IUL School of Social Sciences

Department of Political Economics

Cost-benefit analysis in climate change adaptation: the use of participatory methodologies

Filipe Miguel Moreira Alves

Dissertation submitted as partial requirement for the conferral of

Master in Economics and Public Policies

Supervisor:

Catarina Roseta Palma, Associate Professor,
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This Master thesis is dedicated to all of those working in climate change adaptation who believe in the power of participatory inclusive processes to mobilize and trigger action, and in the wisdom of local stakeholders to value and better judge their investments towards greater resilience and sustainability using alternative methodologies to conventional cost-benefit analysis.

Part of the action-research leading to the results presented in this Master thesis, namely the case study implementation documented in chapter 6, has received funding from the European Community's Seventh Framework Programme under Grant Agreement No 308337 (Project BASE).

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Resumo

A análise custo-benefício, enquanto ferramenta económica de avaliação de projetos públicos ou privados, tem evoluído significativamente nos últimos 200 anos, acompanhando e seguindo quer os desenvolvimentos ao nível da ciência económica, nomeadamente Economia do Ambiente, quer os desenvolvimentos ao nível da análise de projetos e políticas públicas. Apesar das inúmeras e contínuas críticas que lhe são apontadas quer ao nível teórico-académico, quer político, quer socioeconómico, a análise custo-benefício tem-se mantido no centro de uma crescente cultura de avaliação económica dentro dos países da OCDE e tem inclusive ganho cada vez mais peso, nomeadamente ao nível da União Europeia. Nesta tese, fazemos uma análise histórica da evolução teórica e prática da análise custo-benefício, com particular interesse à sua utilização na análise de estratégias e medidas de adaptação às alterações climáticas, apresentando ferramentas e metodologias alternativas e culminando com uma proposta inovadora de uma análise benefício-custo participada, metodologia desenvolvida e testada no caso de estudo de Cascais no âmbito de um projeto europeu de investigação-ação.

Abstract

Cost-benefit analysis, as an economic evaluation tool of public or private projects, has evolved significantly in the last 200 years following the developments in terms of economics, namely Environmental Economic, and developments in project analysis and public policy evaluation. Despite numerous and ongoing criticisms both at a theoretical, academic level as well as at a socio-economic, political level, cost-benefit analysis has remained at the center of a growing culture of economic project appraisal within OECD countries and has even won increasing weight and political recognition, particularly in the European Union. In this thesis, we make a historical analysis of the theoretical evolution and practice of cost-benefit analysis, with particular interest in terms of its use in the analysis of strategies and measures for climate change adaptation, presenting alternative methodologies and tools for the economic appraisal of projects and culminating with an innovative proposal for a participatory benefit-cost analysis, a methodology developed and tested in the Cascais case study under an European action-research project.

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List of Abbreviations

ABCD – Asset-based Community Development

APA – Portuguese Environmental Agency

AR – Assessment Report

BASE – Bottom-up Adaptation Strategies towards a Sustainable Europe

CBA - Cost-Benefit Analysis

CCIAM – Center for Climate Change Impacts, Adaptation and Modelling

C.M.C. – Cascais Municipality

EEA – European Environmental Agency

ELECTRE – Elimination and Choice Expressing Reality

EPA – Environmental Protection Agency

E.U. – European Union

FCUL – Faculty of Sciences of the University of Lisbon

FP7 – Framework Program 7

GDP – Gross Domestic Product

GHG – Green House Gases

IPCC – Inter-governmental Panel for Climate Change

WFD – Water framework Directive

MAUT – Multi-attribute Utility Theory

MCDA – Multi-criteria decision Analysis

MCDM – Multi-criteria Decision-making

NPV – Net Present Value

OECD – Organization for Economic Cooperation and Development

PAR – Participatory Action-Research

PBCA – Participatory Cost-Benefit Analysis

PECAC – Strategic Plan of Cascais for Climate Change

PROMETHEE – Preference Ranking Organization Method for Enrichment Evaluation

SDR – Social Discount Rate

STPR - Social Time Preference Rate

SPCBA – Simplified Participatory Cost-Benefit Analysis

UK – United Kingdom

UNFCCC – United Nations Framework Convention for Climate Change

U.S. – United States of America

1. Introduction

Every day we make decisions, choices, we select between options. Whenever we make a choice, whether it is buying a car or choosing the path home, unconsciously or consciously, we weigh the costs and benefits of each alternative, sometimes even considering both the present and the future. We might not always monetize our options but we do weigh uncertainty, overall contribution to our welfare, to the welfare of others, pleasure versus pain, among many other factors, and we choose. Several times a day, we undertake simple, individual, informal, cost-benefit analysis of different alternatives. It is even possible to state with relative certainty that human beings have been measuring the costs and benefits, i.e., the perceived positive and negative direct impacts and externalities of their actions, since the emergence of the first societies (Omura, 2004). However, one must acknowledge that the structured, formal, methodology to conduct an economic assessment of costs and benefits of any given project or investment is relatively recent in human history and can only by traced back in the literature to the (not often cited) fourth Secretary of U.S. Treasury, Abraham Alfonse Albert Gallatin (1761-1849), a Swiss-American who as early as 1808 recommended to the U.S. congress the comparison of costs and benefits in major, state-owned, water-related projects (Hanley, 1993). Gallatin, Secretary of Treasury in the U.S. for 13 years due to his mastery of public finances, was a man deeply concerned with a healthy and balanced state deficit, and preceded by 35 years the work of the Italian-French civil engineer Jules Dupuit (1804-1866). Dupuit, considered one of the founding fathers of cost-benefit analysis, was one of the first to really confront the issue of mediating between individual preferences and aggregate social functions. Although a seemingly logical and relevant development in political economics at that time, the fundamental question of preference aggregation still remains till this day a major source of debate, criticism and limitation for full economic assessment an overall social well-being considerations (Nyborg, 2012).

Although Dupuit and many of his contemporaries started the debate over marginal utility for specific projects it took a few years until Herman Heinrich Gossen, the famous nineteenth century Prussian economist, was able to generate the first General Theory of Marginal Utility in his book '*The Laws of Human Relations and the Rules of*

Human Action Derived Therefrom' (1854). The theoretical discussion over utility functions, individual preferences versus socially aggregated preferences, which is at the core of cost-benefit analysis, really took off in the 1870's, a period known as the Marginalist Revolution, led by the works of Leon Walras, William Jevons and Carl Menger. But, it was only with a second generation of Marginalist thinkers lead by Alfred Marshall that it was properly mainstreamed into economics. These, together with the development of the notion of externalities by Henry Sidgwick (1883), Marshall (1890), A. C. Pigou (1920) and finally in the work of John Hicks (1939, 1943), Nicholas Kaldor (1939) and others such as Vilfredo Pareto, are the theoretical foundations of CBA - Welfare Economics – and the notion of overall social welfare functions (OECD, 2006). These economic theoretical foundations of CBA, which have been evolving hand-in-hand with its practical application as well as with the developments in environmental economics, and more recently with the sustainability agenda, will be discussed further in chapter 2.

As an economic appraisal tool which has continuously gained momentum and importance throughout the twentieth century, withstanding fierce and growing criticism from all corners, CBA has become central to an evaluation and project appraisal culture in the developed world (Shapiro, 2010; EEA, 2012). In chapter 2, we will further review CBA, while existing methods and alternative solutions are presented and discussed in chapter 3. In fact, CBA is not alone and many other tools for economic appraisal of projects have co-evolved in the past 50 years. Some run parallel to CBA, others compete directly, while many are used to complement or suppress CBA's limitations. Cost-Effectiveness Analysis (CEA), Multi-Criteria Decision Analysis (MCDA), as well as Participatory CBA will be compared and analysed in chapter 3 where the focus of our analysis will be the use of such tools in climate change adaptation and mitigation projects, acknowledging the words of Sir Nicholas Stern: "*Climate change is the biggest market failure the world has ever seen*" (Stern, 2007). In fact, the past two decades saw a great increase in concern over climate change, supported by growing scientific evidence and confidence, as well as increased pressure from the environmental movement, from affected populations worldwide and even from business leaders, who in a 2011 survey from the independent think-tank SustainAbility ranked Climate Change as the single most important challenge facing society today (SustainAbility, 2011). Climate change is an appropriate test for CBA due to its intrinsic public good nature, intergenerational

equity issues, distributional challenges, uncertainty and complexity. While many claim CBA to be obsolete and inefficient to deal with the scale and nature of climate change (Sáez, 2006), entities such as the European Environmental Agency consider it a priority tool for policy-makers at the EU level and decision-makers at the local level.

Chapter 4 sets the agenda for the use of cost-benefit analysis in climate change, while in in chapter 5 we'll look at the 'Participatory Benefit-Cost Analysis'. This tool, developed under the European Community Seventh Framework Programme project BASE – Bottom-up Adaptation Strategies towards a Sustainable Europe - was applied in the case study of Cascais, which is presented in chapter 6 together with the results from its use in three participatory workshops. Throughout the thesis we will discuss the practicability, adequacy and effectiveness of CBA for projects related to climate change, considering in the conclusion a cost-benefit analysis of CBA for local decision-making processes for climate change adaptation-related projects.

2. Cost-Benefit Analysis: theory, applications, limitations and criticism

> *"*Legislators have prescribed the formalities necessary for certain works to be declared of public utility; political economy has not yet defined in any precise manner the conditions which these works must fulfill in order to be really useful; at least, the ideas which have been put about on this subject appear to us to be vague, incomplete and often inaccurate. (…) The law ought merely to confirm the facts demonstrated by political economy. How is such demonstration to be made? Upon what principles, upon what formula, does it rest? How, in a word, is public utility to be measured?*"*
>
> (Dupuit 1884)

2.1 Theoretical background

As noted in the Introduction, Albert Gallatin's request to the U.S. Congress in 1808 stands as the first concrete and official cost-benefit analysis to ever be demanded for public investments. However, it is Jules Dupuit and his work 'De la Measure de l'Utilité des Travaux Publics' (1884) which truly launches the cost-benefit debate into political economics and public decision-making. Dupuit gained a reputation as an economist with several important articles, some of them introducing the first attempts to describe the fundamentals of what was latter tagged as Marginalism, a central piece of the 'cost-benefit analysis puzzle'. Dupuit focused on very specific phenomena, like the optimum toll for a bridge or the economic justification for a road, trying to show how the net benefits were measured by the consumer surplus (OECD, 2006). By consumer surplus Dupuit meant the difference between the price one had to pay for a certain product or service, and the price one was willing to pay for it. He even goes further in saying that "(...) the only real utility is that which people are willing to pay for" (Dupuit, 1952: 84).

Dupuit developed his own theory of utility and willingness to pay (WTP), but he openly admitted the inherent limitations of the tools available for this measurement, either statistical, theoretical or ethical, and pointed the way for future developments in political economy stating in his conclusions that "…the less complete and accurate are the available data in problems of political economy, the more needful it is that the rigor

of fundamental scientific principles be applied to them if they are to be handled skillfully and effectively in practice".

The quest for scientific objectivity in economics was the dominant objective of the Marginalist Revolution which strongly influenced the development of microeconomics and which was fundamental in shaping the economic thought from the late nineteenth century till today. The famous economist Alfred Marshall and his mathematical-analytic method was of paramount importance in this transition from classical political economics to neo-classical theory, namely regarding consumer theory and marginal utility. Marshall was able to develop Dupuit's consumer surplus and WTP discussions further and draw not definitions but mathematical theorems – for example the Marshallian Consumer Surplus, which is given by the mathematical area below the demand curve (Figure 1).

