# MAKING URBANIZING DELTAS MORE RESILIENT BY DESIGN

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## INTRODUCTION

Talking about 'resilience' and 'adaptability' seems to be a new fashion in the world of architecture and urbanism. Many people use these terms without explaining what they mean. Both terms are often used in combination with, and even as synonym of, terms like 'incremental' and 'bottom-up' and as an alternative of large scale 'top-down' interventions by the state.

But it is far more than a new fashion; the use of these terms indicates a process of fundamental transition of paradigms in planning and design. This paradigm-change is related to a farewell of modernist and reductionist ideas and approaches in science, engineering and design. For a long time these modernist ideas were dominating, suggesting that it is possible to *know and understand* the world (the social world as well as the physical world) completely, and that, based on this knowledge, it is possible to *plan and control* the development of the world completely.

A large range of events contributed to the rising idea that it is impossible to know, predict and control the world completely: the social revolts of the 1960s, the messages of the Club of Rome in the 1970s, the concerns with climate change since the 1990s and many more. They contributed to an increasing awareness that systems in nature as well in society are *complex*, and that the developments of these complex systems are non-linear, with a basically *uncertain future* ( Scheffer 2009; Mitchell 2009). This uncertain future means that we have to take into account that disturbances can happen suddenly, unexpected, and also that external conditions can change substantially. Moreover, the size and scale of these disturbances and changes are unknown.

The situation and the challenges in urbanizing deltas are interesting examples in the current discussion. In a recent report, composed by TU Delft and the Delta Alliance, commissioned by the Dutch Ministry of Foreign Affairs for the preparation of the UN-Habitat-III conference, the authors argue that delta regions are the most promising regions of the world, but in the same time these regions are the most vulnerable zones, were floods, draught, salinization and pollution result in major risks for millions of people, for economic development and for the environment (Meyer, Peters 2016).

Deltas function as magnets for economic development and urbanization already during many centuries. Their position at the crossroads of navigation routes created many transshipment points of international trade; the fertility of alluvial plains and the estuarine and coastal waters, make deltas attractive for agriculture and fishing.

At present, deltas are magnets for urbanization and economic development more than ever. In 2050, ca 650 million people will live in delta and coastal urban regions. In many nations, delta- and coastal regions are the engines of the national economies with the highest contributions to national GDPs.

However, these same conditions for economic growth, urbanization and prosperity generate also a growing risk for flooding, resulting in increasing numbers of victims, severe economic damage and ecological downgrading. The concentration and densification of urban and industrial land use has resulted in the disappearance of the natural formative power of deltas. Increasing flood risk is a consequence of this disappearance of delta territories' natural resilience capacity and is reinforced by sea level rise caused by climate change.

