks, latter called Critical Areas – Relocation) located in sandy littoral, the POC Team has identified three options – so-called '*Scenarios of Intervention*': *Scenario of Intervention* A (non-intervention), *Scenario of Intervention* B (stabilization of the shoreline, through sediment nourishment), and *Scenario of Intervention* C (planned retreat). Based on a comparative assessment of the three *Scenarios of Intervention*, through a cost-benefit analysis, the Team has selected the best / most advantageous option for the 'Critical Areas – Relocation': scenario C. For other parts of the coastal zone ACE, the strategy of adaptation was soft protection through sediment nourishments, and the re-establishment of the sediment balance (at the scale of sediment cells). In a few cases, the strategy chosen will also involve the maintenance or rehabilitation of pre-existing hard defences.
		How were strategies designed / assembled?	The four *Adaptation Scenarios / Strategies* of the POC-CE can be deemed four possible adaptation alternatives (different strategies) that were available for the critical areas. Despite this, these *Adaptation Scenarios / Strategies* do not offer a '*robust and flexible set of measures to deal with uncertain future changes*' (as key-element 4 implies). These *Adaptation Scenarios / Strategies* do not fully ensure the *robustness* and *flexibility* required in a 'dynamic adaptive plan' (containing a	The Team devised and formulated three main options for 'problem spaces' (in terms of coastal erosion problems, or sea overtopping inundations and floods, of cliff instability). Such options were denominated '*Scenarios of Intervention*': A (non-intervention), B (stabilization of the shoreline through soft protection measures); C (planned retreat). These options were not devised as 'adaptation pathways', instead,

			'*robust and flexible* set of actions'). The four *Adaptation Scenarios / Strategies* were not devised as 'adaptation pathways' (each Strategy does not provide a pathway). Instead, they consist of four possible alternatives mainly focused on the near future. The POC did not ensure the possibility of switching of options (Adaptation Scenario / Strategy) or of adaptation measures, as conditions change, over time – i.e. it did not account for the eventual need of shifting from a given measure to a different one, or from a given Adaptation Scenario / Strategy to a new one. The Team did not plan the various 'Adaptation Scenarios / Strategies' as diverse pathways and options available and viable in the future.	they consist of three options focused on the short- and mid-term (from which, the Team chose one). For the 'Critical Areas – Relocation', the Team chose the *scenario C*, based on a comparative assessment of the three *Scenarios of Intervention* through a cost-benefit analysis. Each 'scenario of intervention' was not conceived as a pathways, and, in their whole, the three scenarios devised do not provide alternative pathways (viable and possible under the plausible future assumed). Each *scenario of intervention* has its own lifespan (only the *scenario of intervention C* is effective and cost-beneficial under the plausible future assumed). It is not allowed switching of measures or options (*scenarios of intervention*) over time, if developments require so. There was no anticipated planning of different options for the future.
		What criteria were considered in the design of strategies and / or definition of measures (flexibility, robustness, resilien-ce, structural / non-structural, hard / soft, low-/no-regret, win-win measures)	The main criteria considered for assessing the Adaptation Scenarios / Strategies and selecting (choosing) the scenario / strategy to be used in each Critical Area was the cost-benefit ration. The various Adaptation Scenarios / Strategies were not assessed on their robustness (as no other plausible futures were used), on their flexibility and adaptability over time. Despite that, some of the measures proposed by the POC-CE (for the Critical Areas and for other zones) are inherently flexible, e.g. beach nourishments. Moreover, the POC-CE has not considered the low-/no-regrets properties as an important criteria to explore and select the *Adaptation Scenarios / Strategies* or their measures.	The main criteria considered, and upon which the selection (choice) between the three *scenarios of intervention* was based, were the costs and benefits of each *scenario of intervention* in each 'problem space' (in terms of hazardousness). The scenario of intervention C was chosen because it is expected to be effective over the periods of shor-, mid- and long-term defined by the POC (and under the plausible future assumed), and because it presented the highest cost-benefit ratio (among the three scenarios devised). Not all the three *scenarios of intervention* will be effective in the mid- and long-term periods considered (each has a different lifespan associated). Most often, the scenarios A and B do not constitute possible viable options for the long-term period. Besides this, for some areas, the POC defined measures that are intrinsically flexible (e.g. sediment nourishments).
		Whether and how is the timing of measures taken into consideration?	The POC-CE specifies the timing of implementation of its actions in the Program of Actions. The timing for an action is mainly related with the urgency and priority given to such action. The definition of the timing for action did not stem from the identification of critical thresholds or tipping-points of prior or existing measures. Actions were distributed throughout the period of implementation of the POC-CE (10 years).	The timing envisioned for implementing the *scenario of intervention* C is located in the short-term (0-4 years). In the Program of Actions, the actions are programmed throughout the period 2018-2028. It was not addressed the eventual need of switching of measure / option over time, nor of anticipating / postponing measures, if changing conditions require so.
Step 5	Adaptive Plan (action plan)	How were the preferred strategies identified and selected?	The selection (choice) of the preferred 'Adaptation Scenario / Strategy' for each Critical Area was mainly based on the criteria of costs and benefits. The Adaptation Scenario / Strategy that presented the highest cost-benefit ratio in the plausible future assumed by the POC, and which was most effective, was the one chosen.	The preferred option (*scenario of intervention*) for the 'problem spaces' was selected based on cost-benefit analyses of the three *scenarios of intervention*. For the 'Critical Areas – Relocation', the POC-ACE Team chose the scenario of intervention C (planned retreat).For other locations, the POC proposes measures of soft protection (sediment nourishment), some hard protection measures (maintenance and rehabilitation of hard defence structures), and accommodation measures.
		How were the preferred strate-gy(ies) translated into a plan?	The adaptation measures proposed by the POC-CE, including the 'Adaptation Scenario / Strategy' chosen for each Critical Area (and its type-interventions), are listed in the Program of Actions (the action plan of the POC-CE). Such measures are distributed per Strategic Axis, and not presented per location. Therefore, it is difficult to grasp the range of adaptation measures / actions that the POC has defined for a given zone / area.	The measures (projects and actions) proposed by the POC are programmed in the Program of Actions, presented per Strategic Line. The *scenario of intervention C* (planned retreat) involves interventions of relocation or removal of built assets, and whenever necessary, re-settlement of people, and re-naturalization of the remaining space. Other measures of coastal adaptation (e.g. soft protection measures for specific sites) are also identified in the Program of Actions.
		How is the robustness and flexibility of the Plan ensured and safeguarded? What does the Action Plan / Investment Plan look like?	The POC-CE did not purposedly aim to deliver robustness and flexibility in the Programme and its Strategies. However, the POC states the goal and intention of delivering and operationalizing an approach of *adaptive planning and management.* The POC-CE's Program of Actions identifies the adaptation measures proposed by the POC organized per Strategic Axis, which hampers the comprehension of the spectrum of adaptation measures, their co-relations and interactions, and their specific location, and articulation in time and in space. The Program of Actions does not contemplate any alternative adaptation measures that could be left open for the future (as alternatives or measures additional to the measure prescribed for the next 10 years).	The Team did not intentionally seek to ensure *dynamic robustness* and *flexibility* in the POC, neither to develop a 'dynamic adaptive plan / programme'. However, the POC mentions the aim of delivering an adaptive planning and management, and the intention of ensuring the adaptability of the Programme to changes that might occur over time. The Program of Actions of the POC presents the actions and projects organized per Objective and Strategic Line, not per location. Thus, it is difficult to understand the set of actions that will be implemented in a given area. Moreover, no alternative actions / options were planned or envisaged for the mid- and long-term (neither represented in a scheme or timeframe).
Steps 6-7	Implementation and Monitoring	Were the monitoring and re-evaluation of the Plan accounted for in the Plan itself?	Yes. The POC-CE defines its monitoring and evaluation system, including the various indicators (output and outcome indicators) that must be used to monitor and evaluate the POC itself and the evolution of the coastal zone. This system considers the main drivers of change and risk, however, it does not include some relevant variables / parameters for detecting trends about climate change effects (SLR, changes in storm patterns). It also does not specify triggers (trigger-values in variables) that indicate the need to take a new decision / action. This system also does not refer that is it necessary to monitor progresses in scientific knowledge and new climate projections over time. An analysis of the indicators listed in the monitoring and evaluation system shows that more indicators could have been included on the effects of anthropic pressures and the effects of climate change in the coastal dynamics, namely SLR and changes in storm patterns and wave climate. Moreover, the POC-CE's monitoring and evaluation system does not explain how it will ensure that Programme and its contents – namely the actions implemented and planned for the Critical Areas – will be adapted, if the monitoring results call for this or if unexpected changes occur, for example: will it be necessary to shift to other measure, which measures will be available by then, and whether it will be viable to anticipate / postpone a measure.	Yes, the POC included the definition of a monitoring and evaluation programme, aimed at monitoring and evaluating the coastal zone and of the Programme itself. Such monitoring and evaluation programme will serve to reassess (evaluate) the Program of Actions, and, adjust it, if necessary. It specifies the indicators to be monitored, but does not cover new / updated scenarios of climate change and of socioeconomic development that might emerge, neither relevant changes in some variables (e.g. SLR, storm patterns). Moreover, no trigger-values or decision-points were defined. It is not clearly explained how the Program of Actions, and especially, the POC itself – i.e. its contents, e.g. the Directives, Territorial Model, the adaptation actions and strategies proposed, including the 'Scenario of Intervention' chosen for the 'Critical Areas – Relocation' – might be adapted / adjusted over time, as conditions change (for example, as new information arises, monitoring results emerge, unexpected changes are detected, or every time the POC is reviewed). The POC does not mention the possibility of shifting to other measures (as these were not planned in anticipation), but refers the possibility of adjusting the timing and definition of the actions programmed in the Program of Actions. It seems to exist an over-reliance on this monitoring and evaluation system as the main (and almost unique) ingredient required to ensure the adaptation(s) of the Programme and an approach of adaptive management.

Table E'. List of questions addressed for each step of the process of an Adaptive Planning and Management. Source: own elaboration.

Table S. Main topics and aspects analysed

Aspects analysed	POC-CE	POC-ACE
Type of planning instrument	It is a Programme for the Coastal Zone (*Programa da Orla Costeira – POC*). POCs are the main Portuguese spatial planning instruments for coastal planning and management and coastal risk management. The POCs are under the leadership of APA (Portuguese Environment Agency). The POC-CE covers the coastal zone from Caminha to Espinho. It was elaborated in 2018 and is still waiting for approval.	It is a Programme for the Coastal Zone (*Programa da Orla Costeira – POC*). POCs are the main Portuguese spatial planning instruments for coastal planning and manage-ment and coastal risk management. The POCs are under the leadership of APA (Portuguese Environment Agency). The POC-ACE covers the coastal zone from Alcobaça to Cabo Espichel. Its elaboration occurred until 2018. It was approved and published in 2019.
Factors that led to the deve-lopment of new POCs	- Recognition of increasing risks of coastal erosion and coastal flooding and sea overtopping inundations, associated with the effects of climate change and anthropic pressures. - Existence of significant sediment deficits along the sandy littoral - Patterns of artificialization of the coast (due to urban development), as drivers of increasing risks - Need to review the first generation POOCs	
Claims and calls for the introduction of an Adaptive Planning and Management approach	Before and during the elaboration of the POCs, several policy and guidance documents and planning strategies that recommended the adoption of an approach of Adaptive Planning and / or Management, and which contained general or concrete references to features and components of Adaptive Planning approaches, have arisen in Portugal, e.g.: the Decree-Law nº159/2012; National Strategy on Integrated Management of the Coastal Zone (ENGIZC 2009); National Strategy for Adaptation to Climate Change (ENAAC 2010); Sectoral Strategy of Adaptation to Climate Change for Hydric Resources (including coastal) (ESAAC-RH); APA's guidance about the development adaptation strategies (provided in its website); the GTL Report (GTL 2014). In addition, in a recent interview, the APA's President claimed that the new POCs assume '*a new stance regarding the planning of the littoral by aiming to ensure a governance and management that are continual in the face of the acting coastal dynamics (which are uncertain)*', and adopt '*a new approach of integrated and adaptive management' of the coastal zone, and propose more suited solutions (of prevention, protection, accommodation or planned retreat) according to the current situation and the expected future dynamics*'(CEZCM / APRH 2020). Moreover, given the characteristics of the coastal zone, and its vulnerability to SLR, '*the principles of prevention and precaution were taken as central and strategic for the definition of the model of adaptive planning and management that constitutes the trademark of all new POCs*'; and '*a continual management of the littoral requires specialized scientific and technical knowledge and a monitoring system able to share information and support decision-making at national, regional and local levels*' (CEZCM / APRH 2020). These are examples of strategic and policy documents, guidance and reference information, that advocate and encourage the use of an *Adaptive Planning and / or Management approach*. Most of these documents provide several (general or specific) guidelines regarding an approach of adaptive management and its application in the field of coastal management and planning. Some documents contain specific references to aspects that are related with an Adaptive Planning and Management approach or its key-elements. The new POCs claim to have adopted an 'Adaptive Management approach', however, the existing guidance specifically focused on Adaptive Planning and Management approaches has not been fully absorbed in the new POCs and their elaboration. To be assimilated by the POCs, these documents should have been explicitly prescribed by APA to the Project Teams charged of their development. APA was responsible for providing these documents to Project Teams, which did not occur in a clear way.	
Requisites set for the Plan or Planning Approach	The Decree-Law n.º159/2012 sets the **specific objectives** of the POCs, among them: '*promoting the sustainable development of the coastal zone through a prospective, dynamic and adaptive approach*'; and '*identifying and establish regimes of safeguard of the 'risk strips' in the face of the diverse uses and occupations in a mid- and long-term perspective'*. The Decree-Law n.º 159/2012 also sets seven general principles to be observed in the elaboration of the POCs: 1) sustainability and intergenerational solidarity; 2) cohesion and equity; 3) prevention and precaution, by predicting and anticipating consequences and adopting a precautionary attitude, by minimizing risks and negative impacts; 4) subsidiarity; 5) participation; 6) shared responsibility / accountability; and 7) operationality (DL n.º 159/2012, *in* POC-CE 2018, p.29; POC-ACE 2018, p.33).	
Principles upon which the POC should be based	The POC-CE Team defined **four principles** on which the elaboration and operationalization the POC and its strategy should be founded: 1) an eco-systemic approach; 2) Adaptive management, *based on the effective and systematic monitoring of the coastal zone, and which strengthens the agility and adaptability in the management of coastal risks*; 3) Integrated management (which *reinforces the adaptability of decisions*); and 4) territorial cooperation and institutional articulation. The POC-CE sought to adopt '*a model of adaptive management* (POC-CE 2018, p.31). The POC sought to internalize this 'model' in in its Strategy. The principle of prevention and precaution was crucial in the definition of a model of adaptive planning and management' (this principle is set in the DL n.º159/2012).	The POC-ACE was elaborated based on the seven principles set in the Decree-Law nº 159/2012, mainly the principles of 'sustainability and intergenerational solidarity', 'cohesion and equity', and 'prevention and precaution' (POC-ACE 2018, p.33-34). The principle of 'Prevention and Precaution' involves: *predicting and anticipating problems, by adopting a cautionary attitude in the face of knowledge deficit or insufficient capacity of intervention, and minimizing risks and negative impacts.*
Objectives of the POC (relative to coastal risk management)	One of the Objectives of the POC-CE is the 'prevention and reduction of coastal risks and of the vulnerability to climate change' (General Objective 1). The POC then defines five specific objectives within this objective: 1.1) Maintain the integrity of the coastline (shoreline) in the context of a broader strategy of adaptation to current and future coastal risks. 1.2) Adopt a strategy of integrated management of sediments that ensures the preservation of borrow sites (…). 1.3) Define a model of land use and occupation of the coastal zone that restrains the territorial exposure to coastal risks in the long-term. 1.4) Adapt the forms of urban occupation of the coastal zone. 1.5) Ensure the public fruition of the Maritime Public Domain in safety. It also aims to *promote a model of adaptive management of beaches and ensuring safety conditions for their utilization* (specific objective 4.3).	One of the General Objectives of the POC-ACE is to 'prevent and reduce coastal risks and the vulnerability to climate change' (Sectoral Objective 1). This Objective is subdivided into 5 specific objectives / strategic lines: 1.1) Ensure the preservation of the current shoreline based on the re-settling of sediment balan-ce existent in a natural regime. 1.2) Ensure the preservation of 'borrow sites' and the utilization of sediments dredged from port channels, sandbars and access channels, for the nourishment of beaches. 1.3) Contain the territorial exposure to coastal risks, by establishing regimes of safeguard for the 'risk strips', in a mid- and long-term perspective. 1.4) Promote the planned adaptation of urban settlements to coastal erosion, sea overtopping inundations and floods. 1.5) Ensure the public fruition of Public Mariti. Domain in safety. In its Transversal Objectives, the POC-ACE also defines the specific objective 5.5) *Promote a flexible and adaptive management that allows responding with efficacy to environmental, social and economic changes*
Denomination and conceptualization of the Adaptive Planning approach devised	The POC-CE claims that it has adopted '*a model of adaptive management*' to cope with the challenge of the prevention and reduction of coastal risks. As mentioned, the POC-CE Team defined four principles on which the elaboration and operationalization of its Strategy (of Planning and Management of the Coastal Zone) should be founded, among them: *adaptive management* (POC-CE 2018, p.30). This *adaptive management* should be '*based on the effective and systematic monitoring of the coastal zone*', and it should '*strengthen the agility and adaptability in the management of coastal risks*' (POC-CE 2018, p.30). The POC sought to adopt '*a model of adaptive management'* that allowed '*dealing with the challenge of the prevention and reduction of coastal risks*'. Such model was required '*to ensure that the options taken in terms of planning of land uses and activities do not aggravate the vulnerability to coastal risks in the future (given that the current situation is already quite complex), and on the other hand, ensure that the strategies and measures of adaptation to such risks, which will be adopted, do not preclude future strategies*' (POC-CE 2018, p.31). The POC-CE underlines that '*a model of adaptive planning and management' constitutes, in a certain way, the trademark / key feature of the POC*' (POC-CE 2018, p.31). The POC-CE also mentions that, '*in the face of the coastal dynamics and the need to tailor and streamline practical solutions, it is proposed* (…) *a management process of the POC that is adaptive in time and in space, in order to progressively adjust the Strategy (…)*' (POC-CE 2018, p.52). The POC-CE refers that it is necessary '*a management model that allows a continual adaptation of the POC in function of the coastal dynamics and risks for people and assets*', which implies '*a system of information and continuous monitoring of the evolution of the coastal stretch and of the implementation of the Program of Actions, which sustains and informs the periodical evaluation of the POC*' (POC-CE 2018, p.96). The '*adaptive management model*' of the POC is based in the following guidelines: - '*In the face of the coastal dynamics, the imponderability and unpredictability of the climate factors that induce to phenomena of coastal erosion, coastal floods and sea overtopping inundations* (…), *and the consequent risks for people and assets, the process of management of the POC-CE must be adaptive in time and in space, in order to progressively adjust the 'strategy of safeguard and protection of natural resources and of land use and occupation*' (POC-CE 2018, p.96).	The POC-ACE also sought to adopt an approach of 'adaptive planning and management'. According to the POC-ACE, it is important to develop an '*adaptive planning*', that is, '*a planning more adaptive to the contextual changes and which accounts for the variability of phenomena and situations with which the Programme will be faced with*' (POC-ACE 2018, p.92). The POC-ACE mentions the intention of following an *adaptive management approach* in its Strategic Model, namely in the Specific Objective / *Strategic Line LE5.5 – Promote a flexible and adaptive management that allows responding with efficacy to environmental, social and economic changes* (POC-ACE 2018, p.36, 145). Within the Transversal Objective OT1, some of goals identified are *'to ensure the flexible and adaptive management of maritime beaches'*, and '*to promote an increasing flexibility in the forms of occupation of the Hydric Domain*' (POC-ACE 2018, p.69). The Directives state *'the aim of developing a proactive adaptive management of the* (coastal urban) *settlements'* (POC-ACE 2018 d, p.71). Despite the aim of pursuing an Adaptive Planning and Management approach, the POC-ACE does not provide more detail and explanation of such approach, what it entails and how to carry (operationalize) it. Moreover, it is not explicitly mentioned that the POC-ACE should be an *adaptive programme* (or a *robust* and *flexible* programme), as pre-requisites previously set for the Programme. Notwithstanding, a quick analysis of the various documents of the POC-ACE showed that it contains references to aspects related with the key-elements identified in this Thesis as essential for an Adaptive Planning and Management approach and required to develop a *dynamic adaptive plan / programme.* The POC-ACE refers (directly or indirectly) to some of these key-elements. The POC argues that the exercises of 'scenarization' (development of 'scenarios of intervention / response', i.e. adaptation options) assume a great usefulness in the process of spatial planning and territorial development, '*as a tool to support decision-making in the short-term, as a model that ensures that the options taken in the present do not jeopardize future generations and opportunities existent or emergent in the territory, and as an instrument of support to a planning that is more adaptive to contextual changes*' (POC-ACE 2018, p.92). Monitoring is essential for the regular evaluation of the Program of Actions and '*to ensure a strategic, planned and adaptive management of the coastal zone*' (POC-ACE 2018 a, p.12).

	- The process of adaptive management must be supported by the monitoring system of the POC (ibid). - The implementation of a process of adaptive management implies that the Norms concerning the enforcement of '*strategic principles of planning / adaptation*' (strategies of adaptation proposed), and the actions defined in the Program of Actions, may be suspended, or altered, if this contributes to better defend and safeguard people, built assets, or natural values (ibid, p.96).	