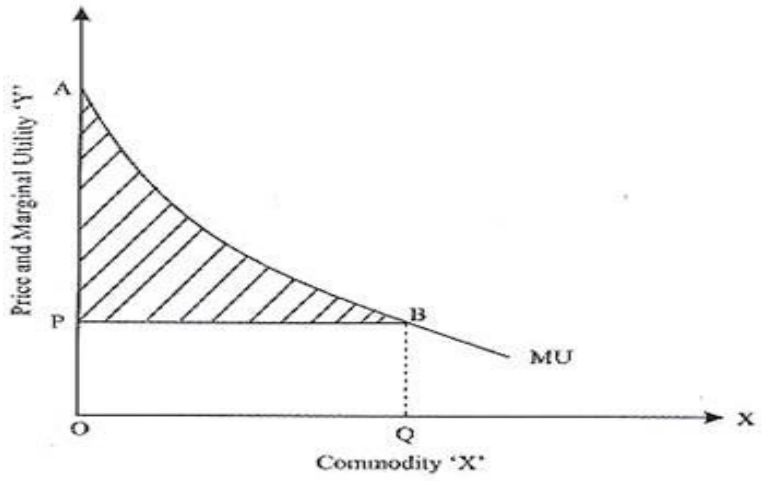

Figure 1 - Marshallian Consumer Surplus

Nevertheless, it is important to mention that during the period of the Marginalist Revolution in England, even the concept of utility, on which everything else rests, varied from author to author and was neither stable nor immune to criticism (Martionoia, 2003). Jevon's definition of utility was based on added pleasure minus added pain regarding overall happiness of any given person. Sidgwick on the other hand stated that by utility of material things "we mean their capacity to satisfy men's needs and desires" (Sidgwick, 1883). According to Rozenn Martionoia, Marshall himself was dubious on the matter and moved between concepts in his writings on welfare economics. The central issue was, of course, how to accurately measure changes in

pleasure, pain or desire, both individually and then collectively in order to draw conclusions on the social impact of a project. As he once wrote: "It cannot be too much insisted that to measure directly or *per se*, either desires or the satisfaction which results from their fulfillment is impossible, if not inconceivable" (Marshall, 1920: 78). Moreover, even if such measurement was possible, other authors like Harsanyi (1955, 1997) argued that concepts like happiness, well-being and so forth, may not even be consistent with empirical choices, adding another layer of complexity to the objective at hand. Amartya Sen (1985) went even further in clearly distinguishing between "what is good" for each person and what that person considers good for him/her, separating desire from well-being and in doing so, adding yet another question mark to the theoretical foundations of CBA.

These 'impossibilities', to which we'll return, already questioned by the marginalists, did not stop Marshall, and his work continued through the indirect evaluation of desire using money as a measure, thus returning to Dupuit's WTP as a quantitative measure of desire. The challenge that troubled Marshall was to find conditions under which a money measure of consumer welfare would be equal to the 'real' utility surplus. Although this might seem reasonable and logical, the assumptions that allowed Marshall to develop his theory, specifically the constant marginal utility of money (MUM)[1] and the path (in)dependency of money measures, were, and still are under strong attack, opening a "Pandora's box" with the monetization of utility.

Just et al (1982, pp.82) state clearly that:

> "[...] the economic implications of these conditions on the consumer indifference map are so restrictive as to prevent the use of "money measure of utility change" approach in an a priori sense for essentially all practical purposes."

While Hanley (1993, p. 31) continues:

> "This is a strong attack upon the practicability of using the consumer surplus measure of utility. If this applied problem is combined with the underlying utilitarian background of

[1] Marshall's constant MUM is an extensively criticized assumption in the economic literature, which simply put considers that a change in the consumer's supply of money does not affect the marginal rate of substitution between money and any given commodity. See for example Georgescu-Roegen, Nicholas (1968), Revisiting Marshall's Constancy of Marginal Utility of Money, Southern Economic Journal, Vol. 35, No 2

> cardinal analysis, the consumer's surplus measure as proposed by Marshall becomes totally unacceptable."

Hanley's quote above introduces another key element and layer of complexity within the utilitarian debate – Cardinal versus Ordinal utility - which also concerns our discussion of CBA, since any concrete economic application of a cost-benefit analysis will be rather incomplete, probably unfair and hard to trust if only ordinal utility is considered (Nyborg, 2012). While ordinal utility provides a comparative ranking of different options, it says nothing on the extent to which an option is better or worse. Cardinal utility, on the other hand provides an estimate of how much more, or less, something is preferred against something else, or how much someone has gained from another person's loss. Nevertheless, one has to consider that even knowing this estimate might not be sufficient for us to draw conclusions, because unless cardinal utility is comparable between individuals, we cannot reach an aggregate social welfare change and therefore make a confident and coherent judgement regarding the overall desirability of a project. Of course, one might not see this as an issue for cost-benefit analysis – taking cardinal utility as it is – but there still remains a huge gap between theoretical deduction and practical implementation. Ordinal utility is relatively straightforward once one can observe and register revealed choices; cardinal utility on the other hand, involves measuring complex concepts like happiness, life-satisfaction, well-being, or resilience, a rather tricky endeavour at best, in what is still a new field of research where much further development is needed (MacKerron, 2011).

In the end, what many economists working with CBA would like to have is a transparent, solid and scientific method to assess interpersonal, comparable cardinal utility. For example: the decision whether to buy a new car is more important for Inês than deciding whether to take the train home or go by bike is for Filipe.

$$U\text{Inês}(A) - U\text{Inês}(B) > U\text{filipe}(A) - U\text{filipe}(B)$$

Still, a measure of individual comparability wouldn't be enough to enable aggregate utility assessments due to what is better known in social choice theory as "Arrow's Impossibility theorem". Kenneth Arrow was able to demonstrate that it is not possible to convert ranked preferences of individuals into one overall social ranking, while

meeting certain pre-specified criteria, namely unrestricted domain[2], non-dictatorship[3], Pareto efficiency[4] and independence of irrelevant alternatives[5] (Arrow, 1950). In other words, it is not possible to aggregate ordinal utility or even cardinal utility, unless there's perfect comparability, itself an impossibility recognized by Harsanyi (1995). However both Sen and Harsanyi argue that partial comparability – partial interpersonal comparisons - is conceivable and acceptable as human beings share some common backgrounds, cultural experiences, etc. Sen's method of information broadening is proposed as a viable escape from the theoretical traps on aggregation and comparability since Lionel Robbins strongly addressed them in 1935.

Aggregation of utility for overall social welfare functions faces other criticisms as well: firstly, as individual citizens we might have a different utility function than we have in our role as consumers (Sagoff, 1988); secondly, at different moments and in different contexts, our preferences are subject to change, while in some cases we might not even have explicit preferences, limited information on relevant alternatives or be unable to monetize such preferences. Kahneman *et al* (1993) also argue that a person's WTP regarding a specific environmental good or service, may not represent the real utility provided by that good or service but rather the person's ethical or political positions. Thirdly, Utilitarianism, is mainly an anthropocentric perspective focused on human welfare and is most of the time separated from broader contexts such as ecosystem or animal well-being. Although some authors like Kaplow (2008) have argued that, indirectly, a more holistic view on utilitarianism can internalize such non-anthropocentric views on the well-being of life and accommodate the

[2] 'Unrestricted domain' or 'universality' is the condition identified by Arrow for social welfare functions under which a complete and unique ranking of social choices can only be achieved if all voters are allowed to express their preferences (Arrow, 1950)

[3] 'Non-dictatorship' is the condition identified by Arrow under which the social welfare function cannot rely on the sole final preferences of one man. (Universality and non-dictatorship are connected but they are not the same as one can have unrestricted allowance for a voting process but the aggregated social ranking is discarded by a 'dictator')

[4] 'Pareto efficiency' - or 'Pareto optimality' – is a condition put forward by Vilfredo Pareto (1848-19323) and recognized by Arrow which represents a certain allocation of resources in which it is impossible to make any one individual better off without making at least one individual worse off

[5] 'Independence of relevant alternatives' is the condition identified by Arrow under which "*Just as for a single individual, the choice made by society from any given set of alternatives should be independent of the very existence of alternatives outside the given set"*(Arrow 1950: 11)

interconnectedness of human happiness and overall ecosystem well-being, the case is that in standard economic analysis, namely CBA, this is not common practice.

All of these constraints challenge the notion of the "true value" found with WTP or willingness to accept (WTA) methods.

It is important to mention that although these debates over utility and social welfare functions started in the late nineteenth century and early twentieth century with the Marginalists, many of the alternative methods and creative solutions regarding cost-benefit analysis for stated and revealed choices, namely regarding social and environmental variables, only really took off in the 1960's and were mainstreamed into public policies in the 1980's. We discuss some of them in chapter 3 and also in chapter 6, as a response to many of the challenges so far discussed.

It is also important to recognize that most of the developments in economic project analysis have proceeded by trial and error in co-evolution with economic theory from the 1930's onwards, namely in the U.S. and the U.K., and the developments in social choice theory.

A more detailed analysis of the historical evolution of CBA implementation is fundamental in contextualizing its development and transformational path, as well as in identifying important milestones along the way.

Still, one shouldn't forget the words from Steven Kelman (Kelman, 1981: 2):

> "Utilitarianism is an important and powerful moral doctrine. But it is probably a minority position among contemporary moral philosophers. It is amazing that economists can proceed in unanimous endorsement of cost-benefit analysis as if unaware that their conceptual framework is highly controversial in the discipline from which it arose— moral philosophy."

Before providing such an analysis in the next section, it is useful to present a formal definition of CBA. According to Nick Hanley (Hanley and Barbier, 2009: 1-3), CBA:

> "[…] is a technique for measuring whether the benefits of a particular action are bigger than the costs, judged from the view point of society as a whole.[…]
> One important feature of CBA is that all relevant effects are expressed in monetary values, so that they can be aggregated. The general principle of monetary evaluation in

> CBA is to value impacts in terms of their marginal valuation cost or marginal social benefit."

Cass Sustein, an American legal scholar from Harvard University complements the above definition in a clear and straightforward manner, in his 2001 paper 'Cognition and Cost-Benefit Analysis':

> "Cost-benefit analysis is best taken as a pragmatic instrument, agnostic on the deep issues and designed to assist people in making complex judgments where multiple goods are involved."

In this Master Thesis, CBA is understood as an economic tool and a method for the appraisal of private and/or public marginal projects, i.e., projects that do not have the scale and power to influence equilibrium prices or growth rates within an economy. Although some authors use the concept in a more holistic and broad context, even considering cost-benefit analysis for world-wide transformative projects like climate change mitigation, as studied by Nordhaus or Stern, this thesis, taking into consideration the inherent limitations identified and explained in section 2.5, will focus solely on marginal projects, arguing that for non-marginal projects other tools and methods, like computable general equilibrium models, are best fitted and more adequate (Dietz and Hepbrun, 2010; Nyborg, 2012). According to Dietz and Hepburn (2010), using conventional CBA for large projects within small economies or even applying CBA logic for climate change mitigation, carries large qualitative as well as quantitative errors and could led to erroneous suggestions or recommendations regarding which actions to undertake.

2.2 Practical implementation and evolution

A stepping stone for the introduction of CBA in public investments was the U.S. Flood Control Act of 1936, which represented one of the major commitments by a Federal Government regarding the protection of people and assets against environmentally-driven damages until that time (Hanley, 1993). Covering an area of about 400.000 km^2, this Act, passed into law by President Roosevelt just after the Big Depression clearly stated that *'The only limitations on federal flood control projects were that the economic benefits had to exceed the costs, and local interests had to meet the ABC requirements for local projects'* (U.S. Flood Control Act of 1936, Section I), namely:

A) "provide without cost to the United States all rights in land and other property necessary for the construction of the project;
B) hold the government free from damages in connection with construction;
C) maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of War"

These requirements and CBA logic were then further developed, interestingly and for at least four decades, in the water sector, namely in the constitution of the subcommittee on Benefits and Costs for the Federal Interagency River Basin Committee, which in 1950 launched, after four years of preparation, the Green Book with proposed practices for economic analysis of river basin projects. Considered nowadays an impressive document due to the profoundness of microeconomic and welfare understanding as well as the recommendations of concrete guidelines and proposals for its use and implementation, this document served as a reference and basis for the Budget Circular A-47 of December 1952 which, although it only lasted for 10 years, had a great impact on water-related projects due to the strict economic restrictions it imposed (Hufschmidt, 2011). The launch of the Green Book in 1950 associated with great investments in water projects in the U.S. attracted academia, namely economists with a growing interest in cost-benefit analysis. Harvard University established the Harvard University Water Programme in 1955 and between 1958 and 1960 four major books were published - Eckstein 1958, Krutilla and Eckstein 1958, McKean 1958 Hirshleifer, DeHaven, and Milliman 1960 -, along with several scientific papers, making the 1950's/60's the first decades during which CBA was scientifically and systematically analysed and considered in economic theory and practice (Hufschmidt, 2011). This was particularly relevant due to a number of growing concerns in CBA's, namely the conceptual issues of externalities, opportunity costs, private versus public costs and benefits.