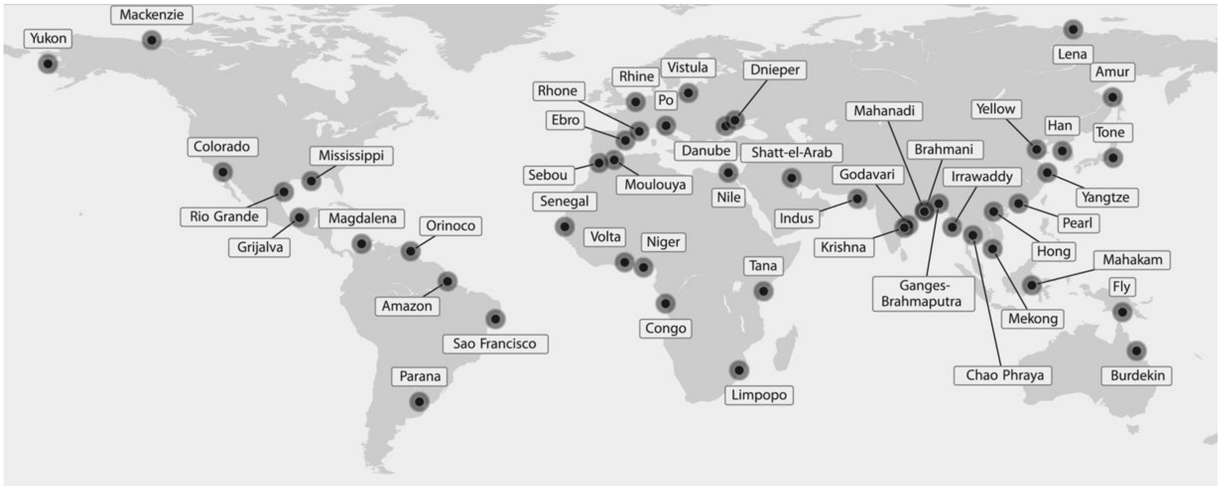
Land subsidence as a result of intense drainage and groundwater extraction increases the vulnerability of urbanized as well as rural areas, often dropping below mean sea level. Between 1980 and 2013, the global direct economic losses due to floods exceeded $1 trillion (2013 values), and more than 220,000 people lost their lives (Winsemius et al. 2015). It is expected that populations vulnerable to flooding by storm surges will multiply tenfold or more over the 21$^{st}$ century and this will affect an estimated 100 million people each year (Nicholls et al. 2007). Floods in urbanizing deltas have disastrous impacts on the economy as well as on the ecology of entire countries. As a consequence of flooding, local and national economic activities are disrupted for a long time, leading to a substantial decrease in GDP. The 2015 World Economic Forum (WEF) Risks Report has put the impact of Water Crises as the number one global risk (WEF 2015).

The high risk for flooding, heat stress, water shortages and poor air quality, resulting in increasing amounts of socio-economic impacts; huge economic losses, increasing amounts of lives at risk and severe ecological downgrading or impacts on natural capital. Worldwide the impact of climate change, if adaptation is not taken place, is expected to grow to 500 billion or 1 trillion US Dollars a year by 2050 (World Bank, 2013).

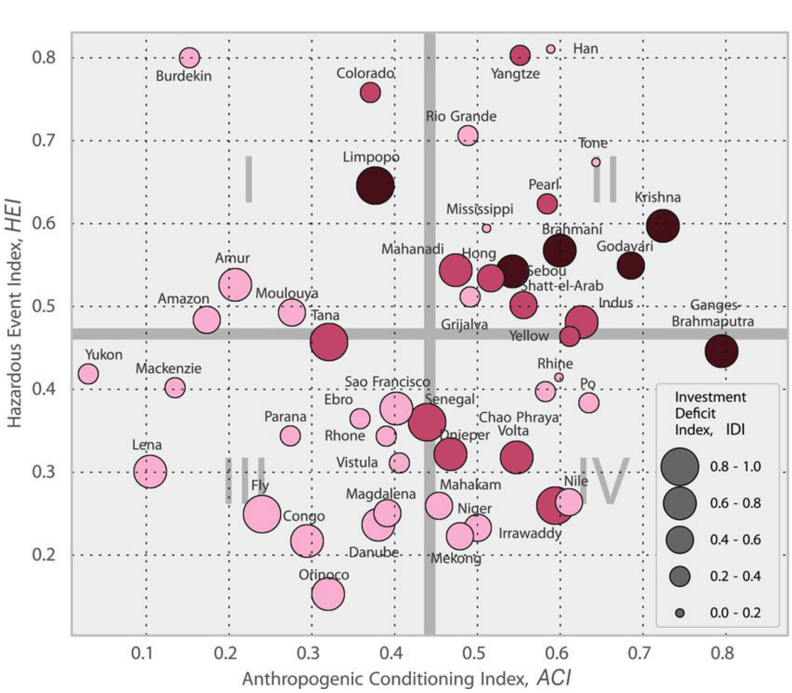
Because of increasing flood risk and flood hazards, mass migration to deltas and coastal areas can quickly turn into the reverse – which is already the case in some areas. Floods in New Orleans (2005) and east Japan (2011) resulted in the departure of many people who never returned.