Process of Adaptive Planning and Management	The process of elaboration of the POC-CE followed several stages / phases.
	In stage 1.4) *Characterization of the Territorial Situation*), the Team focused on:
	- Characterizing the shoreline and analysing the tendencies of evolution in the last 50/100 years.
	- Identifying the occurrence of coastal floods, overtopping inundations, and destruction of built assets.
	- Characterizing biophysical, socioeconomic and territorial systems, and patterns of human occupation.
	Then, in stage 1.5 (*Diagnostic of the Reference Situation*), the Team focused on (POC-CE 2015, p.21,430):
	- Identifying the existing coastal protection works and evaluating their behaviour and efficacy.
	- Assessing pressures on coastal hydric resources.
	- Determining and mapping-out (in a cartography) the hazards associated to erosion of beaches or dunes, retreat (regression) of the shoreline, coastal flooding and overtopping inundation, including the production of a 'hazard map' for the entire coastal stretch.
	- Checking the adequacy of the 'risk zones' defined in the current POOC (still in force).
	- Identifying critical areas in terms of destruction of human and natural resources and environmental degradation.
	- Defining the 'Critical Areas' in terms of susceptibility to coastal risks.
	- Identifying opportunities and constraints that might arise in the mid-term.
	- Formulating four possible '*Adaptation Scenarios or Strategies*' (i.e. '*Response* or *Intervention Scenarios*').
	- Assessing, through cost-benefit analyses, the '*Adaptation Scenarios / Strategies*', namely planned retreat *versus* protection.
	For the Critical Areas, the POC-CE Team developed four possible '*Adaptation Scenarios or Strategies*' (which are four different adaptation strategies possible):
	- 'Adaptation Scenario 0 – Reactive Strategy of Emergency Protection'. It consists of keeping the policy (philosophy) of hard defence works and localized interventions, mostly based on emergency interventions, with a short-term perspective.
	- 'Adaptation Scenario 1 – Strategy of Planned Retreat / Relocation'. This strategy involves the programmed removal (withdrawal) of built assets from coastal zones at high risk of flooding, overtopping inundation and / or erosion, and implies a long-term vision.
	- 'Adaptation Scenario 2 – Strategy of Protection / Planned Maintenance'. It involves the maintenance of the existing defence structures in the mid-term, including their reinforcement or upgrade/adaptation, and the strengthening of dune systems whenever possible. It aims to defend the built environment by reducing the frequency of floods and overtopping inundations and limiting potential damages on built assets and infrastructures. This Strategy accepts a certain reduction of the dimensions of beaches and an eventual loss of recreational and landscape values.
	- 'Adaptation Scenario 3 – Strategy of Mixed Protection / Planned Anticipation'. It involves mixed solutions, in a long-term vision; e.g. integrated interventions of re-establishment of the sediment cycle by means of artificial sediment nourishments complemented by smaller protection interventions to protect the shoreline, which might imply innovative protection or accommodation solutions tested in pilot-cases, and/or a possible combination of the prior solutions (mix of integrated or complementary interventions).
	In the phase of Characterization and Diagnostic, the Team developed the four possible 'Adaptation Scenarios / Strategies' for the critical situations, and, then assessed them through a cost-benefit analysis (POC-CE 2015, p.424). The POC-CE Team carried out a comparative assessment the four 'Adaptation Scenarios / Strategies', through cost-benefit analyses, for each of the Critical Areas (POC-CE 2018 f, p.190).
		During the development of the POC-ACE, the Team has explored possible adaptation options for 'problematic spaces' (in terms of vulnerability and susceptibility to coastal risks – erosion, flooding and cliff instability).
		It was also necessary search for the most advantageous solutions for the situations that present greater hazardousness (POC-ACE 2018, p.90). The adaptation response to current problems and future vulnerabilities – i.e. accommodation, protection, or planned retreat – should be supported in cost-benefit analyses and multi-criteria analyses that allow a sustainable decision, in line with the GTL recommendations. The POC sought to envisage and assess various forms of intervention in the stretches that presented greater hazardousness (due to erosive processes and land use patterns), which implied the formulation of 'options' (proposals) to reduce risks – and this exercise was denominated 'scenarization' (POC-ACE 2018, p.90). It was necessary to equate the best forms of action and predict the costs and non-material benefits (the social cost of the analysis of benefits) of the diverse measures (alternatives), through cost-benefit analyses (POC-ACE 2018, p.91).
		***Exercise of 'scenarization'* – development of '*Scenarios of Intervention*':** The POC-ACE Team has defined '*Scenarios of Intervention*' (response scenarios) and assessed them. This required formulation of various alternative solutions, and the assessment of their costs and benefits. In specific, considering a given problem and its implications, the Team formulated (devised) various possible responses (in function of the level of priority that the community attributed to the minimization of problems or impacts that might occur and of the financial resources that can be mobilized) (POC-ACE 2018, p.92).
		The methodology applied by the POC-ACE Team involved a sequence of steps that allowed the selection of the most advantageous option for specific problem-spaces (later called Critical Areas – Relocation):
		- **Step 1**: description of reference situation, including the problem under study; definition of issues (departing questions) that frame the need of intervention; and overview of the sensitivity and positioning of the main actors regarding the problem.
		- **Step 2**: definition of three '*base scenarios*' that structure the response, denominated 'scenarios of intervention'. This required an indication of the main characteristics that conform each '*Scenario of Intervention*', of the typology and extension of the interventions and their estimated costs (including maintenance costs). The POC developed three 'Scenarios of Intervention' for critical areas in sandy littoral:
		  - Scenario A – Non-intervention;
		  - Scenario B – Stabilization of the Shoreline through beach nourishments (and, eventually, maintenance and rehabilitation of hard defences); and
		  - Scenario C – Planned Retreat.
		- **Step 3**: assessment of each '*Scenario of Intervention*' envisaged on three dimensions (economic, social and environmental dimensions; and against diverse descriptors that structure each of the 3 dimensions), i.e. analysis of benefits. This step also involved the attribution of a level of impact. This allowed the calculation of the final score per each dimension. The result was then pondered, in function of the relevance of each dimension of analysis. These were the main elements of the analysis of benefits.
		- **Step 4**: a new ponderation was carried based on the estimated costs and identified benefits (per dimension), and on the calculation of the cost/benefit ratio for each '*Scenario of Intervention*' (POC-ACE 2018, p.93). The Team carried cost-benefit analyses of the 'Scenarios of Intervention' for each 'problem space'. It developed a methodology of cost-benefit analysis, to estimate, for each of the six 'problem spaces' ('Critical Areas – Relocation), the costs and benefits associated to the diverse '*Scenarios of Intervention*'. Then, based on the cost-benefit analyses (of each *Scenario of Intervention*), the Team decided to use (chose) the Scenario C.

POC's contents analysed	The main contents of the POC-CE that were analysed: - Territorial Model, which defines the main zones subjected to different regimes of protection, regimes safeguard from coastal risks and regimes management, including the Strips for Safeguarding from Coastal Erosion for 2050 and for 2100, the Strips for Safeguarding from Coastal Flooding and Sea Overtopping Inundations, and the 'Critical Areas' (areas highly susceptible to the risks of coastal erosion and coastal flooding and sea overtopping inundations). In the case of the Critical Areas, this work has analysed the four main adaptation strategies (i.e. the four '*Adaptation Scenarios / Strategies'*) proposed for each of them. - Directives (Norms) - Program of Actions - Monitoring and Evaluation System of the POC-CE	The main contents of the POC-ACE that were analysed: - Territorial Model, which defines the main zones subjected to different regimes of protection, regimes safeguard from coastal risks and regimes management, including the Strips of Safeguard from Coastal Erosion for 2050 and for 2100, the Strips of Safeguard from Sea Overtopping Inundations and Coastal Floods for 2050 and 2100, and the Strips of Safeguard in Cliff Littoral, and the 'Critical Areas - Relocation' (areas that present high hazardousness in terms of coastal risks in the mid-term). In the case of the Critical Areas – Relocation, this work has analysed the three '*Scenarios of Intervention*' (proposed for these 'problem spaces'). - Directives (Norms). - Program of Actions - System of Monitoring and Evaluation of the POC-ACE

1. Findings and Results of Part B: answering the specific research questions

In the 2nd part of this research (Part B), the study-cases were two Portuguese coastal management programmes (*Programas de Orla Costeira – POCs*): a) the Coastal Programme Caminha-Espinho (*Programa da Orla Costeira Caminha-Espinho POC-CE*, which is under approval), focussing on the coastal zone of the Metropolitan Area of Porto; b) the Coastal Programme Alcobaça-Cabo Espichel (*Programa da Orla Costeira Alcobaça-Cabo Espichel, POC-ACE*), focussing on the coastal zone of the Metropolitan Area of Lisbon.

Both cases (the two POCs selected) claim that they have purposely adopted an approach of '*adaptive planning and management*'and have sought to introduce and apply it in the development and implementation of the Programme and its strategies of coastal climate adaptation. Part B focused on each case to analyse and answer the following research questions:

III. Is an Adaptive Planning and Management approach being introduced and applied in the Portuguese cases, to address coastal adaptation / coastal risk management? Have the selected study cases applied approaches of Adaptive Planning, and how?

IV. Whether, and how, the key-elements of an Adaptive Planning approach were used in the two cases? Are the key-elements essential to develop a *dynamic adaptive plan* present in each case?

V. What barriers can be found in the study-cases that hinder a truly *Adaptive Planning and Management* of the coastal zones, and preclude / hamper the development of a *dynamic adaptive programme* and a *more adaptive* approach to coastal climate adaptation?

1.1. Answering the Specific Research Question III

In this phase, the research has analysed: if an Adaptive Planning approach was applied in each case, how do the selected cases conceptualize and define their 'approach of adaptive planning and management', and whether the principles of *dynamic robustness*, *flexibility* and *adaptability* were taken as guiding principles for the elaboration of the POCs and their planning / management approaches.

Definition and conceptualization of the Adaptive Planning approach devised

The POC-CE claims that it has adopted '*a model of adaptive management*' to deal with the challenge of the reduction and prevention of coastal risks. The POC-CE Team defined four principles on which the elaboration and operationalization of its Strategy (of Planning and Management of the Coastal Zone) should be founded, among them: *adaptive management*. This *adaptive management* should be based on the systematic monitoring of the coastal zone, and it should *strengthen the agility and adaptability in the management of coastal risks*' and in decisions (POC-CE 2018, p.30).

The POC-CE underlines that '*a model of adaptive planning and management' constitutes, in a certain way, the trademark / key feature of the POC-CE*', and that '*the principles of prevention and precaution were absolutely central in the definition of such model*' (POC-CE 2018, p.31). The POC-CE aimed to internalize this *model of adaptive management* into its strategies, which implies ensuring that '*the options taken in terms of planning of land uses and activities do not aggravate the vulnerability to coastal risks in the future (...), and on the other hand, ensure that the strategies and measures of adaptation to such risks, which will be adopted, do not preclude future strategies*' (POC-CE 2018, p.31).

According to the POC-CE, it was necessary '*a management model that allows a continual adaptation of the POC in function of the coastal dynamics and risks for people and assets (to which the area of intervention is intensely and unpredictably subjected)*', which required '*a system of information and* *continuous monitoring of the evolution of the coastal stretch and of the implementation of the Program of Actions, which sustains and informs the periodical evaluation of the POC*' (POC-CE 2018, p.96).

The '*adaptive management model*' of the POC-CE is based in the following guidelines:

- '*In the face of the coastal dynamics* (and *imponderability and unpredictability of the climate factors that induce to phenomena of coastal erosion, coastal floods and sea overtopping inundations,* and consequent risks), and given '*the need to streamline practical solutions*', the management process of the POC must be '*adaptive in time and in space, to progressively adjust the Strategy*'
- The process of adaptive management must be supported by the monitoring system of the POC.
- The process of adaptive management implies that the Norms regarding '*strategic principles of planning*' (i.e. the adaptation strategies proposed), and the concrete actions defined in the Program of Actions, may be suspended or altered, if this contributes to better safeguard people, built assets, or natural values (POC-CE 2018, p.96, 52).

In its turn, the POC-ACE sought to adopt an approach of 'adaptive planning and management'. According to the POC-ACE, it is necessary to develop an '*adaptive planning*' that is '*more adaptive to the contextual changes and which accounts for the variability of phenomena and situations which the Programme will face*' (POC-ACE 2018, p.92). The aim of following an *adaptive management approach* is stated in the POC-ACE's Strategic Model, particularly in the '*Specific Objective / Strategic Line LE5.5 – Promote a flexible and adaptive management that allows responding with efficacy to environmental, social, and economic changes*' (POC-ACE 2018, p.36, 145). Within the Transversal Objective OT1, some of goals identified by the POC are *'to ensure the flexible and adaptive management of maritime beaches'*, and '*to promote an increasing flexibility in the forms of occupation of the Hydric Domain*' (POC-ACE 2018, p.69). Moreover, the Directives highlight need of developing *'a proactive adaptive management of the* (coastal urban) *settlements'* (POC-ACE 2018 d, p.71).

Despite the aim of pursuing an approach of 'adaptive planning and management', the POC-ACE does not provide sufficient detail nor explanations of such approach, what it entails, and how to carry it.

In sum, each of the Portuguese cases claims that it has adopted a new approach of 'adaptive planning and management'. Both cases aimed to introduce such an approach in, and through, the new POCs. Both cases seek to establish a novel 'adaptive planning and management' of the coastal zone. In addition, APA (Portuguese Environment Agency, responsible for the leadership and supervision of the POCs) has itself also claimed that the new POCs have launched a 'new approach of adaptive planning and management'.[78] However, and despite these claims and the intentions, the two cases have not applied nor developed a *real* methodological approach of Adaptive Planning in the elaboration of the POCs, and they did not intentionally aim to develop a *dynamic adaptive plan / programme*. None of the studied POCs explicitly mentions that the POCs should be an *adaptive programme*, or a '*robust* and *flexible*' programme, as pre-requisites defined for the Programme, for its planning / management approach, or for its strategies. While the intention of pursuing an 'adaptive planning and management' is stated in both cases, none of the POC has clarified how this will be ensured and what elements / requisites are necessary to accomplish and operationalize it.

[78] As mentioned, APA's President has claimed that the new POCs aim to 'ensure a governance and management that are continual in the face of the acting coastal dynamics (which are uncertain)', that the POCs adopt 'a new approach of integrated and adaptive management' of the coastal zone'; that the 'model of adaptive planning and management' constitutes the 'trademark of all new POCs'; and that 'a continual management of the littoral requires specialized scientific and technical knowledge and a monitoring system able to share information and support decision-making at national, regional and local level (CEZCM / APRH 2020).

Although there were already some strategic guidance documents and policy documents that recommended an 'adaptive planning and management approach' (and some of them discussed aspects associated to the Key-elements of the methodological approaches of the paradigm of APM identified in this Thesis), the two selected cases demonstrate that a methodological approach of Adaptive Planning was not truly applied. Each of the studied POCs presents a brief description / definition of its proposed 'adaptive planning and management approach', which provides little information and a scarce explanation of: what such approach should involve and imply (i.e. key-elements, requirements and ingredients necessary in the Programme, and in its elaboration and implementation process), and how to deliver it (process of steps required). While the POC-CE provides more information to explain what an 'adaptive planning and management model' would imply, the POC-ACE offers few explanations.

Each POC did not apply a *true* Adaptive Planning approach (with its underlying principles and key-elements). The in-depth analysis of the various documents of each POC showed that they contain slight references to aspects related with the principles of '*dynamic robustness*', '*flexibility*' and *adaptability*, and few or no references to the Key-elements that are essential in an Adaptive Planning approach for developing a *dynamic adaptive plan* (which were identified in Part A). Each POC did not implement a real Adaptive Planning approach with its key-elements. Moreover, the studied POCs did not seek to follow a process of Adaptive Planning, with its cycle of sequenced steps, 'from scratch', i.e. since the beginning and during the elaboration of the Programme, and in the subsequent phases of implementation monitoring and evaluation.

In both cases, the 'model of adaptive planning and management' proposed has been insufficiently explored and defined. As it is described in each POC, such *model of adaptive planning and management* will not guarantee that these cases follow and operationalize a true Adaptive Planning and Management approach. Both cases advocate an adaptive planning and management model as being essential to allow the adaptation of the physical environment, but put less emphasis on the need of developing a Programme (POC) that is itself *adaptive* and on the need of operationalizing an (adaptive) planning and management process to ensure the adaptation of the Plan (Programme) and of the physical environment.

The studied cases show that there was little exploration and analysis of what an Adaptive Planning and Management approach truly involves and entails – in the POCs, and especially, in their process of elaboration and implementation, their lifespan and temporal horizon, their contents (e.g. Territorial Model, Norms, and adaptation strategies proposed), in addition to the physical environment that is managed by the POCs. APA also did not provide any details on these subjects, and there was little investigation by the Project Teams on these issues. Notwithstanding, a true Adaptive Planning and Management approach will likely imply a longer temporal horizon for the POCs, increasing *adaptability* within the POCs' contents (e.g. strategies, Directives, programmed actions), and enhancing the easiness of adapting and altering the Programme in the face of changing conditions and uncertain future risks.

To a certain extent, the claims for models of 'adaptive planning and management' in the Portuguese cases suggest a 'copy-paste' exercise, and a tendency for the simple prescription of a new 'trendy' concept, which was not accompanied by an in-depth understanding of, nor the absorption of, the Adaptive Planning paradigm – its underlying rationale and principles, and its diverse methodological approaches (their methods and tools), and their key-elements / requisites. There was no thorough explanation nor detailed design of a methodological approach to be followed during the POC's elaboration. Though there was already some information available on subjects related to Adaptive Planning and Management approaches, namely published in APA's website, most information was dispersed and insufficient to structure, in an organized and simple way, the main elements and process of steps necessary to develop an *adaptive plan* (for coastal risk management / coastal climate adaptation) and to ensure a continuous process of Adaptive Planning and Management (for coastal adaptation).

While the term 'adaptive planning and management' emerged in the Portuguese POCs as an attractive and appealing concept, which seemed useful to tackle the contextual problems associated to emerging and changing coastal risks (related with climate change effects and ongoing anthropogenic pressures) faced in the planning and management of highly dynamic coastal urbanized zones, there was no solid work and study on what a real Adaptive Planning approach requires - namely, what elements / requisites it must meet – neither on how to uniformize its procedures and key-elements for application in all POCs (regardless of the diversity of characteristics of the coastal stretches addressed by the different POCs).

In sum, the answer to the Specific Research Question III is that, although both Portuguese cases have sought to introduce and adopt an approach of '*adaptive planning and management*' – which was a good signal – this has not led to, nor translated into, the application of a *real* methodological approach of Adaptive Planning in the POCs. An Adaptive Planning approach, including its underlying principles and its main key-elements, still needs to be incorporated at the heart of the new POCs and their process of elaboration, implementation, and review.

Overall, the Portuguese cases showed that there is still a large gap between the intention of applying a 'model of adaptive planning and management' (of the coastal zones and of the POCs) and the implementation of a real Adaptive Planning and Management approach. This gap will likely remain, if no solid guidance and explanation are provided on the paradigm and methodological approaches of Adaptive Planning – and its key-elements and principles – to the Project Teams responsible for POC's elaboration and future reviews. To overcome this gap, it would be important to streamline and facilitate the dissemination of a guide on APM and its basic elements.

Each POC could have further defined and explained its proposed 'adaptive planning and management approach', especially in terms of: what such approach should involve and require (i.e. key-elements required in the Programme and its elaboration and implementation process, and in the planning approach), and how to deliver it (process of sequenced steps). Whereas each POC could have further specified its 'model of adaptive planning and management,' APA could have also provided an uniformized guide / guidance document to all Project Teams responsible for the elaboration of POCs, before the POCs' elaboration started, which did not occur. This guidance document would be important to support the development of a *true* Adaptive Planning approach and to uniformize the methods and tools used in it (e.g. the number and type of *plausible future scenarios* used), in a similar way to the '*ADM Implementation Guide*' that was provided by the national DP staff to all DP Sub-programmes.

Importantly, within the scope of this research, APA was asked to collaborate in interviews with the aim of discussing whether and how a real approach of Adaptive Planning, including its main elements and the underlying process, could be applied in the POCs. However, it did not reply. In their turn, the main coastal municipalities of the metropolitan areas of Porto and Lisbon, which were also invited to participate in individual interviews, manifested their interest in applying an Adaptive Planning approach (including the APs method), but confessed that they alone could not introduce such an approach in their spatial plans (namely in their municipal director plans) without a direct prescription of APA or other higher-level entity. At best, the municipalities could introduce such an approach in their Municipal Strategies of Adaptation to Climate Change (which are strategic documents that cross several sectors and climate-related risks, among them, those emergent in coastal zones).

In the future, a true application of an Adaptive Planning and Management approach in the Portuguese cases will require further analysis on how the main requisites – key-elements – of Adaptive Planning approaches can be delivered and operationalized in, and through, the POCs. The main requisites necessary for an Adaptive Planning approach should be enumerated and described in a clear and simple way, namely in the POCs Reports. Nevertheless, the uniformization of methods, tools, and procedures should be carried by APA. A simple and quick guide on Adaptive Planning and Management that explained its main methods and tools, and its key-elements, could be developed by APA, and provided to all Project Teams charged with the development and review of the new POCs.

Although the POCs aimed to launch a new 'model of adaptive planning and management' of the coastal zones, this has remained more an intention than a real goal that guided the elaboration of the Programmes and which was introduced at their core. More needs to be done to introduce a real approach of Adaptive Planning and Management in the new POCs, in their process of elaboration, implementation and review, and into the long-term process of coastal climate adaptation / coastal risk management. The aim of applying a model of adaptive (coastal) planning and management, *per se*, will not be sufficient to concretize an Adaptive Planning and Management – and it will not necessarily lead to a programme that is more '*adaptive*' in the face of uncertain future changes and evolving coastal risks – and thus, more '*sustainable*' (able to 'survive' uncertain future changes). It will be difficult to implement an Adaptive Planning approach in the studied cases if the Key-elements identified in Part A are not met and applied during the POC's elaboration, implementation, and review.

1.2. Answering the Specific Research Question IV

In this phase, the research focused on investigating whether and how the key-elements of an Adaptive Planning approach that were identified in Part A (as essential to develop a *dynamic adaptive plan / strategy* and required to concretize a process of Adaptive planning and Management) were present in the Portuguese cases.

In general, it was found that the studied cases have not met / accomplished the key-elements of an Adaptive Planning approach. Except the Key-element 4, all the key-elements of an Adaptive Planning approach (identified in Part A), are missing or have been largely disregarded in the studied POCs.

Regarding the **Key-element 1** (the use of a wide range of *plausible future scenarios*, namely to explore possible measures and assess them on their effectiveness and *robustness*), both of the selected POCs have only generated a single plausible future scenario (projection) of the future retreat of the shoreline (associated to coastal erosion) with two projection-years (2050 and 2100), and a single plausible future scenario (projection) of the future floodable area (associated to sea overtopping inundations and floods) with the same two projection-years. In the generation of these projections, both cases have assumed a single value of SLR estimated for each of the projection-years considered. Other climate change-related variables (e.g. possible changes in storm patterns) were not considered. No scenarios of socioeconomic development were generated. The projections generated served to delimitate risk zones denominated *Strips of Safeguard from Coastal Erosion* and *Strips of Safeguard from Coastal Flooding and Overtopping Inundations*. As the Teams did not generate other projections, no uncertainty margins/ bands – that could encompass different 'lines' correspondent to different projections – were represented.

It should also be highlighted that the POC-CE and the POC-ACE have not used the same figures for SLR for 2050 (the first considered +0,35m, while the latter considered +0,30m); thus, it would be important that the same scenarios of SLR were provided (by APA) – in a range of scenarios uniformized for the same (national) mainland coastline.

Overall, the POCs did not work with various plausible futures (i.e. more than one plausible future scenario, namely *transient scenarios*) – instead, they only generated and used a single scenario for the future shoreline retreat and a single scenario for the future floodable area, for two projections-years (2050 and 2100). Thus, the exploration of possible adaptation solutions was based on a single projection, which, in a certain way, contributed to narrow the spectrum of possible measures available for the future.

Regarding the **Key-element 2** (identification of critical thresholds or adaptation tipping-points, as a departing point in the analysis of potential future risks and vulnerabilities), neither of the Portuguese cases has examined what specific limit-values in certain variables / parameters might be disruptive for the existing or proposed measures. The analysis of potential future vulnerabilities and threats was strongly based on the projections assumed (for the retreat of the shoreline and for the floodable area), rather than focusing on determining under which conditions a given measure becomes ineffective or unacceptable and a new / additional measure is needed (regardless of the plausible future that is assumed). Although the 'Adaptation Tipping-Points approach' offers a methodological approach that is less dependent on, and more neutral to, the scenarios assumed, the POCs' Teams did not use this method. The Teams considered a single plausible future and addressed the analysis of potential future vulnerabilities with such plausible future in mind (and, thus, being strongly influenced by such single future scenario). This shows that if the *plausible future* that was assumed by the POCs fails (i.e. if the future unfolds differently than foreseen, and the projected lines of the retreat of the shoreline and of the limit of the floodable area prove be wrong in relation to the real retreat and extension of floods), then, the proposed measures might also be ineffective, insufficient or excessive. The strong reliance of both POCs in a single future projection to explore the potential future vulnerabilities and threats suggests that both POCs run the risk of becoming obsolete if other future projections arise in the coming years / decades. One way of overcoming this gap, would be to consider various scenarios and use the ATPs' approach (which is more 'scenario-neutral' by focusing on identifying conditions under which a given measure / system ceases to perform well – i.e. limit-values or critical thresholds in certain parameters – and, then, analysing when such tipping-points might occur in time under different plausible futures).