Fuelled by a deeper understanding of CBA and also by rising voices pushing for liberalization and flexibilization of norms and regulations, the beginning of the 1960's witnessed strong dissatisfaction within U.S. congress committees with the current methods and standards for CBA's set in Budget Circular A-47 and a new report, strongly influenced by the Harvard Water Program - Senate Document 97, 87th Congress - was approved in 1962 with significant changes, one of which was the adoption of the multi-objective approach for public project evaluation and overall

economic assessment. This had to take into consideration 1) national economic development, 2) preservation; and finally 3) the well-being of people, in an implicit, triple bottom-line perspective. This report was later, in1964, supplemented by the Water Resources Council in order to allow for diverse ranges of unit/day recreation values for different types of water-based recreation, based on WTP theoretical foundations, another growing movement in the 1960's, interestingly approached by Clawson and Knetsch in their 1966 book *Economics of Outdoor Recreation*. The 1960's and 1970's brought strong criticism as well as deep developments for CBA regarding public investments in water-related projects but it was not until the Presidential Executive Order 12291 of 1983, under Ronald Reagan, that the 'Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies' was established. According to Hufschmidt:

> "Emphasis in the new administration turned to cost-sharing and pricing policy as a means of curbing perceived excessive federal investment in water resources (..) and for projects which emphasized a policy reorientation involving greater state and local responsibility for project costs, financial arrangements and project selection, and increased user fees to recoup costs of projects providing private benefits".

Alongside such important developments for CBA in the U.S., especially in the water sector, across the Atlantic Ocean, CBA applications in the U.K. were undertaken largely for the transportation sector (Hanley 1993). Iconic public investments under the scrutiny of CBA methods involve the M1 Motorway project, the 1970's Channel Tunnel Proposals, important road bridges in London as well as the famous Roskill Commission into the third London Airport, one of the largest, longest and more controversial CBAs ever conducted in the U.K. (Adams 1994). COBA – the British Department of Transport's official procedure for CBA – launched in 1971, stands as the European version of the American Green Book and has been a reference for 40 years regarding economic assessment of transportation-related investments in the U.K., namely regarding the full computation in monetary terms of indirect impacts such as valuation of time and accident savings. Nevertheless, COBA faced strong criticism because it excluded most environmental effects and it has been reviewed and updated regularly in the last 40 years, although as John Adams puts it:

> "For over twenty years the use of CBA (in the form of COBA) by the Department of Transport has inflamed rather than appeased the opposition to the Department's road building programme. Public inquiries to which the COBA results are presented have been disrupted, and road schemes justified by COBA have encountered physical resistance on the ground. The provision of security for both road inquiries and road construction has become a significant element in the cost of new roads."

Authors like Sustein (2001, 2002, 2004) have strongly defended CBA's democratic advantages as well as its capability of 'counteracting predictable problems in individual and social cognition', however and as we will see later in more detail, other authors (Olson, 1984; Kelman, 1981; McGarity, 1987 and 1992; Friedman, 1995; Shapiro, 2005) have asserted that CBA has been used merely as a cover to justify and validate political goals being anti-regulatory, ethically wrong, inefficient and ignoring such crucial issues as distributional impacts.

Nevertheless, the COBA was not alone in the U.K. After 1984 the U.K. Treasury also released its own Green Book on 'Appraisal and Evaluation on the Central Government', a document which served as a reference for the economic assessment of public investments in all sectors and markets. On page 1 it stated: "[A]ll new policies, programmes and projects, whether revenue, capital or regulatory, should be subject to comprehensive but proportionate assessment, wherever it is practicable, so as best to promote the public interest". This responded to a concrete need as CBA's were being requested for development projects besides transportation (Hanley, 1993) and harmonization of procedures and economic assumptions was in order. Indeed, the 1980's witnessed the spread of economic assessments which began to be widely used in public investments, especially those with environmental impacts. Environmental economics developed and the rush to 'price-tagging' culture followed quickly (Hanley, 2009). In the U.S., the Environmental Protection Agency (EPA) launched their 'Guidelines for performing Regulatory Impact Analysis' in 1983, reviewed and re-issued in 2000 after an extensive period of consultation (Hanley, 2009) as a way of bringing standardization to economic appraisal of public investments, although as we see later in the works of Hahn and Dudley (2007) this was not really achieved in practice. The spread of CBA in public investments not only went hand-in-hand with the development of environmental economics but also with the shifting concerns of governments, interestingly put by the UK Department of Environment in 1991:

> "A governments' policies can affect the environment from street corner to stratosphere. Yet environmental costs and benefits have not always been well integrated into government policy assessments, and sometimes they have been forgotten entirely. Proper consideration of these effects will improve the quality of policy making."

As Hanley (1993, 2009) showed with several different case studies, CBA has been used extensively in the U.K. and U.S. since the 1980's not only in the water management sector, but also for soil conservation projects, flood risk management, transportation, coastal zone protection areas, major land drainage projects and even "pushing the methodology to limits, attempted to apply CBA techniques to the choice of sources of electrical energy generation" (Hanley, 1993). As for the rest of the world, the use of CBA for public investments has been somewhat more timid and slow to develop. Through the Commonwealth, the U.K. brought CBA to the rest of the Anglo-Saxon world in the 1990's and the European Union followed the U.K. and U.S. from 1989 on, namely with the introduction of the first European Community Directive on Economic Assessment in 1989 and the introduction of cost-effectiveness analysis (CEA) in the E.U.'s Water Framework Directive. In the 1990's, CBA was a pre-requisite for all infrastructure projects of EUR 25 Million or more within the E.U. structural funds. But the E.U. took CBA practice further than any other country after the introduction of the 'Guide to Cost-Benefit Analysis of Investment Projects' (1997, 1999, 2002 and final revision in 2008) and the 'Impact Assessment Guidelines' (2005), which not only include much broader types of impacts than standard CBA Guidelines (for example E.U. competitiveness and internal markets) but also replace the "single-sector type assessments and assesses the potential impacts of new legislation on policy proposals in economic, social and environmental fields" and extends the CBA logic to "all major E.U. policy initiatives and legislative proposals" (Hanley, 2009). This is clear in the 2008 Revision (Introduction, paragraph 2):

> "The objective of the Guide reflects a specific requirement for the EC to offer guidance on project appraisals, as embodied in the regulations of the Structural Funds (SF), the Cohesion Fund (CF), and Instrument for Pre-Accession Assistance (IPA). This Guide, however, should be seen primarily as a contribution to a shared European-wide evaluation culture in the field of project appraisal."

This is considered as another major stepping-stone in the take-up and standardization of CBA as a central tool for economic appraisal of public investments, public policy and overall new legislation and, at least for the E.U. and U.S. the trend is clear. As one can read in the Regulation 1303/2013 of the European Parliament and the Council (Articles 100-103), CBA remains one of the most important tools for investment projects in the current programming period of 2014-2020 and a new CBA guide has been presented recently by the European Institute of Public Administration[6].

As we have seen, it is important to mention that this path of growing recognition, use and confidence regarding CBA for public and private projects, has not been a linear one, especially in the U.S. where a strong anti-CBA literature exists and many have argued against the use of CBA in the regulatory process (Heinzerling 1997, 1999 and 2000), or in the political decision-making process (Olson, 1984; McGarity, 1987; Sinden, 2004). However, one should also acknowledge the resilience of this economic appraisal tool that, despite its weak theoretical basis, strong criticisms from all sides, and competing tools rising in importance, has still become deeply rooted in the core of E.U. public policy and legislation.

2.3 Methods for monetary valuation used in CBA

> "Benefit-cost analysis is not a precise tool that yields firm numerical results, rather, it is a general framework for more carefully accounting for the potential and varied effects of government programs. Some of these effects can be quantified, whereas others can only be assessed qualitatively. Some may be relatively certain, whereas others may be quite speculative"
>
> (US EPA, 2000: 33)

The current use of cost-benefit analysis, both in the public and private sphere, has one or more of the following key purposes:

i) To determine the feasibility or economic justification of an investment/project

ii) To rank projects/investments according to their social preferability

[6] Taken from http://ec.europa.eu/regional_policy/information/evaluations/guidance_en.cfm#1 on the 01st December 2014

iii) To support and inform democratic decision-making processes

While much of the economic literature on cost-benefit analysis tends to focus on purpose ii), in this thesis we make the case that CBA, as well as other economic appraisal tools, should have their focus on purpose iii). This is especially relevant as because of the relationship between mean and ends. In a paper by Arrow *et al* (1996) "Is there a role for cost-benefit analysis in environment, health and safety regulation?" the authors argue that CBA is an important method to provide valuable information for decision-makers but should not be the sole basis for that process and should follow eight key principles for "appropriate use". Arrow et al conclude by stating that "[a]lthough formal benefit-cost analysis should not be viewed as either necessary or sufficient for designing sensible public policy, it can provide an exceptionally useful framework for consistently organizing disparate information, and in this way, it can greatly improve the process and, hence, the outcome of policy analysis". Nyborg (2010) takes a similar approach arguing, however, that although there isn't a single economic project appraisal method that can provide scientific certainty, or ethically neutral economic analysis, CBA's main task is to be "systematically descriptive" in informing political decision makers and henceforth the main question for the person conducting the CBA is not the ranking of projects according to their social preferability but rather the assessment of what is the most important information to be provided to decision-makers. Here we argue that it is not only a question of 'what information' that matters but also the 'when' and the 'how'. Today's decision-making processes are complex systems of interactions and iterations between many actors and stakeholders on multiple levels of governance, deeply interconnected, where ends and means intertwine and become one and the same. For a cost-benefit analyst it's fundamental nowadays to understand the governance model, and specifically the decision-making processes, of the company, community or municipality, in order to assure that the methods used and the information made available are fully aligned and serve properly the ends foreseen and agreed upon. For example, in the 2008 Guide to Cost Benefit Analysis on Investment Projects by the European Commission, the question of timing was directly approached, as represented in figure 1:

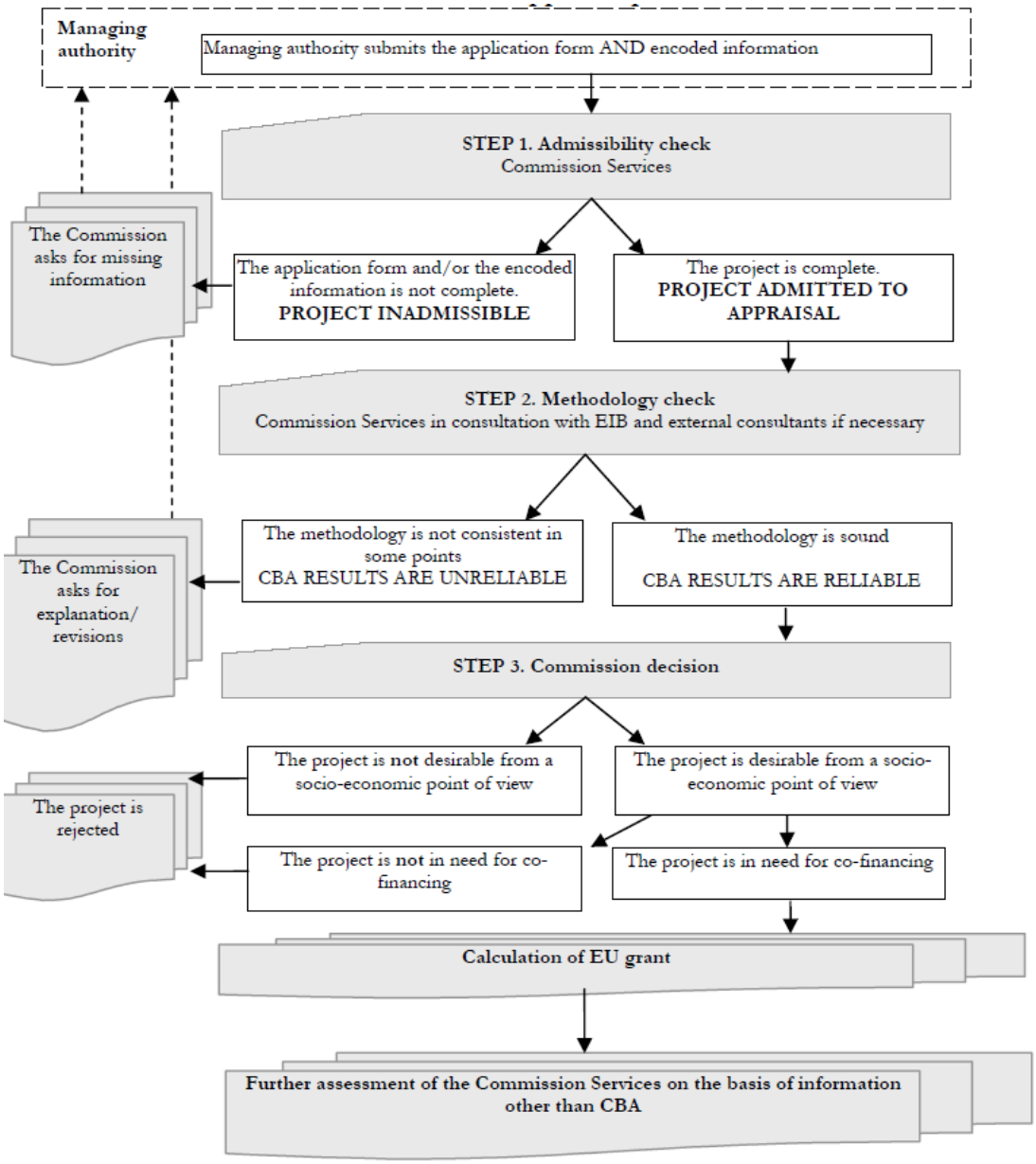

Figure 2 - The role of CBA in the E.U. Comission appraisal process

We look now at some of the available methods, tools and decision-making criteria's for the economic appraisal of projects, namely climate change adaptation investments, before further discussing questions of 'what', 'when', and 'how'.