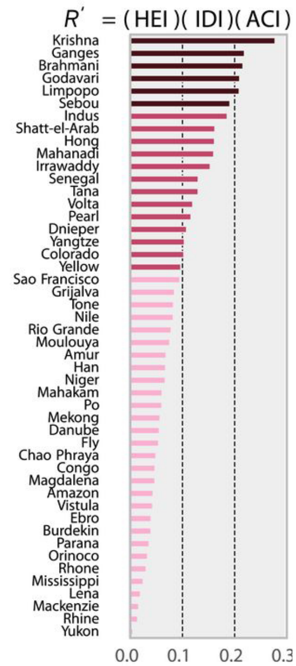
A fundamentally new approach is necessary, creating more room for natural and social processes, which can contribute to an increasing resilience of these urbanizing deltas.

The next paragraphs will address (1) the essence of an approach which lead to an increasing resilience; (2) what is the difference with the approach of modern engineering and planning in leading benchmarks like The Netherlands and the USA, (3) the central role of design in the search of a new approach in two recent projects in The Netherlands and the USA.




A *Map showing the 48 deltas included in a study by Tessler et al., 2015.*




B *Phase diagram of contemporary risk assessment results, showing the three component proxy indices used to estimate per-capita R'. Color density represents a delta's overall risk trend. Quadrant III deltas have predominantly low R', whereas quadrant II deltas have high R'.*

C *Estimates of the relative rate of change in risk, or risk trend, for each delta due to increasing exposure associated with RSLR.*

FIGURE 1 Risk trends for deltas worldwide
The Krishna and Ganges-Brahmaputra deltas, despite being only moderately susceptible to short-term hazardous events, are increasingly at risk because of high rates of RSLR and high socioeconomic vulnerability. Ganges-Brahmaputra is abbreviated to "Ganges" in some panels for brevity.
Source: Tessler et al. 2015.

## RESTORING THE NATURAL AND SOCIAL RESILIENCE AND ADAPTABILITY OF THE DELTAS

### NATURAL RESILIENCE

A widespread misunderstanding is that delta areas are problematic because of the fickleness of rivers, seas and because of the changing climate. However, deltas are the *products* of the convergence of rivers and the seas. This convergence produced the alluvial plains, as the result of the processes of sediment transports and deposits. Dependent on the formative power of sediments transported by river, tidal currents or waves, we can distinguish river-dominated deltas, wave-dominated deltas and tide-dominated deltas (Bradshaw, Weaver 1995). All these different deltas have in common the fact that they contain the richest ecosystems of the world, with the largest amount of ecosystem services (Costanza et al. 1997). The gradual transitions between land and water and between salt and fresh water are the biotopes and nurseries of many species that are crucial for the ecological balance of the world's rivers and oceans. Next to the ecological value in terms of biological productivity and diversity, the ecosystems have significant economic value via ecosystem services such as: coastal protection, maintenance of fisheries and wildlife, erosion control, water catchment and purification, carbon sequestration, nutrient cycling, tourism, recreation, education and research (Barbier et al., 2011; de Groot et al. 2012).

Urbanization, industrialization and modern agriculture has led to a serious depletion of the natural system of deltas, with three characteristics:

A Decrease of the formative power of the deltas through dramatic losses of the ecosystem services. Intense urban and industrial land use, drainage, dredging, reclaiming and damming have deprived the land-water ecosystems of their capacity to absorb the impact of extreme events and their resilience to restore balance after disturbances. Moreover, because of upstream damming and reservoirs, the sediment resources in rivers have been substantially depleted, causing serious erosion of delta and coastal landscapes (Mulder et al. 2010; Campanella 2014). In their research on 40 deltas around the world, Ericson et al. show that sediment trapping is the main cause of erosion in 27 of these 40 deltas (Ericson et al. 2006).

B Land subsidence, caused by intense drainage and (industrial use of) groundwater extraction. As an outcome, urban and agricultural territories in many deltas (including the Nile delta, Rhine-Meuse delta, Mississippi River delta, Jakarta, etc.) have dropped substantially below sea-level, making these territories more vulnerable to flooding. This process is still going on in many urbanizing deltas, leading to uncontrollable flood risk.