Regarding the **Key-element 3** (development of a '*robust and flexible set of measures*' to deal with uncertain future changes, by using the APs' approach), neither of the Portuguese cases has completely met this requisite. For the critical spaces / areas (in terms of vulnerability to the coastal risks of erosion and flooding), the POC-CE has developed four '*Adaptation Scenarios / Strategies*', whereas the POC-ACE has envisioned three '*Scenarios of Intervention*'. However, in both cases, the '*Scenarios*' devised do not consist of pathways – i.e. alternative strategies / trajectories to meet the objectives over time, in which several measures are sequenced and implemented to manage changing levels of risk over time, and which allow switching of measures, or pathways, if developments require so. Although both POCs have explored various alternative adaptation strategies for areas that were considered critical / problematic in terms of vulnerability and exposure to coastal risks, these were not conceived as 'adaptation pathways' – i.e. sets / packages of various measures sequenced over time to manage changing risks throughout time, up to a long-term future (2100 or beyond). The POCs have focused mainly on searching for the best (most cost-beneficial) solution to solve the problem in the near-future (and, ideally, during the period of validity of the POC) and that lasted for as long as possible in time. Criteria of *dynamic robustness* (i.e. performing well under a wide range of plausible futures and being *adaptable* as changes occur) and *flexibility* (capacity to be easily changed / adjusted in order to adapt to changing conditions over time) were not explicitly and intentionally pursuit during the exploration and development of possible solution strategies nor in their assessment. Importantly, some of the measures proposed by the POCs are inherently *flexible* (e.g. beach nourishments), but little detail was provided on how such measures might be changed / adjusted or adapted to changing conditions over time (e.g. additional measures, incremental implementation of various nourishments throughout time, etc). For example, no specific details are provided on the amounts and frequency of sand nourishments required to tackle different scenarios of SLR. This example can be compared against the case of the DP2014: in its *Strategic Decision on Sand*, the DP also proposed sand replenishments and explains that the amount and frequency (scope and distribution) of such operations might be adjusted in function of monitoring results and new insights (e.g. updated scenarios) that may emerge over time.

Overall, both the POC-CE and the POC-ACE have explored a narrow range of possible adaptation strategies, and have not assessed the strategies devised on their effectiveness in the long-term future and under different plausible future scenarios (of shoreline retreat and of the floodable area). A wider range of possible adaptation strategies should have been developed, and the POCs should have assessed the *robustness* and *flexibility* of such strategies over time under different *plausible futures* and changing conditions (e.g. changing levels of risks). It is important to widen the set of possible strategies available for / viable in the mid-and long-term, and assess their effectiveness and performance under different and changing conditions (i.e. under different 'transient scenarios'). To develop a '*robust and flexible* set of measures' (or, more precisely, sets of measures, i.e. several possible strategies, each strategy made of various measures sequenced and applied over time), the POC Teams could use the 'APs approach', which allows assembling and designing diverse possible pathways / routes into the future. An eventual exercise of design of '*robust flexible strategies*' (of 'robust and flexible' sets of measures) – as different pathways feasible – would strongly contribute to enhance the POCs' (and their strategies') *dynamic robustness* and *adaptability*, and thus, their '*long-term sustainability*' over time and under uncertain future change. This would likely help to 'soften' and streamline the future reviews of the POCs: if a '*robust flexible set of measures*' is anticipately planned to cope with multiple plausible future conditions and uncertain change, it will likely be easier and quicker to adapt the Programme to unexpected / unforeseen changes and changing risks.

Regarding the **4th key-element** of an APM approach (definition of a monitoring and re-evaluation system to monitor external changes and the effects of implemented actions, and reassess the Plan and its contents, and, if necessary, adjust it), both Portuguese cases defined their own monitoring and evaluation system, which is a positive aspect. However, in both cases, scarce information is provided on how such systems will inform and allow future adjustments of the POCs and their contents (namely their strategies, Directives, etc.). It is not explained whether and how it will be possible to adjust a given measure (planned or implemented) or its timing (postponing or anticipating in time). As alternative measures / options for the future were not anticipately planned, it is not fully safeguarded the possibility to switch from a given measure to another (such new measure will be planned only when it becomes necessary). In each POC, the monitoring and evaluation system is expected to allow future adjustments of the Program of Actions, but the eventual need of adapting / adjusting the POC itself (its contents) tends to be disregarded, and no explanations are provided on how this will be done. Moreover, in both cases, the monitoring and evaluation system has not accounted for to the need of regularly assessing new / updated scenarios (projections) and new knowledge that arises over time, which might require an adjustment of the POC and its proposed measures. Furthermore, some important climate change-related variables are missing in the indicators to be monitored.

In addition, both cases have put a strong emphasis on the monitoring and evaluation system as the main, and almost unique, element required to ensure an 'adaptive planning and management' and to allow the adaptation of the POC (mainly its Program of Actions) over time. This reveals an important gap – first, because there may be changes in some variables / parameters that are not detectable within the temporal scales of the monitoring system (e.g. the natural variability in some parameters may be difficult to discern from the effects of climate change in a few years / a decade), and, secondly, because the monitoring results *per se* will not be enough to inform about *when* and *how* the Programme must be adapted. In an Adaptive Planning approach, the monitoring and reassessment system usually defines trigger-points or decision-points (whose determination is associated to the analysis if critical thresholds or ATPs), as occurred in the cases of the TE2100 and DP2014. These trigger-points or decision-moments help to detect when it is necessary to take a decision or activate a new action. Moreover, in an Adaptive Planning approach, it is necessary to leave open alternative actions (keep them 'at hand') for the case they become necessary – which implies an anticipatory planning of possible measures for the future.

These two aspects were not ensured in neither of the Portuguese cases: no trigger-points or decision-moments were defined, and there was no anticipatory planning of different possible measures for the mid- and long-term future.

Regarding the **Key-element 5** (the ongoing process of development of a *dynamic adaptive plan* and the associated cycle of *Adaptive Planning and Management*, which is crucial to operationalize coastal climate adaptation as a continuous long-term process itself), the Portuguese cases demonstrate that their process of elaboration and implementation is still strongly framed within the pre-existing standards of planning. The elaboration of the POCs – with its several steps / phases – is scarcely described in both POCs' Reports, but, apparently, it has followed a quite linear process (not circular nor cyclical). The POCs implicitly assume that the future adaptations of the POCs will be a natural step after its implementation, but do not explain how such adaptations might be carried (*when* and *with what measures*). Considering that the review of the 1st POOCs (1st generation of coastal management plans) has occurred many years after the date that was initially expected for their first review, it would be important to represent the process of development, implementation, and review of the POCs in a diagram/ scheme that illustrates how the monitoring and reassessment system will feed back information into the re-planning of the POC, in a similar way to the scheme provided in the DAPP approach (or in the ADM approach of the DP2014), in order to facilitate and streamline future reviews of the POCs. Indeed, the ongoing process (circular cycle) of Adaptive Planning and Management will only be concretized provided that it is possible to adapt the Programme and its contents (without the need of creating a completely new Programme every ten years or so, but, instead, allowing quicker adjustments in some parts / contents of the POCs). To ensure this, it is important to feed back the results of the monitoring and evaluation system into the first steps of the process, and repeat the process whenever necessary to ensure that the Programme remains 'fit for purpose' over time and under uncertain change.

In sum, the answer to the specific research question IV is that, in general, the five key-elements of an Adaptive Planning approach (that were identified in Part A) are not present nor accomplished in the studied POCs. Most elements are missing or have largely disregarded / dismissed (by the Project Teams) as essential ingredients to develop the POCs as a *dynamic adaptive plan / programme* and to ensure (operationalize) a true process of Adaptive Planning and Management. Except the Key-element 4 (which is partially accomplished), the other key-elements were not met in the POCs. Although both POCs sought to adopt a 'model of adaptive planning and management', they have not explored what are the main elements (requisites) necessary to deliver such model, and they have not absorbed such elements. However, it seems hardly possible to adopt a *real* approach of Adaptive Planning if the key-elements identified in Part A are not met (each and all of them, especially the Key-elements 1, 3, and 4).

1.3. Answering the Specific Research Question V

The specific research question V was specifically targeted at identifying barriers to the adoption and application of an APM approach in the Portuguese cases. This task implied a wider analysis of different sources of information, including the POCs, but also other studies and prior analyses of the POCs. However, due to the limited time available, this task was not fully completed. It is important to understand why (the reasons why) a real approach of Adaptive Planning and Management has not yet been applied in the Portuguese cases, although both claim and seek to adopt it.

Some of the main barriers that were identified in this research, and that hinder the real fulfilment of an approach Adaptive Planning and Management in the selected POCs are:

- The stability and rigidity of the POCs and the associated difficulty found in introducing new methodological approaches, and the lack of a clear guidance on an Adaptive Planning approach that was provided to the POC's Project Teams by APA. Moreover, there is an intrinsic stability in the national legislation (legal framework), despite the recent claims for a more strategic role of the POCs and the public discourse of APA that advocates that an approach of *adaptive planning and management* has been adopted in all new POCs.
- The debility of institutions and the lack of technical staff to develop, and to put into practice, a real approach of Adaptive Planning and Management. There is a clear scarcity of qualified and specialized human resources to address the introduction of new methodological approaches. This constitutes a strong barrier to the use of innovative methodological approaches of Adaptive Planning and Management that imply working with various scenarios and designing several pathways.
- Moreover, the inexistence / lack of a technical staff specifically trained (with technical expertise) on coastal climate adaptation / coastal risk management, namely at the municipal level, is notorious. To a certain extent, municipalities tend to wait for higher-level authorities to provide them with concrete instructions on methodologies, which is also a form of institutional 'stickiness' and 'rigidity'. Although good methodologies may emerge (namely within the scientific community), these may not be applied because there is no explicit indication for their use by the entity responsible for steering the elaboration and implementation of the POCs (in this case, APA) and for the provision of guidance to the Project Teams (APA again).[79] On the other hand, the consultancy groups and Project Teams charged of the elaboration of the POCs usually lack time to search for new methodological approaches that are more adequate and suited. Moreover, the involved entities, often use the excuse of lack of time to absorb and apply new methods, which apparently are more complex and sophisticated, while, in fact, such methods could simplify the planning process and make the plan more *robust* and *adaptable* to change and uncertain future conditions.
- While some guidance and policy documents that served as a reference to the elaboration of the new POC already recommended aspects that are characteristic of the approaches of Adaptive Planning (their methods, tools), none of such documents offered a clear methodological guide that explains the key-elements required in an Adaptive Planning approach and the process of steps necessary to develop an *adaptive plan*. APA has gathered information about climate adaptation and the design of adaptation plans / strategies in its website, but it does not prescribe any concrete recommendations for the use of an Adaptive Planning approach.
- Complexity on the roles and responsibilities, e.g. who should be responsible for elaborating the maps of adaptation pathways – the POC Team (under supervision of APA) or the municipality (in conjunction with APA) – and how should the municipality integrate a map of APs (which has a strategic and exploratory nature) in its spatial plans (which have normative / regulatory character).
- Overreliance on the monitoring and reassessment system as being sufficient to ensure an adaptive planning and management. Even though, the other four key-elements are essential to ensure a real process of Adaptive Planning and Management. There may be changes and developments not detectable within the temporal scales of the monitoring system. In both Portuguese cases, the monitoring and reassessment system has not considered the need of a targeted evaluation of new information and knowledge (e.g. updated scenarios). In both POCs, it is not sufficiently explained how the Programme can be adapted as the monitored information arises or if new knowledge

[79] In interviews carried during this research, several coastal municipalities showed interest in adopting the APs approach at the scale of the municipal coastal zone, but mentioned that, to do this, APA (or a higher government entity) would have to explicitly prescribe the methodology to them – in a top-down approach.

emerges. Moreover, monitoring and re-assessment have been historically jeopardized in Portugal (e.g. the first POOCs waited almost 20 years to be reviewed, though they expected to be reviewed every 10 years), in part, due to the quite complex coastal governance system with its overlapping jurisdictions. The lack of regular collection, interpretation, and organization of information has been an important weakness of the Portuguese coastal spatial planning system, which also hampers the application of predictive models that support decision-making in a perspective of *adaptability*.

- Resistance to change and tendency for the status-quo, as well as a low perception of coastal climate adaptation as an ongoing process (iterative risk management cycle) where the plan must be more regularly reviewed and adapted.
- Lack of understanding of the advantages of using an Adaptive Planning approach, as: (1) a tool to support planning under deep uncertainties about future conditions and change, namely under changing risks, (2) a means to increase the *dynamic robustness* and *adaptability* of the Plan / Programme, and, thus, its long-term sustainability (as the capacity to 'survive' change over time, rather than perishing or becoming obsolete, for example, a few years after its publication), and (3) a methodological approach suited and adequate to plan for coastal climate adaptation / coastal risk management (as an ongoing long-term process, in ever-changing / dynamic coastal environments).

Part C. Final conclusions and recommendations

1. THEORETICAL FRAMEWORK: FROM THE RECOGNITION OF THE COASTAL ZONES OF PORT-CITIES AS '*RISK-FOCCI*', TO COASTAL CLIMATE ADAPTATION, TOWARDS THE EMERGENCE OF THE PARADIGM OF ADAPTIVE PLANNING

The topic of this research emerges at the intersection of three domains that are interlinked: the transformations of coastal zones of port-cities and the increasing recognition of these spaces as *hotspots* in terms of exposure and vulnerability to emerging coastal risks, coastal climate adaptation, and the paradigm of Adaptive Planning approaches under uncertainty about future changes. Each of the three domains has naturally driven to the next one and has led to the formulation of the main research question.

There is a vast body of literature available on the transformations occurred in the coastal and estuarine zones of port-cities, however, and although these spaces are increasingly recognized as '*risk-focci*', there are still few examples and studies on how port-cities are dealing with emerging coastal risks associated with the effects of climate change, namely with SLR. This revealed a gap in the field of the transformations of port-cities' coastal zones. Meanwhile, since the 1990's, coastal climate adaptation has developed and consolidated as a scientific field *per se*, in parallel with the increasing knowledge on the effects of climate change and ongoing anthropic pressures as drivers of change and aggravated (exacerbated) coastal risks, namely of the risks of coastal flooding, erosion and submersion. Coastal climate adaptation, which involves actions / measures to reduce or avoid climate change-related risks and potential adverse impacts for socioecological systems, including measures to reduce the vulnerability of such systems, has gradually progressed. Despite that, 'adaptation deficits' are reported in several coastal port-cities across the world. Besides this, planning for coastal climate adaptation is deemed a 'wicked problem': it is surrounded by deep uncertainties about future changes and conditions, especially about future climate change effects, their magnitude and pace (e.g. how much the sea level will rise until 2100), and by complexity (e.g. lack of consensus on which adaptation measures should be used). In the face of such deep uncertainties (incomplete or imperfect knowledge of the future and on changing risks), and, given the need to make good decisions (with the existing knowledge), a new paradigm for planning and decision-making under uncertainty about future changes has emerged: *Adaptive Planning*. According to this paradigm, under uncertain future conditions and changes, it is necessary to develop a '*dynamic adaptive plan / policy*' that is: *robust* (performs well under multiple plausible futures) and *adaptive* (it can be adapted as conditions change over time). To design such plans, several methodological approaches have emerged within the family of Adaptive Planning, among them, the method of Adaptation Pathways. The approaches of Adaptive Planning have been advocated as useful to plan for climate adaptation and to deal with deep uncertainty about future and changing conditions. The two main examples of application of Adaptive Planning approaches, including the method of Adaptation Pathways, for planning for coastal climate adaptation (i.e. flood risk management) are the *Thames Estuary Project 2100* and the Dutch *Delta Programme 2014*. Notwithstanding, further studies are needed to investigate and assess real cases of application of the methodological approaches of Adaptive Planning for coastal climate adaptation purposes, and to explore their feasibility in different coastal contexts worldwide (different planning instruments). More specifically, further research is needed to understand to what extent Adaptive Planning approaches (namely the Adaptation Pathways' method) are being applied in plans / policies for coastal zones, as a tool to plan ahead for coastal climate adaptation / coastal risk management, under deep uncertainty about future conditions and changes.

Finally, the Portuguese context offered pertinent cases to address this issue: several coastal stretches of port-cities are critical cases in terms of vulnerability and exposure to the risks of coastal erosion and flooding, and there is a recognized 'staticity' and 'rigidity' in coastal planning instruments that contrast with the dynamic nature of coastal environments and with the adaptability necessary to deal with evolving risks and changing conditions. Given this, over the last decades, some scholars have called for an *adaptive planning and management* of coastal zones. More recently, the new Programmes for the Coastal Zone (POCs) themselves claim that they have adopted a new model of adaptive planning and management. Thus, the POCs constitute relevant objects of analysis to evaluate whether and how an approach of adaptive planning has been introduced and used, and to investigate the extent to which it is possible to apply a true methodological approach of Adaptive Planning (including Adaptation Pathways) in such planning instruments, to plan coastal climate adaptation / coastal risk management.

The intersection of the three main scientific fields – and, in particular, the crossing of the main gaps identified in each field – indicated the research problem, and led to the formulation of the main research question: to what extent can the Adaptive Planning approaches, including the method of Adaptation Pathways, be introduced and applied in the planning instruments used in the coastal zones of port-cities, as a tool to support coastal climate adaptation planning, under deeply uncertain future changes?

2. General Conclusions

The main objective of this research was to analyse:

To what extent can the approaches of Adaptive Planning – including the 'Adaptation Pathways method' – be introduced and applied in planning instruments used in coastal zones of port-cities?

To address this question, this work has first examined the two major examples of application of Adaptive Planning approaches for coastal climate adaptation planning purposes (Part A – Reference Cases), and, then, it has evaluated two Portuguese coastal management plans that advocate and sought to adopt a new approach of adaptive planning and management of coastal zones (Part B – Portuguese case studies).

Answering the main research question

This research showed that it is possible to apply an approach of Adaptive Planning, including the 'Adaptation Pathways method' (APs), in coastal spatial planning instruments, provided that a set of requisites are met: the five key-elements identified in Part A as essential to develop a *dynamic adaptive plan* and to put into practice a process of Adaptive Planning and Management. An approach of Adaptive Planning (containing APs) can be introduced in, and operationalized through, planning instruments, and for planning for coastal climate adaptation / coastal risk management, to the extent that the key elements required to develop and implement an *adaptive plan* are accomplished.

In **Part A** (Reference Cases), this research focused on analysing: how an approach of Adaptive Planning was applied in the TE2100 Project and in the DP2014 (specific research question I), and what were the key-elements of the Adaptive Planning approach used that were essential to develop a *dynamic adaptive plan* (specific research question II). In each Reference Case, the work was structured in the following way: presentation of the Plan and its objectives, identification of drivers for creating an Adaptive Planning approach, description of prerequisites set for the Plan, definition the Adaptive Planning approach developed, including a characterization of the APs' approach devised, analysis of the how the Adaptive Planning approach was applied (process of development of the Plan / Programme), analysis of the main contents of the Plan, identification and systematization of the main elements of the Adaptive Planning approaches that were essential to construct an *adaptive plan*, positive effects of applying an Adaptive Planning approach, and barriers / difficulties found in its application.

To answer the Specific Research Question I, the research has focused on: understanding the Adaptive Planning approaches used in the TE2100 and DP2014, identifying their main features, and analysing the process of development and application of such approaches in each case, namely in the elaboration of the TE2100 Plan / DP's Strategies, and of the maps of adaptation pathways generated in each case.

The TE2100 and the DP2014 cases show, in two different ways, how a *dynamic adaptive plan / programme* was developed and how a process of Adaptive Planning and Management was carried. The TE2100 Project has developed a novel planning approach based on the concept of *Dynamic Robustness* – which was called *Dynamic Adaptive Planning approach*, and which aimed at designing a plan that is '*dynamic robust*' (under multiple plausible futures) and '*adaptable to change*'. The TE2100's *Dynamic Adaptive Planning approach* contained an innovative method for designing a *robust adaptive plan*: the Route-map approach / Adaptation Pathways' approach (APs). In the TE2100 Project, a route-map was produced with five main pathways, which together can cover a range of plausible future scenarios of water level rise (four different scenarios of SLR) until 2100. In its turn, the DP2014 has developed its own planning approach based on the DAPP approach (developed by *Deltares* and *TU* Delft, and presented by Haasnoot et al. 2013), and inspired by the TE2100'S approach – so-called *Adaptive Delta Management* (ADM). The ADM approach resorts to the methods of Adaptation Tipping-points (ATP) and Adaptation Pathways (APs), to develop *robust flexible strategies*. The DP2014 applied ADM to develop its Preferential Strategies. Each Preferential Strategy contains a map of *adaptation path(s)* with the measures available for the short-, mid- and long-term, under one of the *Delta Scenarios* considered.

Thus, the two Reference Cases provided two different examples of how an Adaptive Planning approach can be applied in planning instruments – in their development and implementation process – and for managing emerging coastal risks under uncertainty about future conditions and changes (associated with the effects of climate change and socioeconomic developments, their magnitude and rate).

Subsequently, to answer the Specific Research Question II, it was necessary to identify and systematize the main elements essential to develop an *adaptive plan* (and which are fundamental requisites in an Adaptive Planning approach containing the method of Adaptation Pathways) from each Reference Case. In addition, it was carried a review of literature to search for the main ingredients / criteria required in the paradigm of Adaptive Planning approaches.

Based on the two Reference Cases, and drawing on scientific literature on the main ingredients / requisites of Adaptive Planning approaches, five main elements that are essential to design a *dynamic adaptive plan*, and undertake a process of Adaptive Planning and Management, were identified:

1) To prepare for, and work with, a wide range of plausible future scenarios, and use them namely to explore and assess possible adaptation measures and strategies (on their effectiveness over time, and *robustness* across such diverse plausible futures).
2) To examine critical thresholds, i.e. conditions or limits (in certain variables) which might be disruptive for the existing or proposed measures or coastal protection system, regardless of the plausible future scenario considered, or Adaptation Tipping-Points (conditions under which a current or proposed measure ceases to perform well or satisfactorily and a new measure is needed to meet the defined objectives). The identification of thresholds / ATPs is particularly pertinent in the analysis of potential future risks and impacts, and it logically supports and leads to the design of pathways.
3) To develop a 'robust and flexible set of measures' to deal with uncertain future, by using the 'Adaptation Pathways approach'. In an Adaptive Planning approach, a *robust* measure or strategy is one that performs well under a wide range of plausible future scenarios, and a *flexible* measure or strategy is one that can be easily adapted to changing conditions over time. In the APs, a pathway consists itself of a set of measures sequenced and implemented to manage changing risks over time, and several pathways are usually designed. Each pathway provides a strategy throughout this century, which is *flexible* as it allows switching from a measure to a new one, and it is also possible to move from a given pathway to another, if developments over time require so. Thus, *flexibility* and *dynamic robustness* are built-in in the long-term strategy(ies) and in the general Plan, the diverse pathways contribute to deliver these.
4) To monitor relevant changes and Plan's effects, reassess the Plan, and adjust / adapt it accordingly. This implies the definition of a monitoring and reassessment system in the Plan. The monitoring and reassessment system will allow adapting the Plan and its contents – namely implemented or planned measures and strategies, or their timing of implementation and decision – as external conditions change and prompt so, or if new scenarios arise, or whenever the plan is reassessed.
5) The ongoing process of planning, monitoring and reassessment and adaptation (of the Plan and of the physical environment), which is also related with the continual long-term process of coastal climate adaptation and an iterative risk management cycle, which are *learning-oriented* and imply regularly feeding back lessons into the initial phases of the planning process.