Depending on the end purpose of the CBA, as well as on data availability, requirements for modelling and risk assessment, among many other variables, one can choose from a wide variety of available methods in order to assess more fully the costs and benefits of a certain investment or project. Direct costs and benefits are usually easy to account for using market prices and standard economic tools, however in order to internalize indirect costs and benefits or costs and benefits for which there is no market and hence

no price one has to use stated or revealed preference methods (Hanley et Barbier, 2009). Economists tend to prefer revealed preferences over stated preferences arguing that the first is always more reliable than trusting in people's hypothetical or subjective answers, regardless of how well the WTP survey was designed (C. Brown 2003), yet it is clear that some non-use values are impossible to capture without stated preference approaches.

The most widely used valuation method, namely for environmental valuation, is the Contingent Valuation Method (CVM), first proposed and used by Robert Davis in 1963 for estimating the value of big game hunting in the state of Maine, U.S (Boyle J., 2003). CVM consists of directly addressing a sample of consumers regarding their WTP and/or willingness to accept (WTA) for a concrete change in an environmental or social service or good, or for eliciting hypothetical values placed on a certain product or service. WTP is used when the change is mostly desirable and welcome, while WTA is more common to assess the compensation needed for an expected welfare loss. CVM is a stated preference method as it consists of questionnaires or interviews to elicit consumer preferences. It is not only the most commonly applied tool, but also the most controversial and even the most famous, namely in the U.S., where CVM was used to provide an estimate of the damages of the Exxon Valdez oil spill in Alaska in 1989, arriving at an unprecedented damage claim of 2.8 billion dollars (Hanley et Barbier, 2009). After this event a number of recommendations and manuals for proper and legally acceptable CVM were published, namely the Mitchell and Carson book from 1989 "Using Surveys to Value Public Goods: the contingent valuation method" and the NOOAA Report of 1993. Within CVM there are several different sub-methods and techniques and a strong debate amongst its practioners has been going for several decades regarding various question formats for WTP (open-ended; Payment Card and dichotomous choice). Table 1 summarizes some of the advantages and disadvantages of CVM.

Another method that has been gaining popularity within stated preferences is the Choice Experiment **(Choice Modeling or conjoint analysis)** which relies in the '*characteristics theory of value'* and belongs to the so called Attribute-Based Methods (ABM's) group (Holmes and Adamowicz, 2003). According to these authors "the objective of an ABM stated preference study is to estimate economic values for a

technically divisible set of attributes of an environmental good", which states that a value of something, for example a tree, is best explained in terms of the characteristics or *attributes* of that tree – providing shadow, production of oxygen, storing of carbon, production of fruits and leaves, supplying housing for animals, timber, biomass, cleansing the water, and so on. Once again the method relies on questionnaires, interviews and direct observation of people's choices when given different alternatives and attributes. This method is famous among marketing researchers which have been using it since the 1970's to design and test new products or new attributes in existing products (Green and Wind, 1975), as well as research from psychology and transportation (Holmes and Adamowicz, 2003). Its use in economics can be traced back to authors such as Court (1939), Griliches (1961) or Rosen (1974) and the use of hedonic regressions which correlated the demand for goods from their attributes. A summary of pros and cons can also be found in table 1.

Less used than CVM and Choice Experiment (CE) but relying on them, one can also apply a Benefits Transfer **(BT)**. This method consists on extrapolating comparable existing information of value on non-market goods and services from a 'policy site' to a new 'study site' (Brouwer, 2000). BT can also be used to estimate the responsiveness of stakeholders demand for goods and services – demand elasticity - regarding changes in prices and/or quantities. It's an attractive method for political decision-makers due to its efficient and effective characteristic both in time and money. However, the method depends heavily on some assumptions, specifically regarding direct site comparability (Rosenberg and Loomis, 2003). R. Edward Freeman in 1984 was the first economist to formally analyze primary data transferability and to set the specific conditions and protocols under which it could happen, and although he faced strong criticism, his work paved the way for future work by Loomis 1992, Vandenber, Poe and Powell 2001, among others, which have been developing in the direction of more sensitive and reliable models for data collection and transferability (Rosenberger and Loomis, 2001, 2003). Another trend in BT is the increase in the use of function transfer rather than value transfer. Both approaches are accepted for BT but research by Brouwer (2000) expanded by Rosenberger and Loomis (2001, 2003) demonstrated that the average range of error in empirical validity tests within the existing literature shows that function transfers perform better than value transfers. Brouwer (2000) also suggests "using stakeholder engagement involvement methods for verifying transfer data"

(Champ, 2003: 477). According to Morrison et al. (2002) CE offers greater confidence levels to perform BT's., although most of the time the base valuation derives from CVM.

Regarding revealed preference methods one can choose between the well-known Travel-Cost Method (TCM) and Hedonic Pricing (HP). TCM is considered in the literature as the oldest non-market valuation method, as it can be traced back to the 1950's for outdoor recreational modeling in the United States. It focuses on calculating not only the direct monetary expenses with recreational travel but also implicit costs, such as time costs. Traditionally 'single-visit models' were used although nowadays 'Random utility site choice' modeling is becoming more common amongst practitioners, since it allows the possibility of many and diverse substitutes and also the valuation of small changes in site accessibility, quality, and others (Parsons, 2003). TCM has been widely used, for example to assess the recreational value of a beach, the WTP to maintain a forest, the management model of a National Park, accessibility constraints and WTP for a fishing lake, among many other applications. The TCM has its own limitations and criticisms, one of which concerns the 'true monetary value' of leisure time which is a fundamental variable but one for which consensus is extremely hard to find within the economic literature. Another limitation is the possibly large number of variables and substitutes. As an example, imagine assessing your WTP for the use of Guincho beach in Cascais, based on the number of probable trips/year to the beach. That probability will most certainly depend on your age, sex, income, where you live, if you have a car or not, if you kitesurf or windsurf or not, what is your WTA windy conditions or stronger seas, if you have friends in the area, among others. Normally a Poisson Regression – equation 1 - is used to estimate the probability of trips (t) in which a certain parameter (α) is the expected number of trips and is a function of the variables specified in the demand model, which for the example above could be expressed in equation 2.

Equation 1: ——— Equation 2: $\ln(\alpha) = \beta age + \beta sex + \beta inc + \beta kite + \ldots.$

Finally, we can also use Hedonic Pricing. HP is a revealed but indirect valuation method as we do not observe the value that consumers place on attributes but rather infer it from market transactions of similar goods and services in which only small

changes in specific attributes or characteristics exist. In some respects, HP is closely connected with the Choice Experiment, making use of the theory of value developed by Lancaster and Roose. HP has been widely used due to relatively low data requirements and easy empirical implementation, namely in housing markets, but extended literature exists since the 1990's on its use for almost everything, from pricing of new drugs to analyze market sales of Picasso paintings (Taylor, 2003). HP relies heavily on welfare economics theoretical foundations making it theoretically more sound, yet more vulnerable to criticism. Nevertheless, it is popular among economists. A summary table, based on the revised literature presented in this section, assessing the different methods is offered below:

Method	Pros	Cons
CVM	Widely used with an extended existing practice and literature Possibility of including revealed preference methods for validity of results Existing Recommendation Manuals on how to conduct a proper CVM with legal validity/support	Requires careful design and data analysis Large variability in procedures and assumptions Lack of systematic research agenda among practioners Hypothetical market bias; WTP sensitivity to information provision to respondents on the survey Voluntary versus non-voluntary payments
CE	The researcher has greater control over the research by introducing, replacing or withdrawing different attributes. The use of statistical design theory yields greater statistical efficiency and eliminates collinearity between exploratory variables Multi-dimensional response surface is modeled that provides a richer description of preferences Salient attributes of the valuation problem are circumscribed	Accommodating variation in preferences across people (preference heterogeneity) Issues with experimental design (which attributes to include; how to describe them; what price or cost term to use; how many choice sets can respondents deal with) Hypothetical market bias Value of the whole versus sum of the parts?
BT	Cost- efficient Time-effective Non-expert tool	Limitations on data transferability Lack of primary research studies that specifically target BT Lack of research on the use of new technologies for BT
	Oldest method with extended literature and important evolution	Difficulty of placing a monetary value on leisure time;

TCM	in the use of multi-site models and their calibration	How to measure site characteristics? Preference heterogeneity Crowding
HP	Theoretical background Low data requirements Straightforward empirical implementation	Theoretical background Careful design considerations (choice of independent variables; their measurement; price function; etc.)

Table 1 - Pros and Cons of CBA Methods

2.4 Discounting in Cost-Benefit Analysis

> "Similar problems emerge in doing cost-benefit analysis of projects spanning a long period of time. Here the discount factor is the issue. Anything discounted at a rate of 3-6 per cent becomes meaningless after 50-100 years. The economic income of the entire planet shrinks down to the value of a car when so discounted."
>
> (Chichilnisky, 1997)

If we would name one single variable, in cost-benefit analysis, which can be determinant for the final outcome, or more fundamentally, in the final Net Present Value (NPV)[7] of any single project, it would be, without any doubt, the discount rate (*i*) (Lindt, 1995; Chichinilsky, 1997). Discounting, the methodology through which we convert future expected costs and benefits of a certain project into present values is a crucial element within CBA and occupies a special place in the economic literature, filled with deep and meaningful ethical and moral considerations about time preferences and intergenerational equity. There is much controversy around not only the appropriate discount rate to be used in cost-benefit analysis, especially within environmental management and climate change projects, but also on the question of whether a discount rate should be applied at all (Saez and Calatrava, 2006). Most authors defend and use a positive discount rate, leaving the debate to the question of its value – for to choose a high discount rate means that costs and benefits which occur in the future are less important, whereas a low discount rate gives them a higher weight. Others authors argue

[7] Present Value (PV) calculation formula (Hanley, 1993): $PV(X_t) = X_t \left(\frac{1}{1+i}\right)^t$

Net Present Value (NPV) formula formula (Hanley, 1993): $NPV = \sum_{t=0}^{n} B_t \left(\frac{1}{1+i}\right) - \sum_{t=0}^{n} C_t \left(\frac{1}{1+i}\right)$

that a zero discount rate is the only one coherent with the higher purpose of sustainable development and intergenerational equity (Shue, 1999; Saez and Calatrava, 2006) and that discounting future utility would be something like a '*polite expression for rapacity and the conquest of reason by passion*' (Harrod, 1948), while a small minority defends a negative interest rate to be applied in certain public goods, such as national defence, health systems and education (Ciriacy-Wantrup, 1942). The only agreement in the existing literature is that most authors do not agree, neither on which discount rate to use, nor on how the discounting function should behave – constant, exponential, hyperbolic, among others – or even if we should use one at all. As (Goulder and William III, 2012: 2) argue:

> "There remains relatively little agreement as to what might constitute a reasonable value for the consumption discount rate. This can leave policy analysts and decision makers confused about what conclusions can legitimately be drawn."