C Increase of salinization, caused by the combination of intense dredging, land subsidence and sea level rise, and resulting in a shortage of freshwater supply. Many urbanizing deltas find themselves in a paradoxical situation: surrounded by water, but lacking *fresh* water, leading to problems including a lack of drinking water and water for irrigation.

It is necessary to revitalize the capacity of deltas after disturbances. This revitalization must occur by protections and enhancement of the natural land-water transitions: beach and dune systems, salt marsh systems, coastal coral reefs and mangrove forest systems. In the long term, 'building with nature' delivers the conditions for delta regions to adapt to climate change continuously, by using the formative power of nature as the strategy's foundation. Next to it, the introduction of 'green-blue infrastructures' is necessary to create continuous and sustainable groundwater levels, which will provide storage-capacity during rainstorms ànd stop the process of land-subsidence (Bacchin 2015).

Many urbanizing deltas are not only victims of climate change but also *contribute* to climate change through their functions as important centers and transportation hubs of fossil fuel-based economies with large greenhouse gas emissions. The world's largest centers of trans-shipping, storage and fossil fuel processing are situated in deltas; the economy of these delta regions is thus largely based on transshipping, storage, processing, financing, accountancy and insurance of fossil fuels.

The transition to more sustainable energy sources will greatly impact urbanizing deltas. A major challenge is the reorganization of ports and industrial plants, combining adaptation (new types of land use with attention to ecology and flood defense), mitigation (substantial reduction of greenhouse emissions) and developing new initiatives for a circular economy and energy transition. The role of urbanizing deltas in the world's economy and ecology can change in a radical way: from being the crucial hubs of the old fossil fuel-based economy, urbanizing deltas can become the engines of a new, clean energy-based and circular economy.

The development of ports and navigation channels are a critical factor in urbanizing deltas. Dredging in estuaries and rivers has a high impact on upstream areas, leading to higher tidal fluctuations, salinization and flood-risk in these areas. The development of ports and navigation channels can be considered a critical factor in a strategy to enhance the resilience of the deltas. New concepts and policies for the location and lay-out of ports and cargo transport to upriver destinations are a major priority. As an example, the Port of Rotterdam, in collaboration with the World Wildlife Fund and Deltares, developed a new concept of *The Port of the Future*. This concept will be implemented with local stakeholders and citizens, in order to contribute to the environmental and social resilience of the urbanizing delta. The concept is also being explored in Ghana (Schipper 2015).

## SOCIAL RESILIENCE

The improvement of the natural resilience of deltas is linked directly to the improvement of the social resilience. The speed and scale of the current human migration to coastal and delta areas is unprecedented and creates high risk for extreme social inequality. The consequences of increasing flood-risk especially affect the population with the lowest income, often recently arrived in the city and living in areas that were not previously urbanized – often because they are the most vulnerable areas of the deltas. The informal spatial organization of these neighborhoods and weak building construction are often reasons behind the relatively large amount of urban poor victims.

Next to the danger of drowning, floods result in mass health and scarcity problems, disproportionately affecting the urban poor (Wisner et al. 1994).

What makes the problem of the urban poor in delta areas special, is the lack of risk-awareness. Social inclusiveness should start with a strong policy to inform and communicate with the population concerning the increasing risks of the area.

Building sustainable and resilient urbanizing deltas means that strategies for flood prevention and ecological repair should be based on involvement of people living in the most vulnerable areas and lead to a higher quality of life for all social groups.

The inclusion of civil society and the private sector in the implementation of activities means that there is likely to be greater 'ownership' of these interventions, and that they will be maintained and protected more effectively, in part because the capacity of various actors will be strengthened to take proactive measures. If citizens perceive interventions as contributions to their wellbeing they may be more likely to be directly involved in the implementation and maintenance of ecological and resilient projects, potentially generating cost savings.