In each of the Reference Cases, all these five elements were ensured. Indeed, the Reference Cases constitute the two main examples at the international level of application of Adaptive Planning approaches in plans / programmes for coastal climate adaptation / coastal risk management.

In **Part B** (Portuguese case studies), the research has firstly focused on analysing: if (and how) the selected POCs had applied an Adaptive Planning approach (a methodological approach of the family of Adaptive Planning); how the '*adaptive planning and management approach*' advocated and proposed by the new POCs was conceptualized / defined; and whether it was built on the principles of *dynamic robustness* / *flexibility* and *adaptability*. Secondly, the research sought to analyse whether (and how) the key-elements that had been identified in Part A were met in the studied POCs. Finally, some important barriers to the application of true Adaptive Planning approaches were identified.

The Portuguese case studies showed that, despite the aim and intention to launch and adopt a novel 'approach of adaptive planning and management' of coastal zones in the new (2nd generation) POCs, a *true* methodological approach of Adaptive Planning was not applied in the selected POCs (the two POCs that cover the coastal zones of the two major Portuguese port-cities).

In each of the Portuguese cases, there was an explicit intention of adopting an '*approach of adaptive planning and management*' and a more adaptive planning and management of coastal zones. Notwithstanding, none of the POCs explicitly aimed to make the Programme (POC) *dynamically robust* and *adaptive* to changes and uncertain future conditions – indeed, there was no intention of designing the Programme and its strategies as *dynamic robust* and *adaptive* plans / strategies – and, thus, *sustainable* to 'survive' change over time. Although both POCs recognize the deep uncertainties around the projection of future risks, and the inherent dynamism of coastal environments, these spatial plans were not conceived with the aim of being *robust* and *adaptive* in the face of uncertain future changes. In other words, the need to make the Plan *sustainable adaptable* under changing and uncertain future conditions, namely emerging coastal risks, was not addressed / accounted for in the Portuguese cases.

The level of application of a *true* Adaptive Planning approach is still quite weak in the Portuguese cases. The principles underlying the paradigm of Adaptive Planning – i.e. *dynamic robustness* / *flexibility* and *adaptability* – which are necessary to cope with deeply uncertain future changes (and changing risks), were not assumed nor absorbed as guiding principles for the Programme, its process of elaboration and implementation, or its planning and management approach. Moreover, none the POCs used the two methods that are characteristic of the recent family of Adaptive Planning approaches: Adaptation Tipping-Points (ATPs) and Adaptation Pathways (APs).

Despite the willingness to adopt a new 'approach of adaptive planning and management', scarce information is given to define such approach in each POC's Reports and documents. The two selected POCs (and their respective Project Teams) have not explored (sufficiently nor properly) what such approach would imply, namely what are its main elements (i.e. requisites / ingredients necessary to operationalize it), what are its methodological tools, and how the process of development and implementation of the POCs should unfold to pursuit a *real* process of Adaptive Planning and Management. Furthermore, although APA claims that a '*novel approach of adaptive planning and management*' is the trademark of the new POCs, it did not provide a clear guide explaining how such approach should be carried (process), and what it must involve (key-elements required).[1] Overall, little attention was paid to what is necessary to make the Programmes (POCs) dynamic adaptive in the face of uncertain future changes and conditions.

In order to answer the Specific Research Question IV, it was carried an in-depth analysis of both POCs (and their diverse contents) and their comparison (confrontation) against the key-elements that were identified in Part A (to answer the Specific Research Question 2). The analysis of the Portuguese cases showed that most key-elements essential in an Adaptive Planning approach to develop a *dynamic*

[1] While no information is given in the POCs on the principles of *dynamic robustness* / *flexibility* and *adaptability*, APA provided some guidance on these topics in its website (guidelines to support the elaboration of adaptation strategies in the water sector, including coasts).

adaptive plan are missing: except the Key-element 4 (the monitoring and reassessment necessary to allow future adjustments / adaptations of the Plan), all other key-elements are absent – they have been disregarded or not accomplished / met.

Regarding the Key-element 1, rather than working with a wide range of plausible future scenarios, the Portuguese cases only considered and used a single plausible future scenario for the retreat of the shoreline induced by erosion and a single plausible future scenario for the floodable area; and such scenarios were then used in the phase of exploration and assessment of possible adaptation strategies. These scenarios were taken as the '*most likely*' futures.

In what concerns the Key-element 2, although both POCs sought to identify the main vulnerabilities and threats expected in the future associated with the coastal risks of erosion and sea overtopping floods and inundations, neither of the POCs has specified critical thresholds / ATPs (that indicate unacceptable points / conditions under which a given system or measure ceases to perform well or satisfactorily). The analysis of potential future threats / vulnerabilities focused more on *how the future will likely unfold*, rather than on *under what conditions a certain measure will no longer meet the objectives*.

In contrast with the Key-element 3 (which involves the design of a 'robust and flexible set of measures' to cope with uncertain future change, by using the APs approach), in both Portuguese cases, the exploration of measures was mostly focused on identifying measures that could solve problems now and 'for once and for all' (and selecting the one that was most cost-beneficial), and few alternative options (e.g. additional or new measures) were anticipately planned (and kept open) for the mid-/ long-term future. Despite the exploration of different possible adaptation strategies in each case – called '*Adaptation Scenarios / Strategies*' in the POC-CE, and '*Scenarios of Intervention*' in the POC-ACE – these *Scenarios / Strategies* were not devised as adaptation pathways. Neither of the POCs' Teams applied the APs method. The strategies developed constitute different alternatives from which the Team would choose one (based on the assessment of their cost-benefit ratio). *Dynamic robustness* / *flexibility* and *adaptability* were not taken as fundamental criteria in the exploration and assessment of the possible strategies. The measures envisioned for the short-term were not logically linked to viable alternatives (options) in the long-term. The possibility of switching from a measure to another (within a given *Scenario*), or from a *Scenario* to another one, was not contemplated in none of the POCs.

Regarding the 4th Key-element, both POCs defined their own monitoring and evaluation system. However, both POCs seem to put an excessive weight on the role of key-element 4 as the main (and almost single) ingredient required to allow the adaptations to the Programme and deliver an adaptive planning and management of coastal zones, in time and space. In both cases, there seems to be a biased belief that the monitoring and reassessment system alone will be enough to adapt the Plan (and its strategies) and to adapt coastal zones (physically, and their respective adaptation / risk management measures). This indicates an important gap: an overreliance on the monitoring and evaluation system as being sufficient to ensure an Adaptive Planning and Management and guarantee the adaptations / adjustments of the Programme (in fact, of its Program of Actions). Nevertheless, certain changes in some variables will be difficult to detect by the monitoring systems in a few years, and the reassessment of new / updated scenarios was not considered in these systems (thus, if the future unfolds differently than the scenario assumed by the POCs, the Programme will likely 'perish' / become obsolete).[2] Moreover, in both POCs, the process of monitoring and reassessment has not yet been initiated or is at an embryonic state, and the past has shown that monitoring and reassessment are usually disregarded or

[2] This points to the tendency to carry an integral review of the Plan (or elaborate a completely new Plan) whenever a new scenario is issued, which shows the strong dependence of the plan's success on the scenario considered. To overcome these lacunas, it would be necessary to introduce an Adaptive Planning approach containing all the key-elements identified, in the Portuguese cases.

not even carried. Both POCs are placing a huge burden in the next phase (after POCs' approval) as being the main phase to plan and carry adaptations of the Programme and its strategies. However, as the Reference Cases showed, all steps of the process of an Adaptive Planning are crucial, namely the anticipatory planning of various possible measures (including options that are kept open for the future). This does not mean that it is necessary to follow each of the precise steps carried in the Reference Cases, but to ensure that, in the process pursued, the five key-elements outlined are safeguarded.[3]

Finally, the 5th Key-element was also slightly addressed and largely disregarded in both Portuguese cases. The process of elaboration of both POCs is scarcely described in the POCs' documents, but, apparently, is has followed a quite linear process (not circular nor cyclical). It is not explained whether and how the information of the monitoring and reassessment system will be fed back into the initial planning phase. An ongoing (circular) process of planning and adapting is not truly safeguarded. Moreover, both POCs seem to be more focused on adapting the physical space (on ensuring the conditions necessary for the adaptation of the physical environment, in order to reduce the vulnerability and exposure to risks) and less on ensuring the *adaptability* of the Programme (and its strategies of adaptation) to contextual and external changes as these occur over time (although it is mentioned that the actions programmed in the Program of Actions, the Norms, and the limits of the Strips of Safeguard from Coastal Risks might be changed if the monitoring results prompt so, it is not explained how such adaptations might occur). However, both types of *adaptability* are required in an Adaptive Planning approach: the capacity to adapt the physical space (through adaptation measures, namely those that are inherently *flexible*, although many measures tend to be *stable* and *fixed* in space and time, and difficult to adapt), and, on the other hand, the capacity to adapt the Plan (and its measures) to changes over time.

In sum, in the studied POCs, most of the key-elements essential in an Adaptive Planning approach (to build *a dynamic adaptive plan*) were not met; only Key-element 4 was partially ensured in each POC. In general terms, these POCs did not meet the key-elements necessary to develop a *dynamic adaptive plan* and required for an Adaptive Planning and Management: except the Key-element 4 (which is partially accomplished), all key-elements identified in Part A are absent in each POC and were largely dismissed or disregarded or not accomplished. Notwithstanding, to truly apply an Adaptive (coastal) Planning and Management in the Portuguese cases, all the five key-elements should have been met.

Drawing on the confrontation of Portuguese Study-cases with the Reference Cases, it can be deduced that all the key-elements identified constitute key requisites necessary to build a *dynamic adaptive plan* and achieve an Adaptive Planning and Management, and, thus, neither of them can substitute the others (and their function in the process of Adaptive Planning and Management).[4] Regarding the process of Adaptive Planning, it is important to refer that the process of steps does not need to be strictly the same or equal to the way that is illustrated in Diagram 4 (of Part A), but it is important to ensure that each and all the five key-elements that were identified are met throughout the process of planning, implementation, and reassessment / review.

In the Portuguese cases, it would have been possible to apply a real Adaptive Planning and Management approach if the five key-elements (identified in Part A) had been met during the process of elaboration of the POCs, however, it might be viable to introduce each of these key-elements during the next phase of implementation or in future reviews of the POCs.

---

[3] As demonstrated by the Reference Cases, it is necessary to meet the first four key-elements during the process of elaboration and implementation of the Plan and its reassessment and adjustments, i.e. during the 5th key-element (which consists of the ongoing cycle of Adaptive Planning and Management associated to the ongoing process of adaptation). As seen, coastal climate adaptation involves an ongoing process to *adapt* to – or manage – evolving climate-related risks (which is associated to a cycle of iterative risk management).

[4] The Portuguese cases demonstrated that it is not viable to deliver a real Adaptive Planning approach, if (and when) the five key-elements outlined in Part A are not met. It is indispensable to accomplish each and all the five key-elements – it is not enough to ensure one or two of them – to ensure a real Adaptive Planning and Management (a single key-element is not sufficient to develop a plan that is *adaptive*).

The main conclusion that can be drawn from the analysis of the Reference Cases, from the Portuguese case-studies, and from their confrontation, is that: an *Adaptive Planning approach* (that includes the APs' method) can be applied into planning instruments used in coastal and estuarine zones of port-cities, as a tool to support the planning for coastal climate adaptation / coastal risk management in the face of deep uncertainties about future changes and conditions, to the extent that the key-elements essential to develop a *dynamic adaptive plan* and required for a process of adaptive planning and management (which were identified in Part A, based on the Reference Cases) are met.

While the European Reference Cases provided the main examples available to prove that it is possible to develop and apply an Adaptive Planning approach into two different planning instruments used in coastal zones of port-cities and showed how this could be done, the Portuguese case-studies demonstrated that the intention and ambition of introducing 'a novel approach of adaptive planning and management' in coastal management plans, *per se*, are not sufficient to ensure the development and application of a *real* methodological approach of Adaptive Planning.

Besides this, the Reference Cases showed that methodological approaches of Adaptive Planning (containing the APs' method) can be devised and used in planning instruments (plans / programmes), provided that the key-elements above-mentioned are accomplished. Such key-elements are essential to develop a *dynamic adaptive plan* (and provide the necessary *dynamic robustness* / *flexibility* and *adaptability* to such plan) and are required to carry an Adaptive Planning and Management process. As long as these key-elements are fulfilled, it is possible to put in practice an Adaptive Planning approach.

In contrast, in the Portuguese cases, the level of development and application of a true approach of Adaptive Planning and Management is still quite weak. The analysis of Portuguese cases (Part B) showed that all the key-elements identified in Part A are missing in the selected POCs, except the Key-element 4. The studied POCs, and their process of elaboration, did not meet the all the key-elements identified in Part A: only the Key-element 4 was partially accomplished (and the monitoring and reassessment still need to be undertaken to fully meet this key-element). Moreover, the principles that underlie the paradigm of Adaptive Planning – i.e. *dynamic robustness* / *flexibility* and *adaptability* – are absent in the selected POCs and were not assumed nor absorbed in their elaboration nor in their planning / management approach. Moreover, none of the POCs has used the two main methods of the recent family of Adaptive Planning approaches: ATPs and APs.

A real application of an Adaptive Planning approach would be possible to the extent that the key-elements outlined[5] were ensured (all of them). The achievement of an Adaptive Planning approach and its underlying principles is directly related with the level of development and concretization of these key-elements. Such elements (and their sub-elements) are essential components that grant *dynamic robustness* and *adaptability* to the Plan and to the planning / management approach.

In synthesis, the main conclusion of this research, and answer to the main research question, is that: an Adaptive Planning approach (including the APs' method) can be introduced and applied in planning instruments used in coastal and estuarine zones of port-cities, as a tool to support coastal climate adaptation planning under uncertainty about future conditions and changes, provided that five key-elements are met: (1) working with (preparing for) a wide range of plausible future scenarios, namely to explore and assess measures and strategies under diverse scenarios (rather than using a single 'most probable' future scenario); (2) identifying critical thresholds / tipping-points (conditions under which a given measure or system ceases to be effective or acceptable) and determining when these might occur

[5] Identified in Part A, based on the analysis of the Reference Cases and a review of literature on Adaptive Planning and its main elements.

under different scenarios; (3) developing a '*robust and flexible set of measures*' to deal with uncertain future changes, by using the APs approach (i.e. designing *robust flexible strategies*, each strategy as a set of measures, through the APs approach); (4) monitoring external conditions, effects of implemented measures, and new knowledge, and regularly reassessing the Plan, and, if necessary, adapting / adjusting it (its strategies, measures, or their timing); and (5) ensuring an ongoing process of steps necessary to concretize an Adaptive Planning and Management, which is related with the continuous long-term process of coastal climate adaptation and with a (circular) cycle of iterative risk management.

The Reference Cases demonstrated that different Adaptive Planning approaches (that contain the APs' method) can be developed and applied in coastal planning instruments, as long as the five key-elements essential to develop a *dynamic adaptive plan* (above-mentioned) are met. The applicability of a methodological approach of Adaptive Planning is intimately related with, and depends on, the accomplishment and level of development of each and all key-elements identified.

Whereas the Reference Cases offered the main examples of how an Adaptive Planning approach can be developed and applied in plans / programmes (at different spatial scales, in coastal zones, including estuarine areas), the Portuguese Study-cases show that more efforts and further work are needed to adopt or develop a *real* Adaptive Planning approach in the selected POCs. Notwithstanding, an Adaptive Planning approach would be useful and highly beneficial as a tool to support the planning for coastal climate adaptation / coastal risk management, in the face of deeply uncertain future conditions and changes, and complex natural variability and dynamism of coastal environments. It would also be a valuable means to increase and enhance the POCs' *adaptability* and *long-term sustainability* over time (and, thus, their capacity to cope with uncertainties and changes).

3. RECOMMENDATIONS, AND ISSUES FOR FURTHER RESEARCH

There seems to be scope for introducing a true Adaptive Planning and Management approach suited to the Portuguese coastal context in the POCs, namely in their future reviews. In that case, the paradigm of Adaptive Planning approaches, its underlying principles, and the key-elements identified, must be incorporated into the POCs and their process of review and in the re-planning of strategies.

The main recommendation regarding the Portuguese cases is to incorporate or develop a true methodological approach of Adaptive Planning in each POC in the future, including all its key-elements. Specific recommendations can be drawn in line with each of key-elements of an Adaptive Planning:

1) A wider range of plausible future scenarios should be used (including e.g. an intermediate scenario, a low-end scenario, and an high-end / worst scenario, as well as '*transient scenarios*'). The consideration of a wider range of future scenarios is particularly pertinent for the exploration of different possible solutions / measures (coastal risks management / adaptation measures) to manage different and changing levels of risk over time, throughout this century. APA could provide the same range of scenarios to all the POCs' Teams (including the same range of figures for plausible SLR for the entire national coast). The range of scenarios provided should reflect the main uncertainties about climate change-related variables (e.g. SLR, but also changes in storm patterns) as well as about socioeconomic developments.
2) The analysis of potential future risks, vulnerabilities, threats and impacts (associated to the risks of coastal erosion and coastal flooding / overtopping inundations) should include an examination of critical thresholds / tipping-points – i.e. it should encompass the identification of ATPs that might be disruptive for the existing coastal defence system, or for existing or proposed measures – e.g. critical values of flood heights or loss of sediments which will be disruptive or unacceptable. Initially, such

analysis could be carried in an independent way from the analysis (or generation) of plausible future scenarios, in order to be less ‘scenario-dependent’, and then, the ATPs identified could be assessed under different plausible future scenarios to detect when they might be reached (i.e. their moment in time in each scenario). Although the identification of ATPs is not always easy and straightforward, such ATPs might be identified in terms of physical limits of the existing systems, or spatial limits (e.g. an area can erode up to a certain line, and then a new measure is needed, or a flood is acceptable once every X years up to the road Y, and then a new measure is needed). The identification of ATPs naturally leads to the need to explore possible solutions and design pathways (even in the case of incremental measures or measures that are implemented in a phased way, like, for example, beach nourishments). Once an ATP is in sight, a new or additional measure is required.

3) The APs approach is a useful method that allows developing ‘*robust and flexible set(s) of measures*’ (each set is a pathway, i.e. a strategy). It can be employed in a quick and simple way, and for different spatial scales, as demonstrated by the TE2100 and DP2014 cases. The POCs would highly benefit from the application of this method for exploring possible strategies (and assessing their *robustness* and *flexibility*) up to the long-term (2100, and even beyond it). The use of the APs approach would not only allow widening the range of strategies viable into the future, but also contribute to enhance the POCs’ *adaptability* – embedding both *dynamic robustness* and *flexibility* in its strategies – in the face of uncertain future changes over time. Examples of maps of adaptation pathways that could be developed for different coastal stretches (by using the APs method) were provided in the section of analysis of the presence of the 3rd key-element in the selected POCs. The anticipated planning of different possible pathways / routes would increase the POCs’ *adaptability*, but also their longevity (sustainability) as a long-term plan for coastal risk management / coastal adaptation and coastal spatial planning.

4) It is necessary to further develop the monitoring and revaluation system in each POC. Such system should include other important indicators (e.g. climate change-related variables like SLR and changes in storm patterns), and should specify trigger-values or decision-points (in function of the critical thresholds / ATPs that are previously identified). Moreover, it is extremely important that the monitoring and reassessment system keeps track of new / updated scenarios of climate change and socioeconomic development (or related parameters) that might emerge over time. It is important to ensure the absorption of new knowledge and information produced in and outside the monitoring system, into the reassessments of the POC and its contents. The specification of trigger-values and decision-moments would be useful to detect when it is necessary to make a decision – e.g. change a measure, or activate a new one, or postpone / anticipate a measure, and which measure should be taken.

5) Regarding the 5th key-element, it is important to ensure that the main steps of the ongoing process of APM are followed. Experience shows that, most often, monitoring and reassessment are dismissed or insufficient. It will be crucial to avoid a discontinuity of feedbacks between the monitoring system and the POCs’ adaptations / adjustments (and new cycles of re-planning of measures or pathways). To avoid such discontinuity and streamline the adaptations of the POCs that might be needed in the future (without the need to completely or integrally review the POCs or their contents), it is important that the Plan embeds, as soon as possible, the necessary *robustness* and *flexibility* (e.g. by anticipately planning possible future measures and keeping viable options open), and a well-designed monitoring and reassessment system that allows quick and easy adaptations of the POCs.

With respect to the potential feasibility of Adaptive Planning approaches in spatial planning instruments used in coastal zones, it is also important to highlight that the five key-elements identified in this work as essential to build a *dynamic adaptive plan* and required in an Adaptive Planning approach are themselves ‘flexible / elastic’ enough to receive additional inputs (e.g. sub-elements or additional ingredients) that might contribute to increase the *dynamic robustness* and *adaptability* of the plan (or of the planning and management approach) – and thus, to make it more *sustainable* (to survive change) – or which stem from their adjustment (adequacy) to the context of application. Notwithstanding, the five elements identified seem to be keystones that must be ensured to develop a *dynamic adaptive plan* and are at the core of the recent approaches of Adaptive Planning. They seem to be primary ingredients essential in any case. Nevertheless, a wider exploration of other cases of application of Adaptive Planning approaches is needed to deepen the debate on the key-elements.

Regarding the Portuguese cases, although there were already several guidance documents and references, at the national level, on ‘adaptive planning and / or management’, and on climate adaptation, that contained guidelines directly or indirectly related with the key-elements outlined in Part A, such guidance information was not fully absorbed in the new POCs. There was a lack of integration of already existent guidance into the elaboration of the POCs, though APA is the entity that was responsible for both tasks – steering the elaboration of POCs and providing and disseminating information about coastal climate adaptation and planning tools and methods to support it. This points to an hindrance / barrier to the introduction of Adaptive Planning approaches in the Portuguese coastal planning and management instruments: the lack of incorporation of new guidance into reviewed or new plans / policy programmes, and the lack of systematization and dissemination of all guidance information already existent on Adaptive Planning and Management approaches (how they work, for what purposes can be used, their value and reasons to use them, their key-elements / requisites, the process of steps involved, etc.). There has been an evident lack of provision of clear (simple and quick) information about the Adaptive Planning paradigm, its key-elements and process – to the Project Teams charged of the elaboration of the POCs, on one hand, because, in the Portuguese context, not all the information necessary about Adaptive Planning approaches is gathered and available (including e.g. examples of application of such approaches), and, on the other hand, because the information available is not well organized.