The question of whether or not we should use a discount rate is not central to this thesis and we accept that there is enough empirical evidence and theoretical, morally sound arguments for a discount rate different from zero. For the moment our attention will turn to the question of how a discount rate can be defined. Azar and Sterner (1996) approached this question distinguishing between two common perspectives: the financial discount rate; and the social discount rate (SDR). The first is based on the opportunity cost of capital, i.e., the marginal return on investments; the latter is based on the Social Time Preference Rate (STPR), i.e., the social view on how future benefits and costs should be valued against present ones. In an idealized world of perfectly functioning markets, these two rates should be the same or at least strongly connected and the use of either one could be legitimate for future costs and benefits (Dasgupta, 2008). Still, there exists vast empirical evidence that shows us that they differ and many authors have presented arguments for the existing gap between the two rates as well as the implications of that discrepancy, namely "that resources are not allocated across time periods in a way that maximizes social welfare" (Goulder and Williams III, 2012: 9).

The gap between the financial rate and the STPR can be examined in the comparison of tables 2 and 3:

Asset class	Nominal Annual Return Estimates %	Real Annual Return Estimates %
Large Stocks	9.0	6.4
Mid/Samll Stocks	10.7	8.1
International Bonds	9.1	6.5
Bonds	4.8	2.2

Table 2 - Financial rates - Adapted from E.U. Guidelines on Cost-benefit Analysis for investment projects (2008)

Countries	Social Discount Rate %
France	3.4
Germany	3.1
Netherlands	2.8
Sweden	4.1

Table 3 - Estimated country SDE - Adapted from E.U. Guidelines on Cost-benefit Analysis for investment projects (2008)

According to Goulder and Williams III the distinction between the social and the financial rate is rather important, namely for the discussion of whether 'the choice of discount rate should be based on ethical considerations or empirical information and whether the discount rate should serve a prescriptive or descriptive role' (Goulder and William III 2012: 1). They conclude by stating that the choice will depend on the selected evaluation criteria by the analyst and the decision-makers, where "If the objective is to assess whether a given policy would augment social welfare, the social welfare-equivalent discount rate is appropriate. If the objective is to determine whether the policy would yield a potential Pareto improvement, the finance-equivalent discount rate should be used".

In this thesis we will focus on the SDR taking as a basic assumption that regarding climate change mitigation and adaptation strategies and actions the commonly used discount rate follows the social-welfare-equivalent approach.

Regarding the SDR the question formulated above still remains. If markets set the financial rate, what or whom defines the SDR? Most authors, publications and CBA Guidelines refer to the 'Ramsey equation', named after Frank P. Ramsey, the young

British philosopher, mathematician and economist, who died in 1930 at 26 but whose work has echoed in economics for many decades. The Ramsey equation is:

$$r = \rho + \eta g$$

The above equation above puts together the rate of pure time preference ( ), the growth rate of per capita consumption (*g*) and the elasticity of marginal utility of consumption (η) (Anthoff et al, 2009)[8]. The choice of values for each of the three parameters carries important ethical, political and social considerations, namely regarding the value of – where we take a stand on how we should account for future well-being in the social welfare function - and the value of η – where we select how much increases in consumption contribute to increase the social welfare function. Pure time preference deals mainly with our individual impatience and "inborn preference of immediate over postponed consumption" (Frankhauser, 1993: 13) as well as with our individual 'myopia' as William Cline refers. Still Thomas Schelling argues "that impatience or 'myopia' may be a legitimate basis for a single individual's preferring consumption earlier than later in his lifetime but is hardly a justifiable basis for making intergenerational comparisons" (Schelling, 1995: 3). Azar and Sterner take a similar position arguing that concerning one cannot, and should not, take leads from individual time-preference aggregation or mean – one of the reasons being the divergence between the probability of individual death versus that of humankind extinction - and that there is no good argument for a social time preference different from zero (Azar and Sterner, 1996). This is not a consensual position in the literature has many authors make the case for time-preference based on overall savings and investment behaviours as well as relating such time-differentiation with distance preference or 'empathic distance' – the argument that we tend to care most for those near to us, geographically and culturally. Schelling argues that we, as a society, have a clear tendency to prefer our own consumption over those in distant parts of the world, and prefer people's consumption today - whether in China or Peru – more than that in 100, 200, 1000 years' time. Time correlates with vertical distance in a non-linear

[8] Some authors, while still using the Ramsey equation logic, take different assumptions regarding the meaning of the variables, namely distinguishing "between a discount rate on *utility* and a discount rate on *consumption*" (Goulder and Williams III, 2012:4). For example the E. U. CBA Guidelines (2008:212) which assume that: "*r* is the real social discount rate of public funds expressed in an appropriate currency (e.g. Euro); *g* is the growth rate of public expenditure; *n* is the elasticity of marginal social welfare with respect to public expenditure, and *p* is a rate of pure time preference".

function and for the author that is not a matter of discounting but rather 'depreciation' (Schelling, 1995:2):

> "…when we count future welfare less than our own we are depreciating generations that are distant in time, in familiarity, in culture, in kinship and along other dimensions"

When estimating costs and benefits for climate change action some important authors have chosen to use a positive time preference rate in their SDR calculation. For example, Sir Nicholas Stern (2007) defended a 1.4% discount rate for climate change mitigation using a time preference rate of 0,1%, while Nordhaus (2007) argued for a 4.3% rate using a time preference rate of 3% in his DICE-Model, based on empirical saving rates (see Table 4). This apparently 'small' difference has a major impact as Goulder and William III have noted: "...a given loss of consumption 100 years from now is 17 times smaller using a discount rate of 4.3% as compared with the result under a discount rate of 1.4 % " (Goulder and William III, 2012: 7). These 'small differences' in such a vital parameter were clearly highlighted by Azar and Sterner regarding possible estimation intervals for the marginal cost of CO2 emissions (Table 5).

Leading Authors	*P*	*n*	*g*	*SDR*
Stern (2007)	0.1%	1.0	1.3%	1.40%
Cline (1992)	0.0%	1.5	1.3%	2.05%
Nordhaus (2007)	3.0%	1.0	1.3%	4.30%

Table 4 - Discount variables and rates in leading climate policy evaluation (Goulder and Williams III, 2012)

The marginal cost of CO2 emissions[9]				
	The pure rate of time preference *p*			
	0 % / Year	0.1 % / Year	1% / Year	3% / Year
The marginal cost of CO2 emissions MC1	85-200	75-140	32-33	13-13
The marginal cost of	260-590	230-410	95-98	39-39

[9] In USD/ton C. The lower value in each box corresponds to a time horizon of 300 years, the upper value to a time horizon of 1000 years. In the first row, the distribution of income is not taken into account. In the second row, this aspect is included, and it is assumed that the distribution of income remains constant over time. The calculations have been carried out for a logarithmic utility function, i.e., the negative of the elasticity of marginal utility, Y, is set to one.

CO2 emissions MC2				

Table 5 - The marginal costs of CO2 emissions under different time preferences (Azar and Sterner, 1996)

It is of utmost importance to have a solid, coherent, ethical and empirically-based set of values for , η and g as they determine the effect of discounting and therefore strongly influence the conclusions of any CBA, especially when costs and benefits are spread over a large time horizon. Regarding climate change adaptation, the Portuguese National Strategy for Climate Change Adaptation (ENAAC) does not define the discount rate to use in project evaluation, neither does the European Strategy for Climate Change Adaptation. The European Commission suggests that each member country sets their own country-specific SDR, while at the same putting forward "good arguments in favor of using these two [5.5% SDR for the Cohesion countries and 3.5% for the others] benchmark values…" (EC, 2008: 208). Finally, for our short discussion on discounting for climate change adaptation it is also important to recognize recent evolution within the economics literature accepting uncertainty about future discount rates and by doing so advocating the use of declining discount rates over time (Weitzman, 1998; Goulder & Williams III, 2012; Arrow et al, 2014). Richard G. Newell and William A. Pfizer argue strongly for this case as "...incorporating discount rate uncertainty almost doubles the expected present value of mitigation benefits." (Newell and Pfizer, 2003). For example see in Table 6, the UK's Green Book recommendations and in Figure 3 results from different pure rate of time preferences (PRTP) and declining discount rate schemes from the FUND model.

Period of Years	0-30	31-75	76-125	126-200	201-300	301+
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

Table 6 - UK HM Treasury Green Book recommendation on the use of declining discount rates (2003)

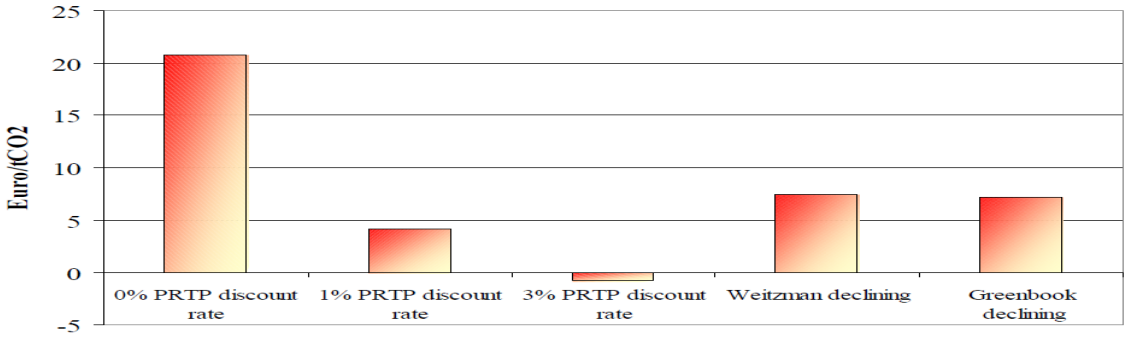

Figure 3 - Modelled costs of climate change with different pure rate of time preference and declining discount rates schmes (Watkiss et al, 2005)

More recently, Arrow et al (2014), have also argued for the use of a declining discount rate by policymakers but advocating a "careful judgment in estimating DDR schedule" as well as a constant update on the DDR as new data becomes available and uncertainty levels change. Arrow et al make the case for a common procedure for the estimation and constant update of DDR for policy-makers (Arrow et al, 2014: 17).

2.5 Limitations and Criticism of CBA

> "As a citizen, I am concerned with the public interest, rather than my own interest; with the good of the community, rather than simply the well-being of my family.[…] In my role as a consumer, […] I pursue the goals I have as an individual."
>
> Mark Sagoff (1988: 8)

In previous sections we have considered superficially some of the limitations and criticisms of CBA and its methods. In this section the main goal is to systematize the existing knowledge, not only to bring clarity and perspective into section 3, but also to better contextualize the participatory benefit-cost analysis (PBCA) presented in section 5.

The anti-CBA literature, as well as the pro-CBA literature, is vast and comprehensive, since many authors have addressed the theoretical, methodological, practical, ethical and political limitations of this economic appraisal tool (Mashaw and Harfst, 1990; McGarity, 1992; Friedman, 1995; Wolfson, 2001; Sunstein, 2001; 2002; 2004; Sinden, 2004; Omura, 2004; Chichilnisky, 1996; Nyborg, 2009). Our objective is not to look in

detail at each dimension but rather to give an overall perspective, based mostly on more recent works by Adam Wolfson, Cass Sunstein, Makiro Omura and Karine Nyborg.

CBA criticisms tend to start, and sometimes end, with its theoretical foundations. As presented in section 2.1 these are deeply connected with the welfare economics of utilitarianism. We can summarize welfarist critics in nine bullet points:

1. No commonly agreed definition of utility among economists (Martionoia, 2003);
2. Our utility as consumers is different from our utility as citizens (Sagoff, 1988);
3. Our utility might not express our consumer preferences but rather our ethical or moral positions within a specific socio-political context, which is constantly changing (Kahneman, 1993);
4. Even if we could agree upon a definition of utility, for example connected with well-being or happiness, we know that happiness is not consistent with revealed choice (Harsanyi, 1957) and;
5. There is a difference between what we consider as good and what is considered to be good from a philosophical point of view (Sen, 1988);
6. No agreed manner to compare, analyse and extract useful data from cardinal and ordinal 'utilities' (Nyborg, 2009);
7. No agreed methodology to aggregate individual's utilities into a common social welfare function (Arrow's impossibility theorem; Arrow, 1951);
8. No agreed solution to move beyond the intrinsic anthropocentric nature of utility into environmental and animal well-being (Kaplow 2008). ,

All of the above arguments deal with the theoretical dimensions of CBA and are the fundamental questions that arise to any economist running a CBA on a given project: who and what is being affected; when; how; and how can we measure it? Of course, if we do not agree upon a measure of impact or if that measure and its methods of measurement have inconsistencies, uncertainties, questions marks, limitations and important subjective dimensions, how can we ever claim the results to be trustworthy? Can the subjective answer of person X, in day Y, in place Z to a questionnaire about their future well-being or happiness connected with investment A be held accountable for the valuation of the benefits of that investment? Can that answer be added to another answer from person X2, same day, same investment, but with different subjective happiness or well-being concepts? Can we extrapolate overall social well-being

equations from these 2 or 200 answers? Can we extrapolate the happiness expectations of people which will be living in place Z, 20, 50 years from now based on person X, day Y subjective answers?