## A SHORT HISTORY OF INCREASING RESISTANCE OF URBANIZING DELTAS

The development of this new approach stands in screaming contrast with the dominating strategies on water management and spatial planning in the 20th century. The two countries who spent the largest part of their national budgets to water- and delta management worldwide during the 20th century, are the Netherlands and the USA (O'Neill 2006). The approach of both countries show exactly the *opposite* of what is necessary as described above.

Especially The Netherlands developed a reputation as the world's leading benchmark in flood control and spatial planning. Especially the large scale works of the Zuiderzee works and the Delta works are considered the icons of a 'battle against the water'.

It is true that these works contributed to an enormous progress of welfare in The Netherlands. They were part of a program which transformed The Netherlands from a retarded and vulnerable delta into a rationalized industrial landscape, creating the condition for the rise of a prosperous welfare-state (Meyer 2012; 2016).

However, a lot of the natural and social resilience capacity of the Dutch delta was lost.

The basic aim of the approach of the Dutch state during the 19th and 20th century was to increase the *resistance* of delta territory. The river-system, the drainage systems in the polders and the coastline were considered as parts of a *machine*, which could be controlled, regulated in order to improve the conditions for economic exploitation and to decrease the flood risk substantially. In this strategy, the national state was in charge, especially the state-organization Rijkswaterstaat, founded in 1798 when The Netherlands were under control of Napoleonic France (Bosch, van de Ham 1998).

Together with the new canals Nieuwe Waterweg en Noordzeekanaal, Serious floods in the regions of the Zuiderzee (1916) and the Southewest delta (1953) accelerated the drive to construct the Zuiderzee works and Delta works during the 20th century. These works resulted in a shortening of the coastline and a transformation of the Zuiderzee and South-west delta into sharp divisions of fresh and salt water. Both Zuiderzee works and Delta works didnot only deliver more safety, but also transformed the estuaries in fresh water basins, which support the extension of agricultural land and the agricultural productivity. Also the petrochemical industry in the Rotterdam port-area would take advantage of the large scale availability of fresh water (de Vries et al. 2010). The choice of petrochemical industrial companies for settlement in the Rotterdam port was based largely on this fresh water availability and resulted in the development of the Rotterdam port to the second largest petrochemical complex of the world.

The *territory* of the delta was reduced from a complex, rich and sometimes dangerous natural environment into a limited amount of water-basins which were organized and controlled in an ordered way, each with their own role and quality.

The goals of the policy concerning flood protection were combined with goals to build a modern, industrial society, and to avoid metropolitan development by building an equally distributed pattern of small and medium-size urban communities. Metropolitan areas were considered uncontrollable, delivering conditions for congestion, diseases, criminality and boring environments. By taking the lead in large scale production of social housing, the national government was able to implement the aims concerning equal spatial distribution of urban growth.

The transformation of the Netherlands into a rationalized delta was a *modern project* par excellence.

The development of the Netherlands in the 20th century was an extreme example of the implementation of the idea that the nation-state can be considered and treated as a rationalized construction, as a *machine*. based upon 100% planning, engineering and control of the natural territory as well of the society. *'Dredge, Drain, Reclaim – The Art of a Nation'* was the title of a book, written by the godfather of the Delta works, Johan van Veen (van Veen 1950).

More than 60 years after this publication, we can say that this 'art of a nation' resulted in a large success, from a point of view of water safety and economic development. However from a long-term perspective on maintenance, supported by the population, the flood risk system is less promising.

As a consequence of 'dredge, drain and reclaim', the land in the western part of The Netherlands is subsiding, the coast is eroding as a result of a lack of natural sediment deposits, dredging resulted in increasing salinization and the reclamation of floodplains in the river area resulted in a decrease of the discharge capacity of the riverbeds. Moreover, many projects suffered a lack of local support.

The big water works of Rijkswaterstaat were not discussed with local people or organizations. That was not so strange in the case of the Zuiderzee works – these works concerned the building of new land, where nobody was living. But in the case of the Delta works, economic and environmental organizations in the Southwest delta plead to get involved in the planning process of these works. The Dutch government rejected these pleas, with the argument that the Delta works were part of a *national* interest (Meyer 2016).