Regarding the barriers to the application of Adaptive Planning approaches in the Portuguese cases, further analysis is needed on whether (and to which extent) the regulatory character that is required in the POCs constitutes a hindrance to an Adaptive Planning and Management, as laws (regulations and norms) are usually devised to be *stable*, and it is often difficult to adjust them regularly or in function of changing risks and uncertain future conditions and changes. This may deeply hamper the adaptation of the entire Plan and, particularly, of its Directives and Strips of Safeguard from Coastal Risks, over time, and in space. The regulatory content of spatial plans (like the POCs) is devised to be steady and reliable over time, and not so much ‘dynamic’ (laws and rules cannot be constantly changed). Thus, in the Portuguese context, the POCs may run the risk of becoming ‘stick’ and too rigid and fixed in time and in space, and not following or matching the pace and nature of changing coastal risks and their expected future changes (associated with climate change) and the intrinsic dynamism and variability of coastal environments. Although there is a recognized difficulty in changing and adapting Plans / Programmes over time, especially their normative content, the POCs must become *dynamic* and *adaptive* enough to ‘survive’ to unexpected future changes and do not ‘perish’ (e.g. be replaced by completely new programmes or plans). Ideally, there should be a common thread that links the options of current POCs to the options of the future POCs, as these are reviewed and adapted. In this sense, the APs approach can become a quite useful tool to plan ahead such possible routes.

Finally, further research and work are needed on the following issues:

- Why an Adaptive Planning approach has not yet been applied in the POCs, despite the intention of doing so (further explore the barriers and hindrances that hamper its application)?

- What scope is there for taking an *adaptive coastal planning* forward in the selected port-cities? How will it be viable to introduce and apply an Adaptive Planning and Management approach (including the APs' method) in the selected cases? What enablers could help to overcome or attenuate the identified barriers and contribute to the operationalization of APM.
- How can APs approach be integrated and applied in the planning instruments of the selected port-cities (e.g. in POCs), as a means to support and operationalize long-term coastal climate adaptation processes – their planning and implementation under uncertainty about future changes?
- What modifications would be necessary to implement an Adaptive Planning approach, including APs, into these planning instruments, what implications and repercussions might this have, e.g., in the current regulatory framework and planning system?

References

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson D, Naess L, Wolf J and Wreford A (2009) Are there social limits to adaptation to climate change? *Climate Change* 93(3): 335–354.

Aerts JC and Botzen WJ (2011) Flood-resilient waterfront development in New York City: Bridging flood insurance, building codes, and flood zoning. *Annals of the New York Academy of Sciences* 1227(1): 1–82.

Aguiar GD (2013) The processes and recent trends in the spatial restructuring of port cities of the Canary Islands and Madeira as cruise destinations. *PORTUS Plus - the jornal* 1 (5): 12

Aiken C, Chase N, Hellendrung J and Wormser J (2014) Designing with water creative solutions from around the globe. The Boston Harbour Association. Available at: http://www.bostonharbornow.org/wp-content/uploads/2017/02/PRT2-Designing-with-Water_Ex-Summary.pdf (accessed 10 October 2016).

AIVP – Association Internationale de Villes et Ports (2015) Plan the City with the Port: Guide of Good Practices. Available at: http://www.aivp.org/es/2015/06/30/hacer-la-ciudad-con-el-puerto-guia-de-buenas-practicas/ (accessed 20 October 2016).

Akhavan M (2017) Development dynamics of port-cities interface in the Arab Middle Eastern world - The case of Dubai global hub port-city. *Cities* 60: 343–352.

Alemany J (2015a) Incidencia del puerto en la ciudad. La experiencia latinoamericana de renovación de los waterfronts. *Revista de Transporte y Territorio* 12: 70–86. ISSN 1852-7175. Available at: http://www.redalyc.org/pdf/3330/333039205005.pdf (accessed 20 June 2016).

Alemany J and Bruttomesso R (2015) Editorial. Problemas y oportunidades de las ciudades portuarias. *PORTUS*: *the online magazine of RETE*, June, 27.

Alphen, J. Van (2015). The Delta Programme and updated flood risk management policies in the Netherlands. Journal of Flood Risk Management 9.

Andrade MJ and Sierra AP (2014) Motores y tendencias de cambio en la ciudad portuaria. Mapping 2035. Reflexiones. *PORTUS: the online magazine of RETE*, May, 27. Year XIV. ISNN 2282-5789.

APA. 2013 a. *Relatório de Progresso Estratégia Nacional de Adaptação às Alterações Climáticas*. APA. Amadora. setembro de 2013

APA. 2013 b. *Sessão Pública de apresentação dos resultados da 1ª fase da Estratégia Nacional de Adaptação às Alterações Climáticas*. APA, 1 de outubro de 2013

APA. 2021 a. *Adaptação às Alterações Climáticas*. Available at: https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118

APA. 2021 b. *A Estratégia Nacional de Adaptação às Alterações Climáticas 2020*. Available at: https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=955

APA. 2021 c. *Estratégia Nacional de Adaptação às Alterações Climáticas - Fase 1. A resposta do Governo Português aos desafios da adaptação*. Available at: https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=391

APA. 2021 d. *Adaptação às Alterações Climáticas. A resposta a um acumular de evidências*. Available at: https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=392

APA. 2021 e. *Adaptação em Portugal. Escala Local*. Available at: https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=395

APA. 2021 f. *Guião para Empresas e Sectores - Ferramenta para facilitar a adopção de medidas de adaptação*. Available at: https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=394

APA. 2021 g. *O Clima em Portugal O Clima em Portugal*. Available at: https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=393

Barnett J, Waters E, Pendergast S and Puleston A (2013) *Barriers to adaptation to sea-level rise: The legal, institutional and cultural barriers to adaptation to sea-level rise in Australia*. National Climate Change Adaptation Research Facility, Gold Coast, 85 pp.

Barnett J, Graham S, Mortreux C, Fincher R, Waters E and Hurlimann A (2014). A local coastal adaptation pathway. *Nature Climate Change* 4(12): 1103–1108.

Barnett J and O'Neill S (2010) Maladaptation. *Global Environmental Change* 20(2): 211–213.

Barron S, Canete G, Carmichael J, Flanders D, Pond E, Sheppard S and Tatebe K (2012) A climate change adaptation planning process for low lying communities vulnerable to sea level rise. *Sustainability* 4(9): 2176–2208.

Bautista E, Hanhardt E, Osorio JC and Dwyer N (2015) New York City Environmental Justice Alliance Waterfront Justice Project. *Local Environment* 20(6): 664–682.

Becker AH, Matson P, Fischer M and Mastrandrea MD (2015) Towards Seaport Resilience for climate change adaptation: Stakeholder perceptions of hurricane impacts in Gulfport (MS) and Providence (RI). *Progress in Planning* 99: 1–49.

Becker A, Newell D, Fischer M and Schwegler B (2011) Will Ports Become Forts? Climate Change Impacts, Opportunities, and Challenges. *Terra et Aqua* 122: 11–17.

Biesbroek GR, Swart RJ, Carter TR, Cowan C, Henrichs T, Mela H, Morecroft MD and Rey D (2010) Europe adapts to climate change: comparing national adaptation strategies. *Global environmental change* 20(3): 440–450.

Bloemen, P., Reeder, T., Zevenbergen, C., Rijke, J., & Kingsborough, A. (2018). Lessons learned from applying adaptation pathways in flood risk management and challenges for the further development of this approach. *Mitigation and adaptation strategies for global change*, *23*(7), 1083-1108.

Blok A and Tschötschel R (2016) World port cities as cosmopolitan risk community: Mapping urban climate policy experiments in Europe and East Asia. *Environment and Planning C: Government and Policy* 34(4): 717–736.

Boland P, Bronte J and Muir J (2016) On the waterfront: Neoliberal urbanism and the politics of public benefit. *Cities* 61: 117–127.

Bolleter J (2014) Charting a Changing Waterfront: A Review of Key Schemes for Perth's Foreshore. *Journal of Urban Design* 19(5), 569–592.

Bordato L and Sánchez MP (2015) Desarrollo sostenible de los Puertos y Ciudades Portuarias Medianas. Una investigación necesaria para el futuro del Mediterráneo. *PORTUS: the online magazine of RETE* 29. June, Year XV, Venice, RETE Publisher.

Boschken HL (2013) Global Cities Are Coastal Cities Too: Paradox in Sustainability? *Urban Studies* 50(9): 1760–1778.

Brown S, Nicholls RJ, Hanson S, Brundrit G, Dearing JA, Dickson ME, Gallop S, Gao S, Haigh ID, Hinkel J, Jiménez JA, Klein RJ, Kron W, Lázár AN, Neves CF, Newton A, Pattiaratachi C, Payo A, Pye K, Sánchez-Arcilla A, Siddall M, Shareef A, Tompkins EL, Vafeidis A, Maanen BV, Ward PJ and Woodroffe CD (2014) Shifting perspectives on coastal impacts and adaptation. *Nature Climate Change* 4(9); 752–755.

Brugge, R. van der, & Roosjen, R. (2015). An institutional and socio-cultural perspective on the adaptation pathways approach. *Journal of Water and Climate Change*, *6*(4), 743-758.

Brugge, Rutger Van der; and Bruggeman, Willem. Delta fact: Delta scenarios and Adaptive Delta Management. Available at: http://deltaproof.stowa.nl/pdf/Delta_scenarios_and_Adaptive_Delta_Management?rId=80 Consulted: 2019.05.21

Bruun, P. 1962. Sea-level rise as a cause of shore erosion. Jour. of the Wat. and Harb. Div. 88, 117-130.

Bruttomesso R (2009) Transformations in the contemporary port landscape: from negotium to otium…and back to negotium, again. *PORTUS: the online magazine of RETE* 18.

Bunce S and Desfor G (2007) Introduction to Political ecologies of urban waterfront transformations. *Cities* 24(4): 251–258.

Buuren, Arwin Van, Gerald Jan Ellen, and Jeroen F. Warner. (2016) "Path-dependency and policy learning in the Dutch delta: toward more resilient flood risk management in the Netherlands?." *Ecology and Society* 21.4 (2016).

Buuren, A. Van, Driessen, P. J., van Rijswick, M., Rietveld, P., Salet, W., Spit, T., & Teisman, G. (2013). *Towards adaptive spatial planning for climate change: Balancing between robustness and flexibility*. Journal for European Environmental and Planning Law, 10(1), 29–53.

Burton I (2004) *Climate change and the adaptation deficit*. Adaptation and Impacts Research Group, Meteorological Service of Canada, Environment Canada.

Busquets, Joan (2013) Old Ports, new ideas: two cycle design. *Portus: the online maganize of RETE*, June, 25.

Campos I, Vizinho A, Coelho C, Alves F, Truninger M, Pereira C, Santos FD and Lopes GO (2016) Participation, scenarios and pathways in long-term planning for climate change adaptation. *Planning Theory & Practice* 17(4): 537–556.

CEZCM / APRH (Comissão Especializada das Zonas Costeiras e do Mar, da Associação Portuguesa de Recursos Hídricos). 2020. Interview to the President and Vice-President of the Portuguese Environment Agency (APA) of 16 July 2020. Available at: https://www.aprh.pt/en/glossario/26-areas-tematicas/comissoes-especializadas. Entrevista da CEZCM a Nuno Lacasta, Presidente da APA e a José Pimenta Machado, Vice-Presidente da APA. *Desafios para a Adaptação do Litoral às Alterações Climáticas; O papel dos portos portugueses na economia nacional e a respetiva estratégia para o futuro próximo (até 2030); Monitorização dos processos costeiros: resposta possível num cenário de incerteza e base para soluções inovadoras de defesa.*

CEZCM / APRH (Comissão Especializada das Zonas Costeiras e do Mar, da Associação Portuguesa de Recursos Hídricos). 2020 b. *Desafios para a Adaptação do Litoral às Alterações Climáticas*. 23/10/2020. Available at: https://www.aprh.pt/en/glossario/26-areas-tematicas/comissoes-especializadas

CEZCM / APRH (Comissão Especializada das Zonas Costeiras e do Mar, da Associação Portuguesa de Recursos Hídricos). 2020 c. *O papel dos portos na economia nacional e a respectiva estratégia para o futuro próximo (até 2030)*. Available at: https://www.aprh.pt/en/glossario/26-areas-tematicas/comissoes-especializadas

CEZCM / APRH (Comissão Especializada das Zonas Costeiras e do Mar, da Associação Portuguesa de Recursos Hídricos). 2020 d. *Monitorização dos processos costeiros: resposta possível num cenário de incerteza e base para soluções inovadoras.* Available at: https://www.aprh.pt/en/glossario/26-areas-tematicas/comissoes-especializadas

Chapapría VE (2014) Cambio y crisis, puertos del mañana. *PORTUS: the online magazine of RETE*, May, 27.

Chapapría VE (2015) Effectos de las nuevas obras de Suez y Panamá sobre los puertos y ciudades. *PORTUS: the online magazine of RETE*, October, 30.

Chemrouk O and Chabbi N (2016) Vulnerability of Algiers Waterfront and the New Urban Development Scheme. *Procedia Engineering* 161: 1417–1422.

Cittá d'Acqua (2000) 10 principios para un desarrollo sostenible de las áreas de los waterfronts urbanos. Declaración elaborada con Wasserstad GMBH. In: *Global Conference on the Urban Future* (ed URBAN 21), Berlin, Germany, 4–6 July 2000. Available at: https://www.oas.org/cip/docs/areas_tecnicas/8_rel_ciudad_puerto/3_principios%20_waterfront.pdf (accessed 10 September 2016).

Clarke B, Tually S and Scott M (2016) Social networks and decision-making for coastal land-use planning, development and adaptation response. *Australian Journal of Maritime & Ocean Affairs* 8(2): 101–116.

ClimAdaPT. 2015. Guia Metodológico para Elaboração de Estratégias Municipais de Adaptação às Alterações Climáticas. ClimAdaPT.Local. janeiro 2015. Available at: https://www.apambiente.pt/_zdata/Alteracoes_Climaticas/Adaptacao/20190327/0ClimAdaPTLocalManualGuiaMetodologico.pdf

Coleman L (2011) Making Soft Infrastructures a Reality in New York City: Incorporating Unconventional Storm Defenses Systems as Sea Levels Rise. *William & Mary Environmental Law and Policy Review* 36(2): 529–563.

Creswell JW (2003) *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications.

DC (Delta Commission / Deltacommissie) (2008) Working together with water - A living land builds for its future. (Findings of the Delta Commission 2008), 138 pp. Available at: http://www.deltacommissie.com/doc/deltareport_full.pdf (accessed 17 March 2017). ||| Deltacommissie. 2008. Samen Werken Met Water _ Een Land Dat Leeft, Bouwt Aan Zijn Toekomst. Bevindingen van de Deltacommissie. http://www.deltacommissie.com/doc/2008-09-03Advies Deltacommissie.pdf

DL Decree-law / Decreto-Lei n.º 159/2012. Available at: https://dre.pt/pesquisa/-/search/179368/details/maximized

DL Decree-law / Decreto-Lei n.º 132/2015. Available at: https://dre.pt/home/-/dre/69773249/details/maximized

DL Decree-law / Decreto-Lei n.º 80/2015. *Regime Jurídico dos Instrumentos de Gestão Territorial*. Available at: https://dre.pt/pesquisa/-/search/67212743/details/maximized

Dean, R.G., Kriebel, D. e Walton, T. 2008. Cross-shore sediment processes. *In:* Walton e King (editors). Coastal Engineering Manual. Part III - Coastal sediment processes. Chapter 111-3.1110-2-1100 USACE. Washington, DC.

Defra (2006). *Flood and Coastal Defence Appraisal Guidance: FCDPAG3 Economic Appraisal; Supplementary Note to Operating Authorities – Climate Change Impacts*, Defra, London. October 2006.

DEHP – Department of Environment and Heritage Protection – Queensland Government (2013) Guideline for preparing a Coastal Hazard Adaptation Strategy. Available at: http://www.ehp.qld.gov.au/coastalplan/coastalhazards.html#guideline_for_preparing_a_coastal (accessed 1 October 2016).

Deltares. Brochure Adaptive Delta Management. Deltares – Enaling Delta Life. Available at: https://www.deltares.nl/app/uploads/2014/11/Brochure-Adaptive-Delta-Management.pdf Consulted in 2018-05-08.

Dessai, S., & van der Sluijs, J. P. (2007). *Uncertainty and climate change adaptation: A scoping study*. Copernicus Institute for Sustainable Development and Innovation, Department of Science Technology and Society.

DP Delta Programme. 2010. The 2011 Delta Programme. Working on the delta. Investing in a safe and attractive Netherlands, now and in the future. Dutch Ministry of Transport, Public Works and Water Management; Ministry of Agriculture, Nature and Food Quality; Ministry of Housing, Spatial Planning and the Environment. September 2010. Available at: https://english.deltacommissaris.nl/delta-programme/documents/publications/2010/09/14/2011-delta-programme (accessed 2018.10.19).

DP Delta Programme. 2011. *The Delta Programme 2012. Working on the Delta. Acting today, preparing for tomorrow*. Ministry of Infrastructure and the Environment; Ministry of Economic Affairs, Agriculture and Innovation. September 2011. Available at: https://english.deltacommissaris.nl/delta-programme/documents/publications/2011/09/20/deltaprogramme-2012 (accessed 2018.10.19).

DP Delta Programme. 2012. *The Delta Programme 2013. Working on the delta. The road towards the Delta Decisions*. Ministry of Infrastructure and the Environment; Ministry of Economic Affairs, Agriculture and Innovation. September 2012. Available at: https://english.deltacommissaris.nl/delta-programme/documents/publications/2012/09/18/delta-programme-2013 (accessed 2018.10.19).

DP Delta Programme. 2013. *Delta Programme 2014: Working on the delta: Promising solutions for tasking and ambitions*. Dutch Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs. Available at: https://english.deltacommissaris.nl/documents/publications/2013/09/17/delta-programme-2014 (2018.10.19).

DP Delta Programme. 2014. *Delta Programme 2015: Working on the delta: The decisions to keep the Netherlands safe and liveable*. Dutch Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs. Available at: https://english.deltacommissaris.nl/documents/publications/2014/09/16/delta-programme-2015 (2018.10.19).

DP Delta Programme. 2016. *The Delta Programme 2017. Work on the delta. Linking taskings, on track together*. Ministry of Infrastructure and the Environment; Ministry of Economic Affairs. September 2016. Available at: https://english.deltacommissaris.nl/delta-programme/documents/publications/2016/09/20/dp2017-en-printversie (2018.10.19).

DP Delta Programme. 2017. *The Delta Programme 2018. Continuing the work on a sustainable and safe delta.* Ministry of Infrastructure and the Environment; Ministry of Economic Affairs. September 2017. Available at: https://english.deltacommissaris.nl/delta-programme/documents/publications/2017/09/19/dp2018-en-printversie (2019.02.19).

DP Delta Programme. 2018. *The Delta Programme 2019. Continuing the work on the delta: adapting the Netherlands to climate change in time.* Ministry of Infrastructure and Water Management; Ministry of Agriculture, Nature, and Food Quality; Ministry of the Interior and Kingdom Relations. September 2018. Available at: https://english.deltacommissaris.nl/documents/publications/2018/09/18/dp2019-en-printversie (2019.06.19).

Desfor G and Laidley J (2011) Changing Urban Waterfronts: A Fixity and Flow Perspective. *PORTUS: the online magazine of RETE*, 21. Available at: http://retedigital.com/wp-content/themes/rete/pdfs/PORTUS_plus/1_2011/Tem%C3%A1ticas/La_recalificaci%C3%B3n_de_los_waterfront/04_GeneDesfor_JenneferLaidley.pdf (accessed 20 October 2016).

Dias JA, Freire P, Freitas C, Klein A and Silva P (2011) Importância do conhecimento sobre a morfodinâmica estuarina e costeira para a gestão do litoral. *Revista de Gestão Costeira Integrada –Journal of Integrated Coastal Zone Management* 11(3): 271–272.

Diedrich L, Kahn A and Lindholm G (2016) Beyond Best Practice. Re-valuing mindsets and models in harbour transformation. *PORTUSplus: the online Journal of RETE*, 6. Year VI RETE Publisher, Venice, ISSN: 2039-6422.

Dronkers J, Gilbert TE, Butler LW, Carey JJ, Campbell J, James E, McKenzie C, Misdorp R, Quin N, Ries KL, Schroder PC, Spradley JR, Titus JG, Vallianos L and Dadelszen JV (1990). Strategies for adaption to sea level rise. Report of the IPCC Coastal Zone Management Subgroup: Intergovernmental Panel on Climate Change. Geneva: Intergovernmental Panel on Climate Change.

Ducruet C (2011) The port city in multidisciplinary analysis. In: Alemany J and Bruttomesso R (eds) *The port city in the XXI^st^ century: New challenges in the relationship between port and city*. RETE, pp.32–48. Available at: https://halshs.archives-ouvertes.fr/halshs-00551208/document (accessed in 5 June 2016).

Ducruet C (2013a) The World Seastems project (2013-2018). *PORTUS*: the online *magazine of RETE*, November 2013, 26.

Ducruet C (2013b) Waterfront redevelopment: the fragility of local benefits. *PORTUS: the online magazine of RETE*, June 2013, 25, Year XIII, Venice, RETE Publisher, ISSN 2282-5789.

Ducruet C and Lee S (2006) Frontline soldiers of globalization: Port-city evolution and regional competition. *Geojournal* 67(2): 107–122.

Dyckamn C, John CS and London JB (2014) Realizing managed retreat and innovation in state-level coastal management planning. *Ocean & Coastal Management* 102: 212–223.

Dynamic Adaptive Policy Pathways: supporting decision-making under uncertainty using Adaptation Tipping Points and Adaptation Pathways in policy analysis (sem data). Haasnoot, Marjolijn and Jeuken, Ad. Available at: https://webcache.googleusercontent.com/search?q=cache:2EbeEPoJ8zsJ:https://www.deltares.nl/en/adaptive-pathways/+&cd=1&hl=pt-PT&ct=clnk&gl=pt. Consulted in 2018-05-08

Dyson K and Yocom K (2015) Ecological design for urban waterfronts. *Urban ecosystems* 18(1): 189–208.

Eakin HC and Patt A (2011) Are adaptation studies effective, and what can enhance their practical impact? *Wiley Interdisciplinary Reviews: Climate Change* 2(2): 141–153.

Ekstrom JA and Moser SC (2014) Identifying and overcoming barriers in urban climate adaptation: Case study findings from San Franscisco Bay Area, California, USA. *Urban Climate* 9: 54–74.

ENAAC. 2010. Estratégia Nacional de Adaptação às Alterações Climáticas 2020. Resolução do Conselho de Ministros n.º 24/2010, de 1 de abril de 2010.

ENGIZC 2009. Estratégia Nacional de Gestão Integrada da Zona Costeira (ENGIZC). Resolução do Conselho de Ministros nº 82/2009, de 8 de setembro de 2009.

ESAAC-RH. 2013. Estratégia Setorial de Adaptação aos impactos das Alterações Climáticas relacionados com os Recursos Hídricos. APA.

Environment Agency (2009) *TE2100 Flood Risk Management Plan: Technical Report*, Main Report and Appendices A to L, TE2100 Project Team, Environment Agency, September 2009

EA – Environment Agency (2012) *Managing Flood Risk through London and the Thames Estuary: TE2100 Plan*. Thames Estuary 2100, Environment Agency, London, UK, 230 pp. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/322061/LIT7540_43858f.pdf (accessed 23 June 2017). Available at: https://www.gov.uk/government/publications/thames-estuary-2100-te2100 https://brand.environment-agency.gov.uk/mb/CtyxlR

EA (Environment Agency). 2016. TE2100 5-Year Monitoring Review

EA (Environment Agency) (2017) Policy paper: Thames Estuary 2100 (TE2100), Updated 2 March 2017. Available at: https://www.gov.uk/government/publications/thames-estuary-2100-te2100 (accessed in 20 July 2017).

Esteves LS (2014) *Managed Realignment: A viable long-term coastal management strategy?* Springer Briefs in Environmental Science. New York: Springer.