These questions are not new among academics nor among CBA practitioners. Different methodologies – explored in section 2.3 – have been in constant improvement, calibration and validation in order to solve some of these questions. Nevertheless, the key underlying challenges remain: what are we measuring? Can we measure it with confidence? Can we cross-validate the results with different methodologies? Can we measure happiness? Well-being? Can we sum up my subjective well-being change regarding project A, with your subjective well-being change regarding the same project? Am I as a consumer better off? And as a citizen? As a father/mother? These questions, and a partial answer to them given by CBA advocates, bring us to a second level of limitations and criticism that we have yet not addressed: the question of monetization. The monetization of ecosystem services and natural capital constitutes a large area of debate within environmental economics, as well as within certain social sciences studying welfare and social impacts. Not only moral and ethical dimensions come into play when one has to value life in all of its complexity and its many forms, but also technical barriers, knowledge constraints, uncertainty and unpredictability (Turner 2003). This second level, in turn, has three separate sub-levels: on one hand the limitations to non-market valuation, either of ecosystems or of human life and death; on the other hand, the limitations regarding shadow prices and the social opportunity costs hidden from the market[10]; and finally, the future valuation of both costs and benefits, having in mind the considerations made in the previous section. Considerations on non-market valuation, shadow pricing and future discounting lead us, inevitably, to a third level of criticism regarding CBA which concerns the economic, political, ethical and moral assumptions behind CBA-based decision-making processes. From the moment the CBA analysts start their process until the moment the decision-maker takes a position on whether or not to support a certain project, dozens of small, but crucial, decisions are made regarding the foundational assumptions for the CBA's practical implementation – which discount rate to use, the time-span, the affected stakeholders, the methods for utility valuation, which shadow prices to consider, if there is perfect

[10] For extensive literature on this subject, please see: (Arrow et al., 2012; Pezzey and Toman, 2002).

substitution or not (weak or strong sustainability), and so on and so forth – each and every one of them strongly influencing the outcomes as well as the process of the CBA. Some authors even claim CBA to be a 'charade', 'merely a cover' for political goals, a 'mechanism for promoting agency decisions rather than scrutinizing them'while other also claim that in the precise moment one has decided to go for CBA as the economic appraisal tool, an economic, political and moral bias for neoclassical theory has already been made (Olson, 1984; Shapiro, 2005). Karine Nyborg, based on empirical evidence, argues that most political decision-makers tend to either misunderstand, undervalue, disregard or even block CBA recommendations, mainly when they contradict their political and moral opinions (Nyborg, 2010). Nyborg argues that it is conceivable that we consider CBA not to be politically neutral. This combination of strong arguments makes the case for CBA to be considered as an expensive, ineffective, obsolete and non-democratic tool for decision-making processes.

All of the above levels of CBA limitations and criticism – theoretical grounds; practical monetization and valuation; political effectiveness and democracy - cast an unavoidable shadow of doubt regarding the use of conventional CBA, namely regarding climate change where uncertainty levels are high, time-periods are large, most benefits of action are outside markets and interdependency, together with complexity within systems, are at their peak. Independently of how appealing CBA is for politicians, decision-makers and some economists, we cannot disregard the overwhelming evidence and arguments against conventional CBA and hide behind 'it's the best we have' argument. We can and we should do better, namely in the public appraisal of climate change adaptation projects as we'll make the case for in chapters 5 and 6.

Makiko Omura (2004: 55), in his conclusions argues strongly that:

> "It is indeed tragic that whilst CBA attempts to overcome subjective judgment, political bias and inefficient public policy implications, it is never free of political influence; whilst CBA is recommend because the market fails to reveal appropriate values for environment and other goods, the very market failure makes it difficult to determine the costs and benefits of those goods to be reflected on CBA."

3. Alternative economic appraisal tools

As mentioned before, CBA does not stand alone in terms of economic appraisal tools for public, and private investments. CBA has co-evolved and co-existed with many other tools available for researchers, practitioners and decision-makers, sometimes complementary to each other, other times not so much. The purpose of this thesis is not to explore deeply each and every alternative tool for the economic appraisal of projects but rather to contextualize the use, evolution, pros and cons of CBA in comparison to different tools, in particular those most used, such as cost-effectiveness analysis, multi-criteria analysis and participatory cost-benefit analysis. A brief definition of each will be given as well as a summary table for comparative advantages and disadvantages.

3.1 Cost-Effectiveness Analysis (CEA)

CEA is an economic appraisal tool for projects which compares the relative costs of two or more measures against a pre-established outcome (Perni and Martinez-Paz, 2013). CEA is only conducted when we assume that all different measures under scrutiny will have the same desired benefits or when the targets established are non-monetary, allowing the researcher/practitioner to focus specifically on the cost part of the equation. If utility maximization is taken as the objective or outcome of the measures, the CEA is also known as Cost-Utility Analysis (CUA).

CEA has been widely used, specifically within the health sector and the water sector, particularly after the 2000/06/EC Directive, also known as the Water Framework Directive, which clearly asked for CEA to be done by the E.U. Member states when studying and implementing the Program of Measures (PoM) to reach good ecological standards (Perni and Martinez-Paz, 2013). Figure 4 shows a schematic of the CEA process under the Water Framework Directive.

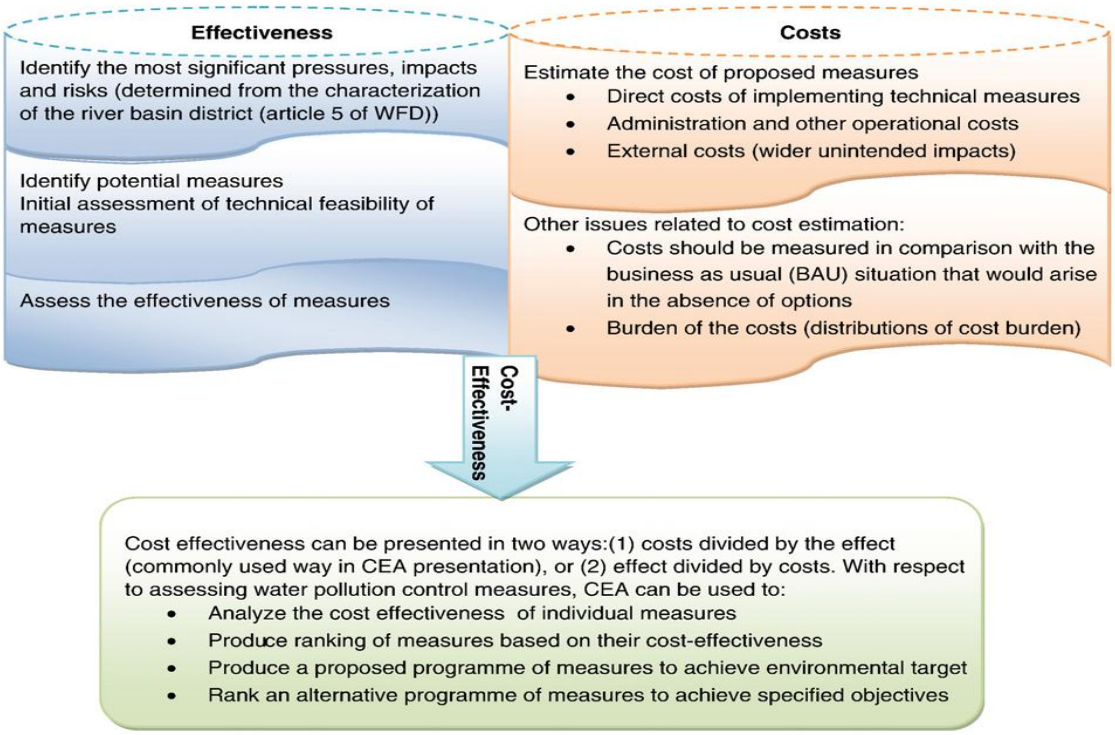

Figure 4 - Schematic presentation of CEA process under WFD (B.B. Balana et al, 2010)

Due to its extensive use within the health and water sector, mainly in the last two decades, many authors have explored possible bridges and links between CEA and CBA, namely in the health sector, where the controversy is stronger as we are dealing with human life, well-being and welfare directly, but attempts either concluded with unreasonable necessary assumptions or where rapidly criticized and replied in the literature (Dolan and Edlin, 2002; Edlin, 2004; Hansen et al, 2004; Celini and Kee, 2010). Stephanie Celini and James Kee writing in the Handbook of Pratical Program Evaluation also conclude that although both tools share some commons steps and objectives, neither one nor the other can be seen as magical 'panaceas' which will provide decision makers with final answers. The authors argue that both processes are important but distinct and that some complementarity might exist and can be explored, for example for sensitivity analysis. Still, Paul Dolan and Richard Edlin concluded that (Dolan and Edlin, 2002: 12):

> "We develop an impossibility theorem that shows it is not possible to link CBA and CEA if: (i) the axioms of expected utility theory hold; (ii) the quality-adjusted life-year (QALY) model is valid in a welfare economic sense; and (iii) illness affects the ability to enjoy consumption. We conclude that, within a welfare economic framework, it would be unwise to rely on a link between CBA and CEA in economic evaluations."

This is a crucial conclusion with strong implications for policy evaluation as they argue against the use and justification of use of CEA on welfare grounds, as CEA tends to look into the objective needs of people rather than their subjective demands or expectations. The authors argue CEA to be, in fact, a non-welfarist tool. This is crucial for the debate over CBA versus CEA use in health care as the underlying discussion is really if we should be taking health care system decisions based on "to each according to need' rather than 'to each according to willingness (and ability) to pay" (Dolan and Edlin, 2002:13). This is a political and philosophical debate that we will not explore here but one that is important to be recognized and approached to contextualize chapter 5. Still, one might argue that this strong position against the linkage between CBA and CEA is sector-specific. David Browne and Lisa Ryan, assessing different evaluation techniques regarding transport policies, made the case for complementarity between CBA, CEA and MCDA, stating clearly that all of them have advantages and disadvantages while arguing for a pluralistic, more holistic approach, rather than a one-for-all tool. The authors also argue for more participatory assessment frameworks and decision-aiding techniques, suggesting in any case that a 'sustainability toolkit' for economic project appraisal, independently of opting for CEA or CBA, should always be complemented by MCDA (Browne and Ryan, 2011).

For the purpose of this thesis it is important to reinforce that recent developments in the practice of CEA in all sectors have been in the direction of more participatory processes (Wright and Fritsch, 2011). As mentioned by Perni and Martinez-Paz (2013):

> "During the WFD implementation process, some authors have recognized that more pragmatic approaches are still necessary to select cost-effective measures. In this line, participatory approaches that serve to complement or substitute CEA are increasingly being supported by the literature on this issue."

3.2 Multi-criteria decision Analysis (MCDA)

As argued in the introduction of this thesis - that human beings have been doing informal non-structured CBA's since the dawn of time - so one might also argue regarding multi-criteria decision analysis or multi-criteria decision-making (MCDA/MCDM). Nevertheless, the International MCDM Society states that the first

known MCDA practice to be put into place in an informal but structured manner belongs to U.S. President Benjamin Franklin (1706 - 1790) whose decision-making process for complex issues would normally involve a piece of paper listing pro and cons and a 'striking out exercise' based on several pre-established criteria. Franklin was either a man ahead of his time or just the first one to have recorded his own decision-making process; still, it took 200 years for the first scientific publications on this matter to appear, as a sub-discipline of Operations Research (OR). Authors like Howard Raiffa, Bernard Roy, Thomas Saaty and Daniel Kahneman, who later came to win the Economics Nobel Prize in 2002, developed from the mathematics of OR, theoretical discussions of game theory and the developments in software programming to establish an entire sub-discipline concerned specifically with complex, strategic decision-making with multiple criteria. This work really took off in the 1980's becoming a major discipline of research and applied science from the 1990's onwards (Bragge *et al*, 2010). Recent research by Huang *et al* (2011) also showed that MCDA use in environmental sciences has witnessed significant growth across all areas of application and that although there is a significant variety of methods used, these do not influence the recommended course of action taken (*ibidem*) – see Figures 6 and 7[11].