With this lack of involvement of local people and organizations in the planning process, the approach of the large water works dug its own downfall. The increasing discontent of people with the serious consequences for the local economy (especially fish- and shellfish industries) and the increasing awareness of the value of environmental and spatial qualities, led to a series of protests against the completion of the large water works. The result was the cancelling of the reclamation of the Markerwaard (the last part of the Zuiderzee works), the construction of a storm-surge barrier instead of a closing dam in the East Scheldt, and the need to change the original dike-enforcements in the central river area into more carefully designed projects, which were adjusted to the spatial character of the landscape.

The development of flood control in relation to spatial planning in the USA is comparable with the Dutch approach in many respects. In the 19th century, flood control was regarded as a responsibility of the federal state; the US Army Corps of Engineers became in charge of this task. Even more then the Dutch Rijkswaterstaat, the Army Corps focused on the organization of the North-American river system as a controllable machine, and didn't tolerate any local meddling (Barry 1997).

The central focus of the Army Corps was on the streamlining of the Mississippi river as the main artery of the US economy (O'Neill 2006). The construction of a dike system along the borders of this river in the Mississippi river delta led to the end of the process of sediment disposal in the delta, and, consequently, to a process of serious erosion of the delta. Louisiana lost nearly 5,000 square kilometers of coastal wetlands – about one-third of the Mississippi delta – since the 1930s (Campanella 2014). The loss of wetlands and the lack of new sediment disposal led to a decrease of the role of the wetlands as a buffer between the sea and the City of New Orleans, and to a total disappearance of the possibility to recover after hurricanes. In order to protect New Orleans against the increasing flood risk, the Army Corps provided the city with a 'system of rigidity' (Campanella 2014), which failed dramatically during hurricane Katrina in 2005.

## TOWARDS A FUTURE OF INCREASING RESILIENCE OF URBANIZING DELTAS

The good news is that new experiments have started in both countries, which can be considered the start of a new approach to flood risk in combination with spatial planning and design.
In the Netherlands, the central river area came in serious trouble during two extreme river discharge events in the 1990s. They were the first signs that the process of climate change developed in another direction than was foreseen.
In the United States, the hurricanes Katrina (2005), Ike (2008) and Sandy (2012) led to huge damage and many deadly victims in New Orleans, Houston and the East Coast.

These events speeded up the awareness that the water safety system should be improved. In the same time, it was clear that the conventional centralistic approach of the state wouldn't work anymore. In both countries the social and economic pressure to combine flood defense strategies with local interests in economic development, spatial environmental quality, was increased strongly.

In the Netherlands, a new program for the central river area ('Room for the River') was implemented in 2005-2015, while a national Delta program started in 2009.

In the US, especially the 'Dutch Dialogues' program in New Orleans (2007 – 2011) and the 'Rebuild-by-Design' program in New York (2013-2015) can be regarded important attempts to develop a new approach.

In both programs, design played a crucial role as a tool of exploration of new perspectives, combining different interests and different scales.

The Dutch program 'Ruimte voor de Rivier' (Room for the River) showed an important innovation in the national policy. The program concerns the total Dutch part of the river basins of Rhine and Meuse, and aims to increase the capacity of the river basins for extreme discharges from 12.000 to 16.000 m3/sec (Rhine). The program can be considered a breaking event because of two reasons.