Fankhauser S and McDermott TJ (2014) Understanding the adaptation deficit: why are poor countries more vulnerable to climate events than rich countries? *Global Environmental Change* 27: 9–18.

Fincher R, Barnett J, Graham S and Hurlimann A (2014) Time stories: Making sense of futures in anticipation of sea-level rise. *Geoforum* 56: 201–210.

Flood S and Schechtman J (2014) The rise of resilience: Evolution of a new concept in coastal planning in Ireland and the US. *Ocean & Coastal Management* 102: 19–31.

Ford JD, Berrang-Ford L and Paterson J (2011) A systematic review of observed climate change adaptation in developed nations. *Climatic change* 106(2): 327–336.

Francesch-Huidobro M, Dabrowski M, Yuting T, Chan F and Stead D (2016) Governance challenges of flood-prone delta cities: Integrating flood risk management and climate change in spatial planning. *Progress in Planning* 114: 1–27.

Galland D and Hansen CJ (2012) The roles of planning in waterfront redevelopment: From plan-led and market-driven styles to hybrid planning? *Planning Practice and Research* 27(2): 203–225.

Geels, F. W. 2004. From sectoral systems of innovation to sociotechnical systems: insights about dynamics and change from sociology and institutional theory. *Research Policy* 33 (6-7):897-920. http://dx.doi.org/10.1016/j.respol.2004.01.015

Gerrits, L., and P. Marks. 2008. Complex bounded rationality in dyke construction: path-dependency, lock-in in the emergence of the geometry of the Zeeland delta. *Land Use Policy* 25(3):330-337. http://dx.doi.org/10.1016/j.landusepol.2007.09.001

Gersonius, B., Rijke, J., Ashley, R., Bloemen, P., Kelder, E., & Zevenbergen, C. (2016). Adaptive Delta Management for flood risk and resilience in Dordrecht, The Netherlands. *Natural hazards*, *82*(2), 201-216.

Giovinazzi O (2015) Rethinking the port landscape. Interpretations and contemporary visions. Portus: the online magazine of RETE, October, 30. Year XV, Venice, RETE Publisher, ISSN 2282-5789.

Giovinazzi O and Giovinazzi S (2008) *Waterfront planning: a window of opportunities for post-disaster reconstruction*. Available at: https://ir.canterbury.ac.nz/handle/10092/3987

Graham S, Barnett J, Fincher R, Mortreux C and Hurlimann A (2015). Towards fair local outcomes in adaptation to sea-level rise. *Climatic Change* 130(3): 411–424.

Graham S, Barnett J, Fincher R, Hurlimann A and Mortreux C (2014). Local values for fairer adaptation to sea-level rise: A typology of residents and their lived values in Lakes Entrance, Australia. *Global Environmental Change* 29: 41–52.

Gray S, O'Mahony C, Hills J, O'Dwyer B, Devoy R and Gault J (2016) Strengthening coastal adaptation planning through scenario analysis: A beneficial but incomplete solution. *Marine Policy*. Epub ahead of print 4 May 2016. https://doi.org/10.1016/j.marpol.2016.04.031

Greenport (2016). Balancing Environmental Challenges with Economic Demands. Available at: http://www.greenport.com/ (accessed July 2016).

Griggs GB (2005) California's retreating coastline: where do we go from here. 85th AMS Annual Meeting, American Meteorological Society - Combined Preprints.

GTL (Grupo de Trabalho do Litoral). 2014. *Gestão da Zona Costeira - O Desafio da Mudança - Relatório do Grupo de Trabalho do Litoral.* Dezembro de 2014

GTL (Grupo de Trabalho do Litoral). 2014 b. *Sumário Executivo e Recomendações – Relatório do Grupo de Trabalho do Litoral*. 10 de Novembro de 2014.

Guimarães FJ (2006) *Cidade Portuária, o Porto e as suas Constantes Mutações*. Colecção Expoentes. Edição Parque Expo. ISBN:972-8106-36-X

Haasnoot, M. (2013). Anticipating Change: Sustainable Water Policy Pathways for an Uncertain Future. PhD Thesis. Utrecht, Utrecht University. UT Twente. ISBN 978-90-365-3559-5

Haasnoot M, Kwakkel JH, Walker WE and ter Maat J (2013) Dynamic adaptive policy pathways: a method for crafting robust decisions for a deeply uncertain world. *Global environmental change* 23(2): 485–498. DOI: 10.1016/j.gloenvcha.2012.12.006

Haasnoot M, Middelkoop H, Offermans A, Van Beek E and Van Deursen WA (2012) Exploring pathways for sustainable water management in river deltas in a changing environment. *Climatic Change* 115(3-4):795–819.

Haasnoot, M., Middelkoop, H., van Beek, E., van Deursen, W.P.A., 2011. A method to develop sustainable water management strategies for an uncertain future. Sustainable Development 19, 369–381.

Haasnoot, Marjolijn and Jeuken, Ad. (no date, online). Dynamic Adaptive Policy Pathways: supporting decision-making under uncertainty using Adaptation Tipping Points and Adaptation Pathways in policy analysis. Haasnoot, Marjolijn and Jeuken, Ad. Available at: https://webcache.googleusercontent.com/search?q=cache:2EbeEPoJ8zsJ:https://www.deltares.nl/en/adaptive-pathways/+&cd=1&hl=pt-PT&ct=clnk&gl=pt Consulted in 2018-05-08

Haegen, Melanie Schultz Van, and Koos Wieriks. 'The Deltaplan revisited: changing perspectives in the Netherlands' flood risk reduction philosophy'. *Water Policy* 17.S1 (2015): 41-57.

Haegen, Melanie Schultz Van. 2014. 'The Deltaplan revisited: changing perspectives in the Netherlands' flood risk reduction philosophy'. Powerpoint presentation 2014-10-17. HELP-Washington. Ministerie van Infrastructuur en Milieu.Available at: http://www.wateranddisaster.org/cms310261/wp-content/uploads/2014/11/6-3.-Netherlands_141012-Changing-perspectives-MSvH-HELP.pdf. Consulted in 2018.09.20.

Hall PV (2007) Seaports, urban sustainability, and paradigm shift. *Journal of Urban Technology* 14(2): 87–101.

Hallegatte S, Ranger N, Mestre O, Dumas P, Corfee-Morlot J, Herweijer C and Wood RM (2011) Assessing climate change impacts, sea level rise and storm surge risk in port cities: a case study on Copenhagen. *Climatic Change* 104(1):113–137.

Hansen HS (2010) Modelling the future coastal zone urban development as implied by the IPCC SRES and assessing the impact from sea level rise. *Landscape and Urban Planning* 98(3):141–149.

Hanson S, Nicholls R, Ranger N, Hallegatte S, Corfee-Morlot J, Herweijer C, Chateau J (2011) A global ranking of port cities with high exposure to climate extremes. *Climatic Change* 104(1):89–111.

Hanson, Susan, and Robert J. Nicholls. "Chapter 2 – Planning for changes in extreme events in port cities throughout the 21st century." (2012): 9-26. in Aerts, J., Botzen, W., Bowman, M., Dircke, P., & Ward, P. (2013). *Climate adaptation and flood risk in coastal cities*. Routledge.

Hein C (2016a) Port cities and urban waterfronts: how localized planning ignores water as a connector. *Wiley Interdisciplinary Reviews: Water* 3(3):419–438.

Hein C (2016b) Port cityscapes: conference and research contributions on port cities. *Planning Perspectives* 31(2): 313–326.

Hein C (2016c) Japanese Cities in Global Context. *Journal of Urban History* 42(3): 463–476.

Hein C (2015) Temporalities of the port, the waterfront and the Port City. *Portus: the online magazine of RETE* 29: 1–8.

Hein C (2014) Port cities and urban wealth: between global networks and local transformations. *International Journal of Global Environmental Issues* 13(2–4): 339–361.

HM Treasury (Treasury, Her Majesty'S). "Accounting for the effects of climate change: Supplementary green book guidance." *HM Treasury, Department for Environment Food and Rural Affairs, Pubs, London* (2009).

Holling CS (1978) *Adaptive Environmental Assessment and Management*. A Wiley – Interscience Publication, The Wiley IIASA International Series on Applied Systems Analysis, Vol. 3, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, and John Wiley and Sons, Chichester, UK and New York, NY, USA, 377 pp.

Hoyle B (2000a) Global and local change on the port-city waterfront. *Geographical Review* 90(3): 395–417.

Hoyle B (2000b) Port city renewal in developing countries: a study of East African waterfronts. Available at: https://eprints.soton.ac.uk/362435/1/1561513-1001.pdf (accessed 20 n 2016).

Hoyle B (1998) Cities and Ports: Concepts and issues. *Vegueta: Anuario de la Facultad de Geografía e Historia* 3: 263–278

Hoyle B and Pinder D (1980) *Cityport industrialization and regional development: spatial analysis and planning strategies.* Elsevier Science & Technology.

Hoepffner N, Dowell MD, Edwards M, Fonda-Umani S, Green DR, Greenaway B, Hansen B, Heinze C, Leppänen JM, Lipiatou E, Özsoy E, Philippart K, Salomons W, Sanchez-Arcilla A, Schrimpf W, Schrum C, Theocharis A, Tsimplis M, Veloso-Gomes F, Wakenhut F and Zaldivar JM (2006) *Marine and Coastal Dimension of Climate Change in Europe - A Report to the European Water Directors*. European Commission - Joint Research Centre, 104pp. ISBN 92-79-03747-1.

Huang-Lachmann J and Lovett JC (2015) How cities prepare for climate change: Comparing Hamburg and Rotterdam. *Cities* 54:36–44.

Hurlimann A, Barnett J, Fincher R, Osbaldiston N, Mortreux C, Graham S (2014) Urban Planning and sustainable adaptation to sea-level rise. *Landscape and Urban Planning* 126: 84–93.

Hurlimann A and March AP (2012) The role of spatial planning in adapting to climate change. *Wiley Interdisciplinary Reviews: Climate Change* 3(5): 477–488.

IPCC IAV (2014) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summaries, Frequently Asked Questions, and Cross-Chapter Boxes*. A Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR and White LL (eds). World Meteorological Organization, Geneva, Switzerland, 190 pp.

IPCC SR5 (2014) *Climate Change 2014: Synthesis Report*. *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IPCC SR4 (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

IPCC SMP (2014) Summary for policymakers. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR and White LL (eds) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32.

Isoard S, and Winograd M (2013) Adaptation in Europe. Addressing risks and opportunities from climate change in the context of socio-economic developments. EEA Report-3/2013. European Environment Agency, Copenhagen

Jeuken, A., Haasnoot, M., Reeder, T., & Ward, P. (2014). Lessons learnt from adaptation planning in four deltas and coastal cities. *Journal of Water and Climate Change*, *6*(4), 711-728.

Jeuken, A., & Reeder, T. (2011). Short-term decision making and long-term strategies: how to adapt to uncertain climate change. *Water Governance*, *1*(2011), 29-35.

Kabat P, Fresco LO, Stive MJF, Veerman CP, Van Alphen J, Parmet B, Hazeleger W and Katsman CA (2009) Dutch coasts in transition. *Nature Geoscience* 2(7): 450–452.

Klein RJ, Nicholls RJ and Mimura N (1999) Coastal adaptation to climate change: can the IPCC Technical Guidelines be applied? *Mitigation and adaptation strategies for global change* 4(3): 239–252.

Klijn, F., Kreibich, H., De Moel, H., & Penning-Rowsell, E. (2015). Adaptive flood risk management planning based on a comprehensive flood risk conceptualisation. *Mitigation and Adaptation Strategies for Global Change*, *20*(6), 845-864.

Klijn, F., Asselman, N. E., de Kruif, A., Bloemen, P. J., & Haasnoot, M. (2016). Implementing new flood protection standards: obstacles to adaptive management and how to overcome these. In *E3S Web of Conferences* (Vol. 7, p. 21003). EDP Sciences.

Kochnower, D., Reddy, S. M., & Flick, R. E. (2015). Factors influencing local decisions to use habitats to protect coastal communities from hazards. *Ocean & Coastal Management*, *116*, 277–290.

Kuijken, W., 2010, *The Delta Programme in the Netherlands: the Delta Works of the Future*, http://www.deltacommissaris.nl; http://www.deltacommissaris.nl/english/topics/ Access date 06-06-2018.

Kwadijk JC, Haasnoot M, Mulder JP, Hoogvliet M, Jeuken A, Van Der Krogt RA, Van Oostrom N, Schelfhout H, Van Velzen E, Van Waveren H and De Wit M (2010) Using adaptation tipping points to prepare for climate change and sea level rise: a case study in the Netherlands. *Wiley interdisciplinary reviews: climate change* 1(5): 729–740. DOI: 10.1002/wcc.64

Kwakkel, J.H., Walker, W.E., Marchau, V.A.W.J., 2010a. Adaptive airport strategic planning. European Journal of Transport and Infrastructure Research 10, 249–273.

Kwakkel, J. H., Haasnoot, M., & Walker, W. E. (2015). Developing dynamic adaptive policy pathways: a computer-assisted approach for developing adaptive strategies for a deeply uncertain world. *Climatic Change*, *132*(3), 373-386.

Kwakkel JH, Walker WE, Marchau VAWJ (2012) Assessing the efficacy of dynamic adaptive planning of infrastructure: results from computational experiments. Environment and Planning B: Planning and Design 39(3):533-550

Langridge SM, Hartge EH, Clark R, Arkema K, Verutes GM, Prahler EE, Stoner-Duncan S, Revell DL, Caldwell MR, Guerry AD, Ruckelshaus M, Abeles A, Coburn C and O'Connor K (2014). Key lessons for incorporating natural infrastructure into regional climate adaptation planning. *Ocean & Coastal Management* 95: 189–197.

Law / Lei n.º 31/2014, de 30 de Maio. LEI DE BASES GERAIS DA POLÍTICA PÚBLICA DE SOLOS, DE ORDENAMENTO DO TERRITÓRIO E DE URBANISMO. Available at: https://dre.pt/legislacao-consolidada/-/lc/57377208/view?consolidacaoTag=Urbanismob

Law / Lei n.º 58/2005 (Lei da Água). Available at: https://dre.pt/pesquisa/-/search/469068/details/maximized

Lawrence, J., & Manning, M. (2012). Developing adaptive risk management for our changing climate. *The New Zealand Climate Change Research Institute*.

Llaquet JE (2012) La sostenibilidad ambiental de los puertos: Una visión panorámica. Environmental Sustainability of Port: An Overview. *Portus: the online magazine of RETE*, December, 24.

Lazarus ED, Ellis MA, Murray AB, Hall DM (2016) An evolving research agenda for human-coastal systems. *Geomorphology* 256: 81–90.

Lennon M, Scott M and O'Neill E (2014) Urban design and adapting to flood risk: the role of green infrastructure. *Journal of Urban Design* 19(5): 745–758.

Linde A te, and Jeuken A (2011) Working with tipping points and adaptation pathways - a guideline (in Dutch). 1202029-000-VEB-0003. Deltares, Delft, NL

Linham M and Nicholls RJ (2010) *Technologies for Climate Change Adaptation - Coastal erosion and flooding*. UNEP Risø Centre on Energy, Climate and Sustainable Development, Roskilde, Denmark, 150 pp. ISBN: 978-87-550-3855-4. Available at: http://orbit.dtu.dk/files/5699563/Technologies%20for%20Climate%20Change%20Adaptation-Coastal%20Erosion%20and%20Flooding.pdf (accessed 15 September 2016).

London Councils' TEC Executive Sub Committee. 2007. *Thames Estuary 2100 – Developing a Flood Management Plan for London and the Thames Estuary*.

London Councils Member briefing. 2018. The Thames Estuary 2100 Plan: How It Could Affect Your Borough.

Lowe, J. A., Howard, T. P., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., Bradley, S. (2009), *UK Climate Projections science report: Marine and coastal projections*. Met Office Hadley Centre, Exeter, UK.

Macintosh A (2013) Coastal climate hazards and urban planning: how planning responses can lead to maladaptation. *Mitigation and Adaptation Strategies for Global Change* 18(7): 1035–1055.

Maier, H. R., Guillaume, J. H., van Delden, H., Riddell, G. A., Haasnoot, M., & Kwakkel, J. H. (2016). An uncertain future, deep uncertainty, scenarios, robustness and adaptation: How do they fit together?. *Environmental Modelling & Software*, *81*, 154-164

Mayor of London (2010) The draft climate change adaptation strategy for London. London. Greater London Authority. Available at: http://www.deltacities.com/documents/London_Climiate_change_adaptation.pdf (accessed 20 August 2017).

Marchand, Marcel, and Fulco Ludwig. 2014. "Towards a comprehensive framework for adaptive delta management." *Delta Alliance, Delft/Wageningen, Netherlands. [online] URL: http://www. deltaalliance. org/gfx_content/documents/documentation/Towards a Comprehensive Framework for Adaptive Delta Management.pdf*

Marchand M, Sanchez-Arcilla A, Ferreira M, Gault J, Jiménez JA, Markovic M, Mulder J, Van Rijn L, Stănică A, Sulisz W and Sutherland J (2011) Concepts and science for coastal erosion management – an introduction to the Conscience framework. *Ocean & Coastal Management* 54(12): 859–866.

Marchau, V. A., Walker, W. E., Bloemen, P. J., & Popper, S. W. (2019). *Decision making under deep uncertainty*. Springer. Retrieved from http://link. springer. com/10.1007/978-3-030-05252-2 doi, 10, 978-3.

Marino E and Ribot J (2012) Adding insult to injury: climate change and the inequities of climate intervention. *Global Environmental Change* 22(2): 323–328.

McLain R, Lee R (1996) Adaptive management: promises and pitfalls. Environ Manag 20(4):437–448

Merk O (2014) Do megaships need megaports? *Portus: the online magazine of RETE*, October, 28. Year XIV, Venice, RETE Publisher, ISSN 22825789

Merk O (2013a) The competitiveness of global port-cities: synthesis report. *OECD Regional Development Working Papers* 13: 0-1.

Merk O (2013b) Global ports and urban development: a presentation of the OECD port-cities programme. *Portus: the online magazine of RETE*, June, 25.

Met Office. 2012. Thames Estuary 2100 Project

MoMA - Museum of Modern Art, New York (2011) Rising Currents exhibition. Available at: https://www.moma.org/explore/inside_out/category/rising-currents/ (accessed on June 2016).

Moser SC, Williams JS and Boesch DF (2012) Wicked challenges at land's end: managing coastal vulnerability under climate change. *Annual Review of Environment and Resources* 37: 51–78.

Mulder JP, Hommes S and Horstman EM (2011) Implementation of coastal erosion management in the Netherlands. *Ocean & Coastal Management* 54(12): 888–897.

Nicholls RJ (2011) Planning for the Impacts of sea level rise. *Oceonography* 24(2): 144–157.

Nicholls RJ, Hanson S, Herweijer C, Patmore N, Hallegatte S, Corfee-Morlot J, Chateau J and Wood RM (2008) Ranking port cities with high exposure and vulnerability to climate change extremes: Exposure estimates. OECD Environment Working Papers, No. 1, OECD publishing. 2008.

Nicholls RJ, Wong PP, Burkett VR, Codignotto JO, Hay JE, McLean RF, Ragoonaden S and Woodroffe CD (2007) *Coastal systems and low-lying areas.* In: Parry ML, Canziani OF, Palutikof JP, Van der Linden PJ and Hanson CE (eds) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge UK: Cambridge University Press, pp.315–356.

Norman B (2009) *Planning for Coastal Climate Change: An Insight into International and National Approaches*. Victorian Government Department of Planning and Community Development and Department of Sustainability and Environment, Melbourne, Australia, 62 pp.

NYC Planning – Department of City Planning of New York (2013) *Coastal Climate Resilience – Urban Waterfront Adaptive Strategies – A guide to identifying and evaluating potential strategies for increasing the resilience of waterfront communities to coastal flooding and sea level rise*. New York City - Department of City Planning, June. Available at: http://www.sustainablenyct.org/news/UWAS_Draft_lowres.pdf (accessed 12 September 2016).

OECD. 2017. *Land-use Planning Systems in the OECD: Country Fact Sheets*, OECD Publishing, Paris. *http://dx.doi.org/10.1787/9789264268579-en*

Oliveira, R.P., Matos, J.S., Monteiro, A.J., 2013, Managing the urban water cycle in a changing environment, *8th Internation Conference of EWRA*, Porto, Portugal.

O'Riordan T, Gomes C and Schmidt L (2014) The difficulties of designing future coastlines in the face of climate change. *Landscape Research* 39(6): 613–630.

O'Riordan T, Nicholson-Cole SA and Milligan J (2008) Designing sustainable coastal futures. *Twenty-First Century Society* 3(2): 145–157.

Pahl-Wostl, Claudia (2007) Transitions towards adaptive management of water facing climate and global change. *Water Resources Management* 21(1):49–30. doi:10.1007/s11269-006-9040-4

Pahl-Wostl, C., Sendzimir, J., Jeffrey, P., Aerts, J., Berkamp, G. e Cross, K. (2007), Managing change toward adaptive water management through social learning, *Ecology and Society*, Vol. 12, no. 2, Art 30.

Pathways Generator – Version 30 November 2017. The Pathways Generator is developed by and remains the copyright of: Deltares, Delft, The Netherlands (www.deltares.nl); and Carthago Consultancy, Rotterdam, The Netherlands (www.carthago.nl). Available at: https://publicwiki.deltares.nl/display/AP/Pathways+Generator. Consulted in 2018-05-09.

Pavia R (2011) Waterfront. Áreas estratégias de las ciudades portuarias. Waterfront. Strategic Areas in Port Cities. *Portus: the online magazine of RETE*, 22.

Pearson S, Windupranata W, Pranowo SW, Putri A, Ma Y, Vila-Concejo A, Fernández E, Méndez G, Banks J, Knights AM, Firth LB, Breen BB, Jarvis R, Aguirre JD, Chen S, Smith AH, Steinberg P, Chatzinikolaou E and Arvanitidis C (2016) Conflicts in some of the World harbours: what needs to happen next? *Maritime Studies* 15(1): 10.

Penning-Rowsell, E. C., Haigh, N., Lavery, S., & McFadden, L. (2013). A threatened world city: the benefits of protecting London from the sea. *Natural hazards*, *66*(3), 1383-1404.

Petersen, A. C., and Pieter Bloemen. 2015. "Planned adaptation in design and testing of critical infrastructure: the case of flood safety in the Netherlands." UCL STEaPP, 2015.

Pinto, Celso Aleixo; and Moniz, Gabriela. 2013. *Relatório Setorial – Zonas Costeiras, Estratégia Setorial de Adaptação aos Impactos das Alterações Climáticas relacionados com os Recursos Hídricos, da Estratégia Nacional de Adaptação às Alterações Climáticas* (ESAAC-RH, ENAAC). Celso Aleixo Pinto & Gabriela Moniz do *Departamento do Litoral e Proteção Costeira*.

Pires I, Craveiro J and Antunes O (2012) Artificialização do Solo e Vulnerabilidade Humana em Zonas Sujeitas a Processos de Erosão Costeira: casos de estudo da Costa da Caparica e Espinho. *Revista Gestão Costeira Integrada – Journal of Integrated Coastal Zone Management* 12(3).

POC-ACE 2018. Agência Portuguesa do Ambiente. 2018. *Programa da Orla Costeira Alcobaça-Cabo Espichel, Relatório do Programa*. Março 2018. Aprovado pela RCM N.º 66/2019. Resolução do Conselho de Ministros n.º 66/2019

POC-ACE 2018 a. Agência Portuguesa do Ambiente. 2018 d. *Programa da Orla Costeira Alcobaça-Cabo Espichel, Programa de Execução e Plano de Financiamento*. Março 2018.