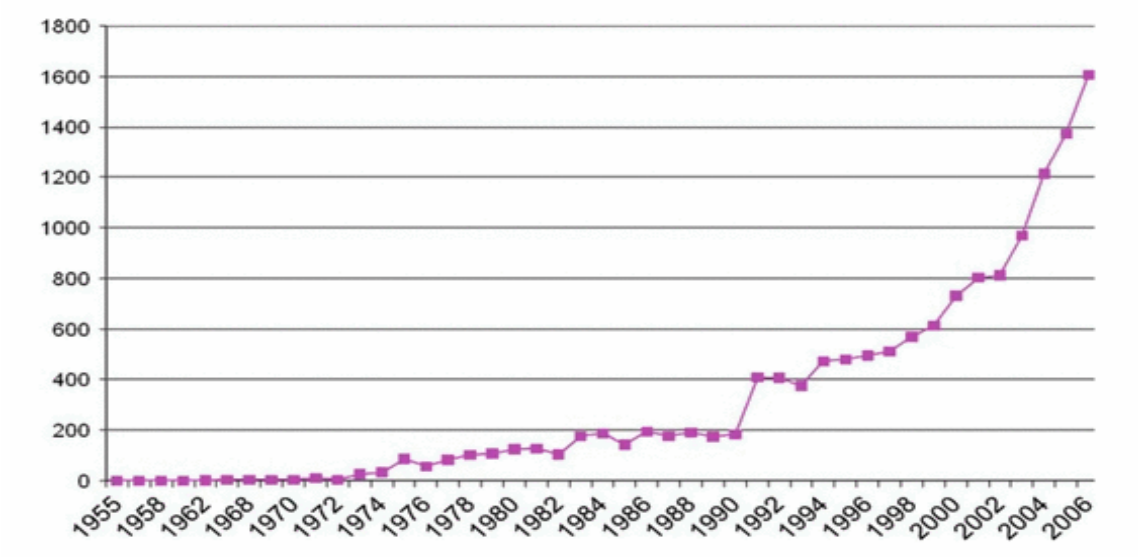

Figure 5 - Yearly publication trend for MCDA/MCDM (Huang et al, 2011)

[11] "Publication in WOS Database normalized to 1990 value. 2010 data are estimated based on first quarter publications." (Huang et al, 2011).

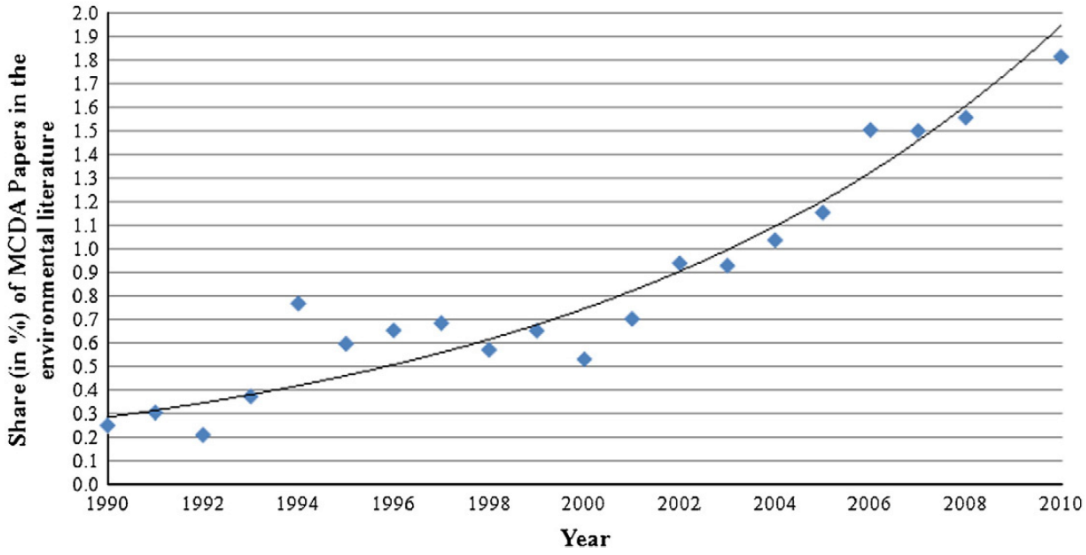

Figure 6 - Ratio of MCDA to total environmental publications (Huang et al, 2011)

This developments of MCDA, regarding a great diversification of methodologies brought us the Analytical Hierarchy Process (AHP); the Analytical Network Process (ANP); the Multi-Attribute Utility Theory (MAUT); ELECTRE; PROMETHEE; VIKOR Method; and finally the well-known, simple-to-use, weighted sum model (WSM), just to mention a few of the most common and widely used methods and models. Out of these methods and concerning the use of MCDA in environmental sciences, AHP/ANP represents about 50% of total MCDA models referenced in the literature, while in 20 out of 312 papers analyzed, multiple methods for MCDA were used (Huang et al, 2011).

The rise in the use of MCDA has several possible justifications, but three of them are of utmost importance for the objective of this thesis: the demand for more participatory, holistic approaches to decision-making processes - for example the FP7 Research project HUNT made a best practice recommendation on Participatory Multi-Criteria Decision Analysis[12]; the demand for methods to complement CBA and CEA and to help deal with uncertainty and complexity (Stagl, 2007); the recognition that MCDA brings transparency to the decision-making process and can help in the building of consensus (Mustajoki, 2004). Browne and Ryan concluded that (Browne and Ryan, 2011: 7):

> "The use of participatory assessment frameworks and decision-aiding techniques such as MCDA is arguably preferable in policy analysis and represents a holistic view of

[12] The HUNT project, in a FP7 funded research looking into sustainable hunting practices in the E.U.. More information available here: htto://fp7hunt.net

> policy impacts at project, policy or programme level. In addition, the use of MCDA avoids a situation where policymakers are required to make decisions solely on the basis of GHG reduction or benefit–cost ratios, without taking account of less tangible or 'fuzzier' impacts"

As with CEA, it is also important to note that recent developments of MCDA include the use of participatory methodologies, as many authors make the case for Participatory Multi-Criteria Decision Analysis (PMCDA). Stagl argues that (Stagl, 2007:16):

> "Valuation and appraisal tools that include public and stakeholder engagement and that are transparent tend to perform better in decision-making for sustainable development."

Stagl 2007 as well as Kowalski *et al* (2008), among other authors, claim that MCDA can be of high relevance for sustainability issues as MCDA i) supports transparency and robustness in decision-making processes; ii) overcomes some limitations and problems regarding the monetization and valuation of impacts found in CBA; iii) can account for multiple dimensions and iv) actively promotes deliberative democratic processes (Kowalski et al, 2008). Still, some authors also argue that PMCDA can not only be a costly and resource-demanding process, but also find numerous barriers if the governance of the organization or municipality is not ready or willing for deliberative democratic processes[13]. This important aspect of project appraisal, which was also approached in the previous chapter is of particular interest for chapters 5 and 6 as the design and proposal of a new methodology must acknowledge the existing tensions within democratic processes and visions as well as the relationship between means and ends.

3.3 Participatory Cost-Benefit Analysis

As noted in the discussion of CBA, CEA and MCDA, there is a clear trend, both in practitioners and academics, to explore, test and research deeper into participatory

[13] Although some authors have made the case for the inclusion of a 'wider range of knowledge's in decision-making processes due to uncertainty and complexity of humankind's challenges (Dryzek, 1990; Habemas, 1984), deliberative democracy – different from the current representative democratic models – is still not the norm in most European countries and municipalities (Stagl, 2007).

methodologies and citizen engagement regarding decision-making processes in environmental protection, sustainability and climate change (Renn, 2006). However, public involvement in decision-making processes has to be conducted within a structured, systematic, framed procedure or the process can become inefficient, ineffective, unclear, irrational and unfair (Okrent, 1998; Cross, 1998; Dietz et al, 1998; Renn, 2006). Renn calls this a dilemma that policy makers have to face between the need for technical expertise that might not easily handle uncertainty and complexity while at the same time ensuring democratic validation and citizen support which "are at least partially based on bias, anecdotal evidence and false assumptions about potential environmental impacts of human actions" (Renn, 2006: 3). This 'dilemma' has no simple solution formula but many layers of complexity as it is also closely connected with the political debate of deliberative democracy versus representative democracy; the academic debate of participatory action-research versus conventional research; or even the economic debate over expert-based appraisal versus the 'wisdom of the crowds' analysis.

It is not the objective of this thesis to research deeper into these fundamental debates but rather to present the meta-trend taking place nowadays, which helps us to contextualize the use of Participatory cost-benefit analysis and chapter 6. It is important also to mention that there exist many different layers of 'participation', even within conventional CBA methods, such as CVM for example.

Participatory cost-benefit analysis (PCBA) is an economic tool that uses participatory-research appraisal (PRA) methods to ensure that the economic, social and environmental benefits and costs of a certain project or action are identified and measured. PCBA differs from a conventional cost-benefit analysis by not requiring as much technical knowledge while allowing input from many different stakeholder groups. As a result, the participatory cost-benefit analysis both captures information that is often unavailable from traditional data sources or is unincorporated in traditional analyses, and it is relatively quick and inexpensive to implement. Participatory cost-benefit analyses are particularly effective with diverse groups of stakeholders and can be facilitated via shared learning dialogues at different levels - community, city, state, or national. Because they capture different information, a participatory CBA should be performed even when a quantitative cost-benefit analysis is also completed.

> "The function of participatory democracy is to gather information on what products are valued, to impart a sense of involvement and commitment to what is chosen, and to provide an ultimate check on abuse of expert methodologies."
>
> (Price, 2000: 9)

Fawad Khan and Kate Hawley from the Climate Resilience Framework, working on their Training Materials series 3 – Building Resilience – make the case for the use of PCBA in communities all over the world dealing with climate change impacts due to its low-cost, low-tech approach and high engagement effects within a community. These authors even go further, suggesting a Simplified Participatory Cost-benefit Analysis (SPCBA). Both of these tools will be further discussed in chapter 5.

Summary table of economic appraisal methods

Tool	Description	Advantages	Disadvantages	Qualitative vs Quantitative	Input	Output
CBA	To calculate and compare total expected monetary costs and benefits of a project or measure. Use of monetary units adjusted for the time value of money (discount rate).	Able to prioritize goals. Comparability of benefits using the same unit of measurement, possible input to CEA and MCDA.	Subjectivity in monetizing benefits, ethical considerations, equity issues, no account for distributional impacts (Kaldor-Hicks theory, all entities are equal), use of discount rate.	Quantitative (monetary assessment)	Monetary units for costs and benefits; info on current and future climate risks, magnitude and likelihood of impacts	Cost benefit ratio or net present value and internal rate of return
CEA	To calculate and compare monetary costs with physical benefits of a project or measure. Used to identify the lowest cost for a certain outcome or highest benefit given the available resources.	Physical benefits easier to quantify than monetary benefits.	Benefits not comparable when expressed in different units (in measures with multiple benefits), use of discount rate.	Quantitative (monetary and non-monetary units)	Monetary units for costs and physical units for benefits. Information on current and future climate risks, with magnitude and likelihood of impacts.	Cost-effectiveness ratio (e.g. $/case or death avoided), incremental cost-effectiveness ratio (ICER: change in costs to incremental benefits).
MCDA	To make comparative assessments between projects or heterogeneous	Assessment of distributional impacts, use of evaluation criteria different from	Subjectivity of the attribution of weights and final ranking (depends on the stakeholders' views),	Quantitative and qualitative	MCA can work with mixed data and incorporate both qualitative and	Ranking or rating of options evaluated with specific weights. The option

	measures, with complex multi-criteria problems. Each option is scored with reference to a number of criteria.	the monetary one and when an impact cannot be quantitatively measured. Not necessarily data intensive. Possible to include robustness of outcomes (uncertainty) as one criterium.	complexity and timespan of the consultation process (agreement can be difficult to reach).		quantitative information. It needs to define objectives and criteria to be evaluated for each option, and to assign weights and scores.	with the highest score is chosen.
PCBA	To use participatory research appraisal (PRA) methods to identify and score financial, social and environmental benefits and costs.	Requiring less technical knowledge than traditional CBA. Allows participants to contribute to the identification of costs and benefits.	Subjectivity related to the ranking and scoring. Costs and benefits are scored according to stakeholders' perceptions.	Qualitative and quantitative	Identification of costs and benefits from a qualitative point of view, assignment of unit monetary values when possible. Information on current and future climate risks, with magnitude and likelihood of impacts.	Cost benefit ratio

Figure 7 - Summary of economic appraisal tools

4 The Agenda for Cost-Benefit Analysis in climate change adaptation in Europe

Among environmental “hot topics” as well as governments' top concerns, the topic of climate change has been clearly and dramatically gaining momentum – scientifically, politically and economically – and is today widely considered the major challenge of humankind regarding its sustainability in the near future (Schellnhuber, 2012).