First, instead of a focus on enhancing and raising the existing dikes, the program emphasized the need to widen the riverbed, in order to provide more room for the river, creating a condition of 'building with nature' ànd improving environmental qualities and ecological conditions of the river beds. Second, the program was not developed completely by a central state organization. A central program-bureau defined a series of general rules concerning the needed capacity of the riverbed. At a local project-scale, these rules were combined with the desires and ambitions of local administrations, civic organizations and business institutions. Interdisciplinary teams of engineers, scientists and urban and landscape designers played a central role in bringing these general rules and local preferences together, in an interactive process of research-by-design and collective workshops. As a result, as well the central program bureau as the local stakeholders agreed that this approach resulted in a substantial improvement of the flood defense system and of the spatial and environmental quality (Klijn et al. 2013). The approach resulted in a strong involvement of local people, sometimes with their own design proposals. In two polders (Overdiepse Polder and Noordwaard) which are determined to be flooded during high water events, farmers succeeded to convince the planners and engineers that it is possible to combine the goal of temporary water retention with their wish to stay with their farms in the polders. Special mounds have been constructed for the new farms, which will stay dry during the high water events.

These initiatives are examples of an increasing involvement of local citizens in the national flood risk program.


FIGURE 2 Overview of projects of the program Room for the River. Source program bureau Room for the River

FIGURE 3 Aerial view of polder Noordwaard during reconstruction, 2015. Aerophoto Schiphol

FIGURE 4 Birds eye perspective of the Greater New Orleans Urban Water Plan 2013. Drawing by Sabien Thomaesz, Palmbout Urban Lanscapes

In the US comparable developments are taking place. In 2007, Dutch designers, scientists and engineers were invited to participate in a collective design process in New Orleans, together with American colleagues, and presented as the 'Dutch Dialogues'. Interesting is that the initiative was taken by local citizens, led by the New Orleans based architect David Waggonner. As a final result, the American-Dutch consortium produced the 'Greater New Orleans Urban Water Plan' (Waggonner et al. 2014). The plan proposes a system which is different from the pre-Katrina system in two ways. First, instead of a continuing soil subsidence by intensive drainage, the new water system will result in a stabilization of soil- and groundwater levels by creating more space for retention and storage of storm water. Second, instead of separating urban districts and downgrading public spaces, the new water system will contribute to new spatial quality and coherence of the urban fabric. The plan shows that innovative water management strategies not only improve protection against flooding, but also create new perspectives for the economic and social future of the delta city. The most innovative aspect of the plan is the way in which hydraulic engineering, spatial design and governance are related to each other from the regional to the neighbourhood scale and the scale of the private parcel. This means that the plan only can be successful if it can count on the a wide support and involvement of local people.

## CONCLUSION ▪ INTEGRATING SCIENCE, DESIGN AND ENGINEERING

Ongoing densification and transformation of urbanizing deltas is possible but requires clear regulations and needs explorations by design. 'Building with nature', stopping the processes of land-subsidence and salinization, and the possibility to combine these ambitions with new economic developments and social inclusion, requires a well-organized balance among science, planning, design and engineering.

It is important to be aware that different scales are strongly linked with each other:

The scale of the *drainage basin* of the river(s), the scale of the *delta* and the scale of *local interventions*. Deltas are dependent on the water and sediment supply from the rivers, which can be trapped by upstream interventions (like hydropower dams, freshwater reservoirs, canalization and deforestation). In return, interventions in the deltas like dredging and damming can lead to ecological downturn in upstream areas and salinization. Communication and negotiation between planning authorities in the drainage basins and delta regions is essential to ensure a delta's sustainable future.

Working on the sustainable future of urbanizing deltas requires an approach that combines long term and large-scale planning with small-scale projects that can be implemented on the short term. Plans and Projects should be considered as two linked and parallel pathways of a sustainable, 'learning-by-doing' planning approach. Projects need to be evaluated and monitored so the results can be continuously used to specify or modify overall plans.

Green-blue infrastructures can play a central role as frameworks which can be adapted to changing conditions in the course of time, delivering space for combinations of long term water- and nature-sensitive urban environments with economic and social initiatives. Open spaces in urban areas (wet, dry and vegetated), provide alternative design possibilities for synergies among nature, infrastructure and users. They provide a new balance among the maintenance, storage and discharge of storm water, resulting in a stabilization of groundwater levels and stopping the process of land subsidence. Moreover, these infrastructures and the process of their design have been proved to play a key role in urban revitalization, economic development and community-building. The Room for the River project and the GNO Urban Water Plan are examples of this approach.

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