POC-ACE 2018 d. Agência Portuguesa do Ambiente. 2018 d. *Programa da Orla Costeira Alcobaça-Cabo Espichel, Directivas*. Março 2018.

POC-ACE 2017. Agência Portuguesa do Ambiente. 2017. *Programa da Orla Costeira Alcobaça-Cabo Espichel, Avaliação Ambiental Estratégica – Relatório Ambiental*. Abril 2017.

POC-CE 2018. Agência Portuguesa do Ambiente. 2018. *Programa da Orla Costeira Caminha-Espinho, Relatório do Programa*. Outubro 2018.

POC-CE 2018 b. Agência Portuguesa do Ambiente. 2018b. *Anexo 3 – Metodologia de Determinação das Faixas de Salvaguarda – Programa da Orla Costeira Caminha-Espinho, Relatório do Programa*. Outubro 2018.

POC-CE 2018 c. Agência Portuguesa do Ambiente. 2018c. *Anexo 4 – FICHAS DE CARATERIZAÇÃO DAS ÁREAS CRÍTICAS – Programa da Orla Costeira Caminha-Espinho, Relatório do Programa*. Outubro 2018.

POC-CE 2018d. Agência Portuguesa do Ambiente. 2018d. *Directivas – Programa da Orla Costeira Caminha-Espinho*. Outubro 2018.

POC-CE 2018 e. Agência Portuguesa do Ambiente. 2018e. *Programa de Execução e Plano de Financiamento – Programa da Orla Costeira Caminha-Espinho*. Outubro 2018.

POC-CE 2018 f. Agência Portuguesa do Ambiente. 2018f. Relatório Ambiental – Programa da Orla Costeira Caminha-Espinho. Outubro 2018.

POC-CE 2015. Agência Portuguesa do Ambiente. 2015. *Caraterização e Diagnóstico da Situação Territorial – Programa da Orla Costeira Caminha-Espinho*. Junho de 2015

POC-CE 2015 b. Agência Portuguesa do Ambiente. 2015 b. *Volume II - Relatório de Balanço da Implementação do POOC Caminha Espinho – Programa da Orla Costeira Caminha-Espinho*. 29 de maio de 2015

POC-CE 2020. Agência Portuguesa do Ambiente. 2020. *Relatório de Ponderação da Discussão Pública sobre o Programa da Orla Costeira Caminha-Espinho*. Junho de 2020.

Portas N (1998) *Cidades e frentes de agua: Cities & waterfronts*. Porto, Universidade Porto.

Preston BL, Westaway RM and Yuen EJ (2011) Climate adaptation planning in practice: an evaluation of adaptation plans from three developed nations. *Mitigation and adaptation strategies for global change* 16(4): 407–438.

Ramsbottom, David, and Sheppard Matthew. (2017) Adaptive Planning standing the test of time: the Thames Estuary. Available at: https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=2897. (consulted 2018.10.20)

Ranger, Nicola, Tim Reeder, and Jason Lowe (2013) "Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project." *EURO Journal on Decision Processes* 1.3-4 (2013): 233-262.

Ranger, N., Millner, A., Dietz, S., Fankhauser, S., Lopez, A & Ruta, G. 2010: Adaptation in the UK: a decision making process, *Grantham/CCCEP Policy Brief*

Ranger N, Reeder T and Lowe J (2013) Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project. *EURO Journal on Decision Processes* 1(3–4): 233–262.

Reeder, Tim and Nicola Ranger. 2011. "*How do you adapt in an uncertain world? Lessons from the Thames Estuary 2100 project*." World Resources Report, Washington DC. Available online at http://www.worldresourcesreport.org

Reguero BG, Losada IJ and Méndez FJ (2013) Las ciudades portuarias ante un clima cambiante. *Portus: the online magazine of RETE* 24: 20–25.

Reguero BG, Bresch DN, Calil J, Meliane I (2014) Coastal-risks, nature-based defenses, and the economics of adaptation: an application in the Gulf of Mexico, USA. *Coastal Engineering, Proceedings* 1(34): 25.

RETE – International Association for the Collaboration between Ports and Cities (2011) *The port city of the XXIst century. New challenges in the relationship between port and city*. RETE, Venice Italy. Edited by R. Bruttomesso , J. Alemany.

Restemeyer B, Woltjer J and Den Brink MV (2015) A strategy-based framework for assessing the flood resilience of cities – A Hamburg case study. *Planning Theory & Practice* 16(1): 45–62.

Restemeyer, Britta, Margo van den Brink, and Johan Woltjer (2017) "Between adaptability and the urge to control: making long-term water policies in the Netherlands." Journal of environmental planning and management 60.5 (2017): 920-940.

Rhee G. Van (2012) Handreiking Adaptief Deltamanagement (Guidance document on Adaptive Delta Management, in Dutch). Stratelligence, Leiden, The Netherlands. Available at: https://deltaprogramma.pleio.nl/file/download/9761712

Ritzema, H. P., and J. M. Van Loon-Steensma. "Coping with Climate Change in a densely Populated Delta: A Paradigm Shift in Flood and Water Management in The Netherlands." *Irrigation and Drainage* 67 (2018): 52-65.

Roosjen, R., Van der Brugge, R., Morselt, T. & Jeuken, A. 2012 Adaptief Deltamanagement. Pilot voor deelprogramma Rijnmond/Drechtsteden. Report. Deltares and Blueconomy, Utrecht, The Netherlands

Rosenzweig C, Solecki WD, Blake R, Bowman M, Faris C, Gornitz V, Horton R, Jacob K, Le Blanc A, Leichenko R, Linkin M, Major D, O'Grady M, Patrick L, Sussman E, Yohe G and Zimmerman R (2011) Developing coastal adaptation to climate change in the New York City infrastructure-shed: process, approach, tools, and strategies. *Climatic Change* 106(1): 93–127.

RCP – Rotterdam Climate Proof – Adaptation Programme (2010) *Rotterdam Climate Initiative*. City of Rotterdam. Available at: http://www.rotterdamclimateinitiative.nl/documents/2015-en-ouder/RCP/English/RCP_ENG_def.pdf (accessed 28 July 2017).

San Francisco Bay Conservation and Development Commission (2009) *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline*. San Francisco. Government of the State of California. Available at: http://www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf (accessed 28 July 2017).

Sánchez-Arcilla A, García-León M, Gracia V, Devoy R, Stanica A and Gault J (2016) Managing coastal environments under climate change: Pathways to adaptation. *Science of The Total Environment* 572: 1336–1352.

Sayers, P.B., Galloway, G.E. & Hall, J.W. (2012) Robust decision-making under uncertainty – towards adaptive and resilient flood risk management infrastructure. In: *Flood Risk Planning, Design and Management of Flood Defence Infrastructure. ICE Publishing* (2012): 281-302.

Scoppetta C (2016) Port-cities on the storm. Discussing post-disaster planning. *PortusPlus: the online Journal of RETE*, March, 6. Year VI RETE Publisher, Venice, ISSN: 2039-6422

Scott H, McEvoy D, Chhetri P, Basic F and Mullett J (2013) *Climate change adaptation guidelines for ports. Enhancing the resilience of seaports to a changing climate report series*. National Climate Change Adaptation Research Facility, Gold Coast.

Schmidt L, Gomes C, Guerreiro S and O'Riordan T (2014) Are we all in the same boat? The challenge of adaptation facing Portuguese coastal communities. Risk Perception, trust-building and genuine participation. *Land Use Policy* 38:365–355.

Schmidt L, Delicado A, Gomes C, Granjo P, Guerreiro S, Horta A, Mourato J, Prista P, Saraiva T, Truninger M, O'Riordan T, Santos FD and Penha-Lopes G (2013a) Change in the way we live and plan the coast: stakeholders discussions on future scenarios and adaptation strategies. In: *Proceedings 12th International Coastal Symposium* (eds DC Conley, G Masselink, PE Russel and TJ O´Hare), Plymouth, England. Journal of Coastal Research, Special Issue 65:1033–1038.

Schmidt L, Prista P, Saraiva T, O'Riordan T and Gomes C (2013 b) Adapting governance for coastal change in Portugal. *Land Use Policy* 31: 314–325.

Schubert D (2015) Smart and resilient cities and ports. Perspectives for Hamburg. *Portus: the online magazine of RETE*, 29.

Seijger, C., Douven, W. J. A. M., van Halsema, G., Hermans, L., Evers, J., Phi, H. L., ... & Koole, S. (2017). An analytical framework for strategic delta planning: negotiating consent for long-term sustainable delta development. *Journal of Environmental Planning and Management*, *60*(8), 1485-1509. https://www.tandfonline.com/doi/full/10.1080/09640568.2016.1231667

Shaw K (2013) Docklands dreamings: illusions of sustainability in the Melbourne docks redevelopment. *Urban Studies* 50(11): 2158–2177.

Shu Y and Qin J (2014) Resilient Development of Urban Waterfront in Fast-Changing - A Case Study of Wuhan, China. *Journal of Civil Engineering and Architecture* 8(81): 1073–1083.

Siebentritt M, Halsey N and Stafford-Smith M (2014) *Regional Climate Change Adaptation Plan for the Eyre Peninsula, Australia*. Report prepared for the Eyre Peninsula Integrated Climate Change Agreement Committee. Available at: http://www.naturalresources.sa.gov.au/files/sharedassets/eyre_peninsula/corporate/climate-change-adaptation-2014-plan.pdf (accessed 25 August 2017).

Sousa João Figueira, and Prista J Costa (2012) As Cidades Portuárias no Contexto das Alterações Climáticas: o Caso da Cidade e do Porto de Lisboa (Port Cities and Climate Climate Change: the case of the City and Port of Lisbon). *Portus: the online magazine of RETE* 24: 4–7.

Storbjörk S (2010) 'It takes more to get a ship to change course': barriers for organizational learning and local climate adaptation in Sweden. *Journal of Environmental Policy & Planning* 12(3), 235–254.

Storbjörk S and Hjerp M (2014) Sometimes Climate Adaptation is Politically Correct: A Case Study of Planners and Politicians Negotiating Climate Adaptation in Waterfront Spatial Planning. *European Planning Studies* 22(11): 2268–2286.

Storbjörk S and Uggla Y (2015) The practice of settling and enacting strategic guidelines for climate adaptation in spatial planning: lessons from ten Swedish municipalities. *Regional Environmental Change* 15(6): 1133–1143.

Swanson, D., Barg, S., Tyler, S., Venema, H., Tomar, S., Bhadwal, S., ... & Drexhage, J. (2010). Seven tools for creating adaptive policies. *Technological Forecasting and Social Change*, *77*(6), 924-939.

TE2100 Appendix L. Environment Agency. 2009. Thames Estuary 2100 – Technical Report – Appendix L – Climate Change Studies in TE2100 Subject.

Tompkins EL, Adger WN, Boyd E, Nicholson-Cole S, Weatherhead K and Arnell N (2010) Observed adaptation to climate change: UK evidence of transition to a well-adapting society. *Global environmental change* 20(4): 627–635.

Tribbia J and Moser SC (2008) More than information: what coastal managers need to plan for climate change. *Environmental science & policy* 11(4): 315–328.

UKCIP. 2007. *Identifying Adaptation Options. Oxford, UK: UK Climate Impacts Programme 2007*. Available at: https://www.ukcip.org.uk/wp-content/PDFs/ID_Adapt_options.pdf

UKCIP. 2013. *The UKCIP Adaptation Wizard v 4.0.* Oxford, UK: UK Climate Impacts Programme, 2013. Available at: https://www.ukcip.org.uk/wizard/about-the-wizard/; https://ukcip.ouce.ox.ac.uk/wizard/

USAID – United States Agency for International Development (2009) *Adaptation to Coastal Climate Change – A Guidebook for Development Planners*. U.S. Agency for International Development (USAID), Washington, DC, USA, 147 pp.

USEPA – U.S. Environmental Protection Agency (2008) *Planning for Climate Change Impacts at U.S. ports*. USEPA – Office of Policy, Economics, and Innovation. White Paper.

Van der Voorn T, Pahl-Wostl C and Quist J (2012) Combining backcasting and adaptive management for climate adaptation in coastal regions: a methodology and a South African case study. *Futures* 44(4): 346–364

Van der Voorn T, Quist J, Pahl-Wostl C and Haasnoot M (2015) Envisioning robust climate change adaptation futures for coastal regions: a comparative evaluation of cases in three continents. *Mitigation and Adaptation Strategies for Global Change* 22(3): 519–546.

Veelen, Peter Christiaan Van, and V. J. Meijer. "Adaptive planning for resilient coastal waterfronts: Linking flood risk reduction with urban development in Rotterdam and New York City." (2016).

Veloso-Gomes F (2010) Contributos Para a Revisão do Plano de Ordenamento da Orla Costeira na Região Centro. In: *Actas 5ª Jornadas de Hidráulica, Recursos Hídricos e Ambiente* (ed FEUP), Porto, Portugal, 2010. ISBN 978-989-95557-4-7

Veloso-Gomes F (2007) A gestão da zona costeira portuguesa. *Revista da Gestão Costeira Integrada - Journal of Integrated Coastal Zone Management* 7(2): 83–95.

Veloso-Gomes, Fernando. 2018. Comentário acerca da *'Definição das Componentes de Recuo para a definição das Faixas de Salvaguarda*' do novo POC-CE. 14 de Dezembro de 2018. Apresentado na reunião de acompanhamento da elaboração do POC-CE realizada em Vila do Conde em Junho 2015, e na sessão de esclarecimento do POC realizada na Ordem dos Engenheiros no Porto, em 23 de Novembro de 2018.

Veloso-Gomes, Fernando. 2014. Comentários e questões sobre o *'Sumário Executivo e Recomendações do Relatório do Grupo de Trabalho do Litoral*'. 26 de Novembro de 2014.

Veloso-Gomes F and Taveira-Pinto F (2003) Portuguese coastal zones and the new coastal management plans. *Journal of Coastal Conservation* 9(1): 25–34.

Veloso-Gomes F et al. (2006a) Section 4 – Mitigation and Adaptation Strategies. In: Hoepffner N, Dowell MD, Edwards M, Fonda-Umani S, Green DR, Greenaway B, Hansen B, Heinze C, Leppänen JM, Lipiatou E, Özsoy E, Philippart K, Salomons W, Sanchez-Arcilla A, Schrimpf W, Schrum C, Theocharis A, Tsimplis M, Veloso-Gomes F, Wakenhut F and Zaldivar JM (eds) *Marine and Coastal Dimension of Climate Change in Europe - A Report to the European Water Directors*. Joint Research Centre. European Commission. pp.74–84.

Viegas, T.; Sancho, F. (2005). Níveis de inundação em zonas costeiras: metodologia de cálculo. Proc. 4as Jornadas Portuguesas de Engenharia Costeira e Portuária, Angra do Heroísmo, 20 e 21 de Outubro de 2005.

Vink, M. J., Boezeman, D., Dewulf, A., & Termeer, C. J. (2013). Changing climate, changing frames: Dutch water policy frame developments in the context of a rise and fall of attention to climate change. *Environmental Science & Policy*, *30*, 90-101.

Walker WE, Haasnoot M and Kwakkel JH (2013) Adapt or perish: a review of planning approaches for adaptation under deep uncertainty. *Sustainability* 5(3): 955–979.

Walker WE, Rahman SA and Cave J (2001) Adaptive policies, policy analysis, and policymaking. *European journal of operational Research* 128(2): 282–289 doi:10.1016/S0377-2217(00)00071-0

Walters C (1997) Challenges in adaptive management of riparian and coastal ecosystems. *Conservation ecology* 1(2).

Wang H (2014) Preliminary investigation of waterfront redevelopment in Chinese coastal port cities: the case of the eastern Dalian port areas. *Journal of Transport Geography* 40: 29–42.

Ward P. J., Pauw W. P., Van Buuren M. W., Marfai M. A. (2013) Governance of flood risk management in a time of climate change: the cases of Jakarta and Rotterdam. *Environmental Politics* 22 (3): 518–536.

Warsewa G (2006). *The transformation of European Port Cities – Final Report on the New EPOC Port City Audit*. IAW University of Bremen. 46 pages. ISBN: 3-88722-672-0

Werners, Saskia Elisabeth, Jantsje Mintsje van Loon-Steensma, and Albert Peter Oost. "Method selection in adaptation research: the case of the Delta Programme for the Dutch Wadden region." *Regional environmental change* 16.1 (2016): 111-122.

Wilby, R. L., & Keenan, R. (2012). Adapting to flood risk under climate change. *Progress in physical geography*, *36*(3), 348-378.

Willows, R., Reynard, N., Meadowcroft, I., & Connell, R. (2003). *Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report*. UK Climate Impacts Programme (UKCIP Oxford)

Wise RM, Fazey I, Smith MS, Park SE, Eakin HC, Van Garderen EA and Campbell B (2014) Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change* 28: 325–336.

Wong PP, Losada IJ, Gattuso J, HINKEL J, Khattabi A, McInnes KL, Saito Y, Sallenger A (2014) Coastal systems and low-lying areas. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR and White LL (eds) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 361–409.

Yohe, G., & Leichenko, R. (2010). Adopting a risk-based approach. *Annals of the New York Academy of Sciences*, *1196*(1), 29-40.

Zandvoort, M. J. van der Vlist & A. van den Brink (2018). *Handling uncertainty through adaptiveness in planning approaches: comparing adaptive delta management and the water diplomacy framework*. Journal of Environmental Policy & Planning, 20:2, 183-197, DOI: 10.1080/1523908X.2017.1347035.

Zevenbergen, Chris; Shah Alam Khan, Jos van Alphen, Catharien Terwisscha van Scheltinga & William Veerbeek (2018): Adaptive delta management: a comparison between the Netherlands and Bangladesh Delta Program, International Journal of River Basin Management, DOI: 10.1080/15715124.2018.1433185

EUROPEAN DOCUMENTS

(2002/413/EC) RECOMMENDATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. of 30 May 2002. concerning the implementation of Integrated Coastal Zone Management in Europe (2002/413/EC)

(2007/60/EC) DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on the assessment and management of flood risks.

COM (2013) 216. Communication: "An EU Strategy on Adaptation to Climate Change», COM (2013) 216

https://ec.europa.eu/clima/policies/adaptation/what_en

EC. YEAR. *The EU Strategy on adaptation to climate change. Strengthening Europe's resilience to the impacts of climate change.* Available at: https://ec.europa.eu/clima/sites/clima/files/docs/eu_strategy_en.pdf

Adaptation preparedness scoreboard: Country fiche for Portugal. Adaptation preparedness scoreboard: Summary for Portugal

COMMISSION STAFF WORKING DOCUMENT. Guidelines on developing adaptation strategies. Commission Staff Working Document, SWD (2013) 134.

COMMUNICATION FROM THE COMMISSION. Report to the European Parliament and the Council: An evaluation of Integrated Coastal Zone Management (ICZM) in Europe. Brussels, 7.6.2007. COM (2007) 308 final.

COMMISSION STAFF WORKING DOCUMENT. Climate change adaptation, coastal and marine issues. Brussels, 16.4.2013. SWD(2013) 133 final

Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for maritime spatial planning and integrated coastal management. Brussels, 12.3.2013. COM(2013) 133

final 2013/0074 (COD).

CEC – Commission of the European Communities (2009) *White paper – Adapting to climate change: Towards a European framework for action* (COM (2009) 147 final). Commission of the European Communities, Brussels.

CEC – Commission of the European Communities (2007) *Green paper from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Adapting to climate change in Europe–options for EU action* (COM (2007) 354 final). Commission of the European Communities, Brussels.

WEBSITES CONSULTED

www.ukcip.org.uk/wizard

https://www.deltares.nl/en/adaptive-pathways/

https://publicwiki.deltares.nl/display/AP/Adaptation+Pathways

https://www.youtube.com/watch?v=ZvA2lt9_SD4

https://publicwiki.deltares.nl/display/AP/Pathways+Generator

https://publicwiki.deltares.nl/display/AP/Video+Tutorial%3A+Condition-Based+Pathways+Map

https://publicwiki.deltares.nl/display/AP/Video+Tutorial%3A+Time-Based+Pathways+Map

https://coastadapt.com.au/pathways-approach

Wise et al.: https://www.youtube.com/watch?v=WmRCCL6s7OM

https://climate-adapt.eea.europa.eu/eu-adaptation-policy/sector-policies/coastal-areas

https://ec.europa.eu/clima/policies/adaptation/what_en#tab-0-0

https://ec.europa.eu/environment/water/flood_risk/index.htm

https://ec.europa.eu/environment/iczm/index_en.htm

https://ec.europa.eu/environment/iczm/prop_iczm.htm

APA

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=955

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=391

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=1375

Programa de Ação para a Adaptação às Alterações Climáticas (P-3AC)

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=1237

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=392

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=395

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=396

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=397

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=989

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=1586

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=393

Guião para Empresas e Sectores: Ferramenta para facilitar a adopção de medidas de adaptação

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=394

https://apambiente.pt/index.php?ref=16&subref=81&sub2ref=118&sub3ref=987

Adaptive Coastal Management

https://www.lifeadapto.eu/home.html

https://climate-adapt.eea.europa.eu/metadata/case-studies/flexible-and-adaptive-coastal-planning-and-protection-approach-in-aurich-lower-saxony

https://climate-adapt.eea.europa.eu/metadata/adaptation-options/adaptation-of-integrated-coastal-management-plans

Dredging works, land claim projects in ports: https://www.dredgingtoday.com/tag/land/page/2/

Coastal vulnerability in coastal cities: http://coastalcare.org/sections/features/sandy-storm/

Digital tools for simulating sea-level rise (flood maps)
https://choices.climatecentral.org/#13/41.1590/-8.6546?compare=scenarios&carbon-end-yr=2100&scenario-a=unchecked&scenario-b=extreme-cuts
https://sealevel.nasa.gov/data/virtual-earth-system-laboratory
https://coast.noaa.gov/slr/
http://flood.firetree.net/?ll=-27.8390,138.1640&z=13&m=7
http://geology.com/sea-level-rise/florida.shtml

Flood maps
https://www.nccoastalatlas.org/maps
http://ngm.nationalgeographic.com/2013/09/rising-seas/if-ice-melted-map
http://sealevel.climatecentral.org/maps

Maps of water flows in Rotterdam
http://thisbigcity.net/cities-on-the-move-visualizing-the-flow-of-rotterdams-urban-landscape/

Images for demonstrating the risk:
http://marenostrumproject.eu/news-events/blog/new-spanish-law-threatens-protection-of-coastal-areas
http://www.jpl.nasa.gov/news/news.php?feature=6254
http://www.miamiherald.com/news/local/community/miami-dade/miami-beach/article41141856.html
Coastal adaptation options
http://www.spur.org/publications/urbanist-article/2009-11-01/strategies-managing-sea-level-rise

Planned Retreat:
http://www.spur.org/news/2013-09-13/fight-or-flight-sea-level-rise-leads-increased-consideration-managed-retreat
http://www.spur.org/featured-project/ocean-beach-master-plan
https://www.groundsure.com/news/managed-retreat-viable-option-coastal-management/
http://www.beachapedia.org/Managed_Retreat

Portugal + sea-level rise
https://www.publico.pt/2014/12/05/local/noticia/subida-do-nivel-do-mar-em-portugal-duplicou-desde-2000-1678461
https://www.publico.pt/2014/05/06/ecosfera/noticia/ha-3600-edificios-em-risco-de-cheias-nas-zonas-mais-problematicas-do-pais-1634890

References cited only in the Annexes

Barragán JM and Andrés M (2015) Analysis and trends of the world's coastal cities and agglomerations. *Ocean & Coastal Management* 114: 11–20.

Bosomworth K, Leith P, Harwood A and Wallis PJ (2017) What's the problem in adaptation pathways planning? The potential of a diagnostic problem-structuring approach. *Environmental Science & Policy* (76): 23–28.

Butler JA, Bohensky EL, Suadnya W, Yanuartati Y, Handayani T, Habibi P, Puspadi K, Skewes TD, Wise RM, Suharto I, Park SE and Sutaryono Y (2016) Scenario planning to leap-frog the Sustainable Development Goals: an adaptation pathways approach. *Climate Risk Management* (12): 83–99.

Carvalho A, Schmidt L, Santos FD and Delicado A (2014) Climate change research and policy in Portugal. *Wiley Interdisciplinary Reviews: Climate Change* 5(2): 199–217.

Carvalho TM and Fidélis T (2013) The relevance of governance models for estuary management plans. *Land use policy* 34: 134–145.

Celliers L, Rosendo S, Coetzee I and Daniels G (2013) Pathways of integrated coastal management from national policy to local implementation: Enabling climate change adaptation. *Marine Policy* 39: 72–86.

DGT. 2013. *Sessão pública de apresentação dos resultados dos trabalhos da ENAAC - 1ª fase (Estratégia Nacional de Adaptação às Alterações Climáticas): Ordenamento do Território e Cidades.* Marta Afonso - Direção-Geral do Território. 1 de outubro de 2013.

Haasnoot, M., van Deursen, W. P., Middelkoop, H., van Beek, E., & Wijermans, N. (2012 b). An integrated assessment Metamodel for developing adaption pathways for the Rhine Delta in the Netherlands. In *6th International Congress on Environmental Modelling and Software 2012: Managing Resources of a Limited Planet: Pathways and Visions under Uncertainty* (pp. 1743-1751). International Environmental Modelling and Software Society (iEMSs).

Kingsborough, A., Borgomeo, E., & Hall, J. W. (2016). Adaptation pathways in practice: mapping options and trade-offs for London's water resources. *Sustainable Cities and Society*, *27*, 386-397.

Kwakkel, Jan H., Warren E. Walker, and Marjolijn Haasnoot. 'Coping with the wickedness of public policy problems: approaches for decision making under deep uncertainty." (2016): 01816001.

Kwakkel, Jan, and Marjolijn Haasnoot. "Computer assisted dynamic adaptive policy design for sustainable water management in river deltas in a changing environment." (2012).

Lawrence, J., Reisinger, A., Mullan, B., & Jackson, B. (2013). Exploring climate change uncertainties to support adaptive management of changing flood-risk. *Environmental Science & Policy*, *33*, 133-142.

Lin, B. B., Capon, T., Langston, A., Taylor, B., Wise, R., Williams, R., & Lazarow, N. (2017). Adaptation pathways in coastal case studies: lessons learned and future directions. *Coastal Management*, *45*(5), 384-405.

Martins, F. (1997). Políticas de Planeamento, Ordenamento e Gestão Costeira. Contributo para uma discussão metodológica. Dissertação apresentada à Universidade de Aveiro para obtenção do grau de Doutor no ramo de Ciências Aplicadas ao Ambiente. Departamento de Ambiente e Ordenamento, Universidade de Aveiro. 270pp.

Park, S. E., Marshall, N. A., Jakku, E., Dowd, A. M., Howden, S. M., Mendham, E., & Fleming, A. (2012). Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change*, *22*(1), 115-126.

Ranger, Nicola, and Su-Lin Garbett Shields (2012). *Accounting for a changing and uncertain climate in planning and policymaking today: lessons for developing countries*, Climate and Development, 4:4, 288-300, DOI: 10.1080/17565529.2012.732919

Rittel, H.W.J., Webber, M.M., 1973. Dilemmas in a General Theory of Planning. University of California, Berkeley.

Rosenzweig, Cynthia, and William Solecki. 2014. "Hurricane Sandy and adaptation pathways in New York: Lessons from a first-responder city." *Global Environmental Change* 28 (2014): 395-408.

Shipman B and Stojanovic T (2007) Facts, fictions, and failures of integrated coastal zone management in Europe. *Coastal Management* 35(2-3): 375–398.

Stojanovic T, Ballinger RC and Lalwani CS (2004) Successful integrated coastal management: measuring it with research and contributing to wise practice. *Ocean & Coastal Management* 47(5): 273–298.

Stojanovic T and Ballinger RC (2009) Integrated coastal management: a comparative analysis of four UK initiatives. *Applied Geography* 29(1): 49–62.

Susskind, L. E., & Islam, S. (2012). Water diplomacy: Creating value and building trust in transboundary water negotiations. Science & Diplomacy, 1(3), 1–7.

Tobey J, Rubinoff P, Robadue Jr D, Ricci G, Volk R, Furlow J and Anderson G (2010) Practicing coastal adaptation to climate change: lessons from integrated coastal management. *Coastal Management* 38(3): 317–335.

Veloso-Gomes, F; and Taveira Pinto, F. (1997). A opção protecção para a Costa Oeste Portuguesa. Colectânea de Ideias sobre a Zona Costeira de Portugal, Associação Eurocoast-Portugal, G. Soares de Carvalho, F. Veloso Gomes and F. Taveira Pinto, Porto, Portugal

Veloso-Gomes F, Taveira-Pinto F, Neves L and Pais-Barbosa J (2006b) *EUrosion-A European Initiative for Sustainable Coastal Erosion. Pilot Site of River Douro-Cape Mondego and Case Studies of Estela, Aveiro, Caparica, Vale do Lobo and Azores, Porto, Portugal.* IHRH, Porto, Portugal.

Veloso-Gomes F, Barroco A, Pereira AR, Reis CS, Calado H, Ferreira JG, Freita MC and Biscoito M (2007) Bases para a estratégia de gestão integrada da zona costeira nacional. In: *2as Jornadas de Hidráulica, Recursos Hídricos e Ambiente* (ed FEUP), Porto, Portugal, 2007. ISBN 978-989-95557-1-6

OTHER REFERENCES (read, but not cited in the text)

Alemany J and Bruttomesso R (2014) Editorial. Future Challenges of Port Cities. *PORTUS: the online magazine of RETE*, May, 27. Year XIV. ISNN 2282-5789.

Antonson H, Isaksson K, Storbjörk S and Hjerp M (2016) Negotiating climate change responses: Regional and local perspectives on transport and coastal zone planning in South Sweden. *Land use policy* 52: 297–305.

Alves FL, Sousa LP, Almodovar M and Phillips MR (2013) Integrated Coastal Zone Management (ICZM): a review of progress in Portuguese implementation. *Regional Environmental Change* 13(5): 1031–1042.

Arens, S. M., Mulder, J. P., Slings, Q. L., Geelen, L. H., & Damsma, P. (2013). Dynamic dune management, integrating objectives of nature development and coastal safety: examples from the Netherlands. *Geomorphology*, *199*, 205-213.

Bai, X., Dawson, R. J., Ürge-Vorsatz, D., Delgado, G. C., Barau, A. S., Dhakal, S., ... & Roberts, D. (2018). Six research priorities for cities and climate change. *Nature*, *555*(7694), 23-25.

Birkmann, J., Garschagen, M., Kraas, F., & Quang, N. (2010). Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. *Sustainability Science*, *5*(2), 185-206.

Brogueira-Dias E and Alves JF (2004) O Porto do Douro. Um porto, duas cidades. *Portus: the online magazine of RETE*, 8.

Brogueira-Dias E and Alves JF (2006) Leixões and Port Heritage. *Portus: the online magazine of RETE*, 12.

Brogueira-Dias E, Estrada JL and Mealha RP (2012). O Novo Terminal de Contentores de Leixões e a remodelação do Porto de Pesca. *PortusPlus: the online magazine of RETE*, 3.

Brown, S., Kebede, A. S., & Nicholls, R. J. (2017). Sea-level rise and impacts in Africa, 2000 to 2100.

Buuren, Arwin Van, Sibout Nooteboom, and Geert Teisman. (2012). *Climate adaptation in complex governance systems. Governance systems between inertia and adaptability*. In G. de Roo, J. Hillier & J. van Wezemael (Eds.), *Complexity and Planning: Systems, Assemblages and Simulations* (New directions in planning theory.) (pp. 221-242). London: Ashgate Publishing.

Caldwell MR, Hartge EH, Ewing LC, Griggs G, Kelly RP, Moser SC, Newkirk SG, Smyth RA, Woodson CB (2013). Coastal Issues. In: Garfin G, Jardine A, Merideth R, Black M and LeRoy S (eds) *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*. A Report by the Southwest Climate Alliance. Washington, DC: Island Press, pp.168-196.

Coelho C, Silva R, Veloso-Gomes F and Taveira-Pinto F (2009) Potential effects of climate change on northwest Portuguese coastal zones. *ICES Journal of Marine Science: Journal du Conseil* 66(7): 1497–1507.

Coelho C, Silva R, Veloso-Gomes F and Taveira Pinto F (2006) A vulnerability analysis approach for the Portuguese west coast. *Risk Analysis V: Simulation and Hazard Mitigation* 1: 251–262.

Coelho R. Formas e desígnios do espaço público na cidade contemporânea: o projecto do espaço público na construção da cidade: casos portugueses. In: *VII Seminario Internacional de Investigación en Urbanismo* (ed DUOT Barcelona), Barcelona-Montevideo, June 2015. Barcelona: DUOT, 2015.

Davoudi, Simin, Elizabeth Brooks, and Abid Mehmood. "Evolutionary resilience and strategies for climate adaptation." *Planning Practice & Research* 28.3 (2013): 307-322.

Dittrich, Ruth, Anita Wreford, and Dominic Moran. "A survey of decision-making approaches for climate change adaptation: Are robust methods the way forward?." *Ecological Economics* 122 (2016): 79-89.

Duarte AT (2016) *A Evolução Urbana de Matosinhos/Sul*. Master Thesis, Faculty of Architecture, University of Porto, Porto, Portugal.

Fazey, I., Wise, R. M., Lyon, C., Câmpeanu, C., Moug, P., & Davies, T. E. (2016). Past and future adaptation pathways. *Climate and Development*, *8*(1), 26-44.

Ferreira, A., Seixas, S., & Marques, J. C. (2015). Bottom-up management approach to coastal marine protected areas in Portugal. *Ocean & Coastal Management*, *118*, 275-281.

Fields B (2009) From green dots to greenways: Planning in the age of climate change in post-Katrina New Orleans. *Journal of Urban Design* 14(3): 325–344.

Fournier, M., Larrue, C., Alexander, M., Hegger, D. L., Pettersson, M., Crabbé, A., ... & Chorynski, A. (2016). Flood risk mitigation in Europe: how far away are we from the aspired forms of adaptive governance?. *Ecology and Society*, *21*(4).

Freitas DM, Smith T and Stokes A (2013) Planning for uncertainty: Local scale coastal governance. *Ocean & Coastal Management* 86: Editorial 72–74.

Fu X, Gomaa M, Deng Y and Peng ZR (2017) Adaptation planning for sea level rise: A study of US coastal cities. *Journal of Environmental Planning and Management* 60(2): 249–265.

Gibbs MT (2015) Coastal climate risk and adaptation studies: The importance of understanding different classes of problem. *Ocean & Coastal Management* 103: 9–13.

González-Riancho P, Gerkensmeier B, Ratter BM, González M and Medina R (2015) Storm surge risk perception and resilience: a pilot study in the German North Sea coast. *Ocean & Coastal Management* 112: 44–60.

Griggs GB (2013) Lost neighborhoods of the California coast." *Journal of Coastal Research* 31(1): 129–147.

Gupta, J., Bergsma, E., Termeer, C. J. A. M., Biesbroek, G. R., van den Brink, M., Jong, P., ... & Nooteboom, S. (2016). The adaptive capacity of institutions in the spatial planning, water, agriculture and nature sectors in the Netherlands. *Mitigation and adaptation strategies for global change*, *21*(6), 883-903.

Gurran N, Norman B and Hamin E (2013) Climate change adaptation in coastal Australia: An audit of planning practice. *Ocean & coastal management* 86: 100–109.

Hill D (2013) New York City Plan to Be Flooded. Letters to the Editor, Journal of Coastal Research 29, 2013.

Hill D (2012) The Lessons of Katrina, Learned and Unlearned. *Journal of Coastal Research* 28(2):324–331.

Hjerp M, Storbjörk S and Alberth J (2015) 'There is nothing political in it': triggers of local political leaders' engagement in climate adaptation. *Local environment*, *20*(8), 855–873.

Ibáñez, C., Day, J. W., & Reyes, E. (2014). The response of deltas to sea-level rise: natural mechanisms and management options to adapt to high-end scenarios. *Ecological engineering*, *65*, 122-130.

Jolicoeur S and O'Carroll S (2007) Sandy barriers, climate change and long-term planning of strategic coastal infrastructures, Îles-de-la-Madeleine, Gulf of St. Lawrence (Québec, Canada). *Landscape and Urban Planning* 81(4): 287–298.

Jongejan R, Ranasinghe R, Wainwright D, Callaghan DP and Reyns J (2016) Drawing the line on coastline recession risk. *Ocean & coastal management* 122: 87–94.

Kashem SB, Wilson B and Van Zandt S (2016) Planning for Climate Adaptation: Evaluating the Changing Patterns of Social Vulnerability and Adaptation Challenges in Three Coastal Cities. *Journal of Planning Education and Research* 36(3): 304–318.

Kato, Sadahisa, and Jack Ahern. "'Learning by doing': adaptive planning as a strategy to address uncertainty in planning." *Journal of Environmental Planning and Management* 51.4 (2008): 543-559.

Ke, Q., Haasnoot, M., & Hoogvliet, M. (2016). Exploring adaptation pathways in terms of flood risk management at a city scale–a case study for Shanghai city. In *E3S Web of Conferences* (Vol. 7, p. 21002). EDP Sciences.

Kettle NP and Dow K (2014) Cross-level differences and similarities in coastal climate change adaptation planning. *Environmental Science & Policy* 44: 279–290.

Kokx, J. M. C., and T. J. M. Spit. "Increasing the adaptive capacity in unembanked neighborhoods? An exploration into stakeholder support for adaptive measures in Rotterdam, the Netherlands." *American Journal of Climate Change* 1 (2012): 181-193.

Kuklicke, Christian, and David Demeritt. "Adaptive and risk-based approaches to climate change and the management of uncertainty and institutional risk: The case of future flooding in England." *Global Environmental Change* 37 (2016): 56-68.

Lawrence, Judy, and Marjolijn Haasnoot. "What it took to catalyse uptake of dynamic adaptive pathways planning to address climate change uncertainty." *Environmental Science & Policy* 68 (2017): 47-57.

Lawrence, J., Bell, R., Blackett, P., Stephens, S., & Allan, S. (2018). National guidance for adapting to coastal hazards and sea-level rise: Anticipating change, when and how to change pathway. *Environmental Science & Policy*, *82*, 100-107.

Maru, Y. T., & Smith, M. S. (2014). GEC special edition – Reframing adaptation pathways. *Global Environmental Change*, (28), 322-324.

Mees, H. L., Driessen, P. P., & Runhaar, H. A. (2014). Legitimate adaptive flood risk governance beyond the dikes: the cases of Hamburg, Helsinki and Rotterdam. Regional Environmental Change, 14(2), 671-682.

New York City Panel on Climate Change (2010) *Climate Change Adaptation in New York City: Building a Risk Management Response: New York City Panel on Climate Change 2010 Report*. Blackwell Pub.   (LIVRO)

New Zealand Government (2017). Coastal Hazards and Climate Change: Guidance for Local Government. p.14

Nicholls, R. J., Townend, I. H., Bradbury, A. P., Ramsbottom, D., & Day, S. A. (2013). Planning for long-term coastal change: experiences from England and Wales. *Ocean Engineering*, *71*, 3-16.

Porter J and Demeritt D (2012) Flood-risk management, mapping, and planning: the institutional politics of decision support in England. *Environment and Planning A* 44(10): 2359–2378.

Potter K, Ludwig C and Beattie C (2016) Responding to a 'flood of criticism': analysing the ebbs and flows of planning and floodplain development in England (1926–2015). *Town Planning Review* 87(2): 125–138.

Ramm, Timothy David, Christopher Stephen Watson, and Christopher John White. "Describing adaptation tipping points in coastal flood risk management." *Computers, Environment and Urban Systems* 69 (2018): 74-86.

Ramm, Timothy David, Christopher Stephen Watson, and Christopher John White. "Strategic adaptation pathway planning to manage sea-level rise and changing coastal flood risk." *Environmental science & policy* 87 (2018): 92-101.

Rauws, Ward, and Gert De Roo. "Adaptive planning: Generating conditions for urban adaptability. Lessons from Dutch organic development strategies." *Environment and Planning B: Planning and Design* 43.6 (2016): 1052-1074.

Rauws, Ward. "Embracing uncertainty without abandoning planning: Exploring an adaptive planning approach for guiding urban transformations." *disP-The Planning Review* 53.1 (2017): 32-45.

Rauws, Ward, and Gert De Roo. "Adaptive planning: Generating conditions for urban adaptability. Lessons from Dutch organic development strategies." *Environment and Planning B: Planning and Design* 43.6 (2016): 1052-1074.

Reguero, B. G., Losada, I. J., Diaz-Simal, P., Mendez, F. J., & Beck, M. W. (2015). Effects of climate change on exposure to coastal flooding in Latin America and the Caribbean. PLoS One, 10(7), e0133409.

Rodiek J (2007) Landscape planning in hazardous zones, lessons from Hurricane Katrina. August 2005. *Landscape and Urban Planning* 79(1): 1–4.

Schmidt L, Santos FD, Prista P, Saraiva T and Gomes C (2012) Alterações climáticas, sociais e políticas em Portugal: processos de governança num litoral em risco. *Ambiente & Sociedade* 15(1): 23–40.

Seattle's Waterfront Design Collaborative (2002) Waterfronts – open spaces and interfaces of edge environments. Available at: https://depts.washington.edu/open2100/pdf/2_OpenSpaceTypes/Open_Space_Types/waterfront.pdf (accessed Sept. 2016).

Smith, M. S., Horrocks, L., Harvey, A., & Hamilton, C. (2011). Rethinking adaptation for a 4 C world. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, *369*(1934), 196-216.

Souto-Moura E, Madureira NA, Pinto CD (2010) Matosinhos, Portugal: one City, one Port and two Marginais. *Portus: the online magazine of RETE*, 20.

Stead, Dominic. "Urban planning, water management and climate change strategies: adaptation, mitigation and resilience narratives in the Netherlands." *International Journal of Sustainable Development & World Ecology* 21.1 (2014): 15-27.

Stephens, Scott A., Robert G. Bell, and Judy Lawrence. "Applying principles of uncertainty within coastal hazard assessments to better support coastal adaptation." *Journal of Marine Science and Engineering* 5.3 (2017): 40.

Stokke K (2014) Adaptation to sea level rise in spatial planning – Experiences from coastal towns in Norway. *Ocean & Coastal Management* 94: 66–73.

Storch HV, Emeis K, Meinke I, Kannen A, Matthias V, Ratter BW, Staven E, Weisse R and Wirtz K (2015) Making coastal research useful – cases from practice. *Oceanologia* 57(1): 3–16.

Swart, R., Sedee, A. G. J., De Pater, F., Goosen, H., Pijnappels, M., & Vellinga, P. (2014). Climate-proofing spatial planning and water management projects: an analysis of 100 local and regional projects in the Netherlands. *Journal of environmental policy & planning*, *16*(1), 55-74.

Tang Z, Dai Z, Fu X and Li X (2013) Content analysis for the US coastal states' climate action plans in managing the risks of extreme climate events and disasters. *Ocean & coastal management* 80: 46–54.

Tompkins EL, Few R and Brown K (2008) Scenario-based stakeholder engagement: incorporating stakeholders preferences into coastal planning for climate change. *Journal of environmental management* 88(4): 1580–1592.

Van der Meulen F and De Haes HU (1996). Nature conservation and integrated coastal zone management in Europe: present and future. *Landscape and Urban Planning* 34(3): 401–410.

Veloso-Gomes F (2017) A variabilidade e as alterações climáticas nos projetos de ampliação e construção de novos portos. In: *Proceedings CLME2017/VCEM 8º Congresso Luso-Moçambicano de Engenharia / V Congresso de Engenharia de Moçambique* (eds FS Gomes et al.), Maputo, Moçambique, 4–8 Setembro 2017. Publ: INEGI/FEUP.

Veloso Gomes F (2015) Frentes marítimas, Ambiente e Património / Seafronts, Environment and Heritage. In: *IV CITCEM Conference – Crossing Borders Connecting Edges of Environmental History*, Vila Nova de Gaia, Portugal, 5–7 November 2015.

Veloso-Gomes F (2014) Os Molhes do Estuário do Douro. Uma primeira avaliação. *Portus: the online magazine of RETE*, May, 27.

Vinhas AA (2014) *Conceção e pré-dimensionamento de estrutura multifuncional na Praia de Matosinhos*. Master Thesis, Faculty of Engineering – University of Porto, Porto, Portugal.

Wadey MP, Cope SN, Nicholls RJ, McHugh K, Grewcock G and Mason T (2015) Coastal flood analysis and visualisation for a small town. *Ocean & Coastal Management* 116: 237–247.

Walker, Warren E., Harremoës, P., Rotmans, J., Van Der Sluijs, J. P., Van Asselt, M. B., Janssen, P., & Krayer von Krauss, M. P. (2003). Defining uncertainty: a conceptual basis for uncertainty management in model-based decision support. *Integrated assessment*, *4*(1), 5-17.

Walker, Warren E., Vincent AWJ Marchau, and Darren Swanson. "Addressing deep uncertainty using adaptive policies: Introduction to section 2." *Technological Forecasting and Social Change* 77.6 (2010): 917.

Wilby RL, Nicholls RJ, Warren R, Wheater HS, Clarke D, Dawson RJ (2011) Keeping nuclear and other coastal sites safe from climate change. Proc Inst Civil Eng Civil Eng 164:129–136

Williams SJ (2013) Sea-level rise implications for coastal regions. In: Brock JC, Barras JA and Williams SJ (eds) *Understanding and predicting change in coastal ecosystems of the Northern Gulf of Mexico*. Journal of Coastal Research, Special Issue No. 63:184-196, Coconut Creek (Florida), ISSN 0749-0208.

Yin J, Yu D, Yin Z, Wang J and Xu S (2015) Modelling the anthropogenic impacts on fluvial flood risks in a coastal mega-city: a scenario-based case study in Shanghai, China. *Landscape and Urban Planning* 136: 144–155.

Yzer, J. R., Walker, W. E., Marchau, V. A., & Kwakkel, J. H. (2014). Dynamic Adaptive Policies: A Way to Improve the Cost—Benefit Performance of Megaprojects?. *Environment and Planning B: Planning and Design*, *41*(4), 594-612.

Zandvoort, M., Campos, I. S., Vizinho, A., Penha-Lopes, G., Lorencová, E. K., van der Brugge, R., ... & Jeuken, A. B. (2017). Adaptation pathways in planning for uncertain climate change: Applications in Portugal, the Czech Republic and the Netherlands. *Environmental Science & Policy*, *78*, 18-26.