At the end of 2013 the Intergovernmental Panel on Climate Change - IPCC - began publishing its Assessment Report 5 - AR5 - which examines the work of thousands of scientists all over the world. The main conclusions are increasingly clear and trustworthy: it acknowledges the phenomenon known as climate change, whose main known impacts are i) increased mean surface temperature, ii) increased frequency and intensity of extreme weather events, iii) increase in mean sea level and iv) reduction of oceans’ pH, stating that this is not just happening but is intensifying and accelerating. Moreover, scientists have 97,5% confidence that the emission of greenhouse gases (GHGs) directly caused by human activity is the main cause for the phenomenon, which deviates from the normal and cyclical climate variability of Planet Earth (IPCC AR5, 2013). Although conservative in its political prescriptions, the AR5 again emphasizes the need for immediate global action on reducing emissions of greenhouse gases under penalty of leveraging positive feedback mechanisms of the phenomenon with incalculable effects on the human race and the balance of life on earth. In fact, the most recent Potsdam institute for Climate Impact Research and Climate Analytics publication for the World Bank (Schellnhuber, 2012) and the European Environment Agency (Adaptation in Europe, 2013) call into question our political, economic and social ability to limit the increase in global average temperature below 2 ° C. This would require the level of GHG to stabilize at 350 ppm - the safety roof recognized by the IPCC, by now already surpassed. Yet these publications warn at the outset that even if we could stop all emissions of greenhouse gases immediately, the effects of the last 200 years of industrialization will lead us inescapably to a warmer, unpredictable and more dangerous world in the coming decades (Schellnhuber, 2012).

Faced with the inevitability of the phenomenon as well as our scientific limitations regarding planetary thresholds, in recent years the political focus partially shifted from mitigation to adaptation to climate change, starting with the European Commission

Green Paper (2007) on adaptation to climate change in Europe, which progressed to the White Paper of the European Commission in 2009 - "Adapting to climate change: towards a European framework for action" – and culminating in the emergence of the "European Strategy for Climate Change", launched in April 2013. Adaptation is defined by the IPCC as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". There are multiple types of adaptation, including anticipatory, reactive, autonomous and planned adaptation (UNFCCC, 2010).

It is important to stress the relevance of this step from mitigation to adaptation, since it is crucial to understand all the associated political, economic and environmental implications. While with mitigation there is a set of well identified and measurable causes - GHG emissions, in particular $C0_2$ and methane - and a well-defined goal to reduce emissions - allowing the design of global strategies, investments and specific targets by sector, by country, and even globally, in the case of adaptation everything is significantly more complex. Mitigation is global and only at this level does it have or could have an impact; adaptation is entirely local, as the impacts of climate change are extremely heterogeneous and substantially dependent on local conditions. The purpose of mitigation is to reduce GHG emissions; the objective of adaptation is to reduce climate vulnerability and increase the resilience of communities and ecosystems. Mitigation is quantifiable and relatively straightforward; adaptation on the other hand is difficult to quantify and entirely non-linear since it cuts across different sectors and multiple and simultaneous impacts. Thus, while dealing with the same phenomenon, the approaches, strategies and policies can be diametrically opposed depending on whether we are aiming for mitigation or adaptation. Often certain measures contribute to both strategies but in the vast majority of cases adaptation measures force us to frame the territory, ecosystems and populations in ways that are more holistic, more integrated and necessarily more complex. As the European Environmental Agency (2013: 8) puts it:

> "Adaptation is not simply about doing more, it is about new ways of thinking and dealing with risk and hazards, uncertainty and complexity. It will require greater public participation to address questions of social need and to find suitable adaptation pathways."

All of the above mentioned factors - i) magnitude and scale of impacts and investments both in time and space; ii) multidisciplinary; iii) cross-sectorial nature with a need for multi-stakeholder engagement and alignment; iv) uncertainties and risks; v) urgency for integrated, worldwide action – together with the inability of governments worldwide to reach a truly global agreement, contribute to what might be called a "global public evil" - since GHG emissions affect everyone and can only be resolved by an common effort. As the benefits of reducing GHG emissions can be considered as a public good - non-rival and non-exclusive - there is a strong justification for major public intervention at all levels (investment, legislation, research). The failure of markets and the inability of normally functioning private agents to respond to the challenge posed by climate change is, and has been, one of the great arguments for public intervention, particularly at international scales (Stern, 2007). In turn, the magnitude of the impacts of climate change as well as the potential effects on strategic economic sectors such as energy, water and agriculture require a coordination of strategies and integrated interventions, traditionally assigned to the public sector. The example of the 2003/2004 drought in Russia affecting global production of several key cereals, leading to an increase in prices in international markets and in turn affecting thousands of hungry people in sub-Saharan Africa is just one of dozens of recent examples of cascading effects caused by natural phenomena, which will increase in frequency and intensity due to climate change (Schellnhuber, 2013).

It should also be noted that, since the main impacts of climate change will be felt progressively more intensely from 2030 onwards, there is a key role to be played by future planning, a task that lies squarely on the public sector. Finally, due to their territorial and temporal transversality, both in terms of knowledge and degree of climate change, these efforts require greater communication and alignment between different economic sectors and actors. Such dialogue can be promoted and driven by science but probably is best if coordinated and supervised by the public sector.

The thrust for public intervention in terms of climate change research, legislation and action since the 2000's brought the attention of economists and politicians to the importance of applying CBA logic to this growing field, especially after the controversial report "Economics of Climate Change" published in 2007. This report went further than any other economic assessment ever had and performed, for the first time, a global CBA for climate change action, justifying that even a cost of 1% of

World GDP would bring benefits in the range from 5% to 20% of world GDP (Stern 2007). It was a bold statement from a well-respected economist, which in spite of criticism launched the economic debate regarding climate change investments in both mitigation and adaptation. The IPCC AR4 reported the literature on adaptation costs and benefits as 'quite limited and fragmented' (Adger et al., 2007), and the OECD study on the 'Empirical estimates of adaptation costs and benefits' (Agrawala and Fankhauser, 2008) found little quantified information even on the costs of adaptation, except in a few sectors (e.g. coasts). Recently, a UNFCCC study (UNFCCC, 2010) on the 'Potential costs and benefits of adaptation options' found the continued lack of detailed analyses of the costs and benefits of adaptation, including in a format that is relevant to decisions on public funding. There is a need for further methodological development, including the treatment of uncertainty, economic valuation and equity. Clearly, this is one of the major 'gaps' requiring urgent attention in furthering analysis. More recently, the FP7 Project Climate Cost, noted that regarding the use of CBA in climate change adaptation in Europe:

> "The review has found that the coverage of the adaptation cost estimates is limited, though the evidence base in now growing (though it is primarily in the grey literature)[…] Even within this small group of assessments, a range of different methodological approaches are adopted, with costs of adaptation being reported in different metrics, time periods, etc… Consequently it is very difficult to compare estimates between studies, i.e. to undertake a systematic review and build up a coherent picture of the overall costs of adaptation in Europe."

Although there are many reasons one can point out regarding the limited and fragmented information on costs and benefits of adaptation in Europe – CBA limitations; use of alternative appraisal tools; difficulties in direct comparability due to inherent complexity and diversity; etc. – two of them, addressed in section 2.5, stand out: it is quite an expensive tool, namely for small to medium investments; and, most of the times it is disregarded by decision-makers and policy-makers. Both are a paradox for CBA promoters but both of them, together with all other CBA limitations, make the case for the use of alternative, simple and cheap, participatory and democratic tools. PBCA, explored in the next chapter represents a move towards that path in economic appraisal tools and methods.

5. Participatory Benefit-Cost Analysis

> "It is time for progressive groups as well as ordinary citizens to retake the high ground by embracing and reforming cost-benefit analysis."
>
> (Revesz and Livermore, 2008)

The **Participatory Benefit-Cost Analysis** (PBCA) is an economic appraisal tool which has been developed and tested by the Center for Climate Impact, Modelling and Adaptation (CCIAM), from the University of Lisbon, under FP 7 Project BASE – Bottom-up Adaptation Strategies for Europe - in order to assess through participatory methodologies the costs and benefits of different adaptation measures of the Strategic Plan for Climate Change of Cascais (PECAC). It is a simple-to-use, resource efficient, solutions focused, pro-active, deliberative process. The PBCA aims to combine the advantages and strengths of multi-criteria analysis with the rationality of Cost-benefit Analysis (CBA), thereby evolving from the simplicity of the Simplified Participatory Cost-Benefit Analysis (SPCBA) as proposed by the Climate Resilience Framework – Training Kits (3rd series) – to deliver an all-in-one procedure for action-researchers working in climate adaptation.

PBCA can be defined as a hybrid methodology of economic project appraisal as it is composed of heterogeneous sources and diverse elements, combining interpersonal deliberation and quantitative methodologies to produce both depth and breadth in valuation and appraisal processes. Hybrid methodologies are another growing trend within economic project appraisal tools and methods as they "*resituate specialist knowledge claims through attention to their framing conditions and boundaries of uncertainty, while co-producing new forms of citizen and stakeholder expertise, thus opening up the appraisal of projects, plans, programmes, and technologies to other forms of framing and reasoning*" (Davies, 2006: 235).

PBCA is conceptually and in practice distinct from PCBA, addressed in section 3.3. The inversion of Cost-Benefit to Benefit-Cost is an intended, conscious decision as the focus of the analysis derives not from a needs/problem analysis but from an asset-based perspective. We focused on creating the space for intentional conversations between stakeholders around potential connections, solutions and actions regarding climate

change adaptation. In doing so we also moved beyond traditional vulnerability analysis and entered into opportunity analysis for building resilience within our communities and ecosystems, following the Asset-based Community Development (ABCD) approach[14].

The PBCA was developed in order to answer most of the challenges we've identified throughout this thesis - namely the conventional CBA limitations summarized in 2.5 -, to embody the new trend towards participatory methodologies as well as the call for more complementarity between economic appraisal tools.

Although the focus is on climate change adaptation, we believe that the method, as proposed, could also be applied to different contexts and circumstances, and different challenges facing our societies today. An example would be with social entrepreneurs and community workers, interested in having a better understanding of their community preferences and perceptions regarding different options as well as facilitating participatory decision-making processes within a structured dialogue along positive and negative effects of concrete measures.

Within the existing literature and the vast bibliography of this thesis, few are the comparable examples of similar hybrid methodologies being used in climate change adaptation, making the PBCA an innovative tool to be considered and evaluated directly from empirical evidence. The results from three workshops held in Cascais will be presented and discussed in the next chapter.

5.1 The Methodology

The PBCA tool was developed together with a wider action-research methodology agreed upon by the Municipality of Cascais and BASE core team[15]. In this sense, PBCA is one of several tools which were designed with an integral perspective and co-evolved within a larger framework whose main objective was to evaluate the implementation phase, efficiency, effectiveness, adequacy, barriers and opportunities for different adaptation measures in Cascais. The tool was tested in three separate participatory

[14] Methodology developed by John Kretzman and John P. McKnight. See reference (Kretzman and McKnight 1996).
[15] For the action-research methodology please see the introduction to chapter 6.

workshops, with local stakeholders, each time in one hour period. The concrete implementation and results are discussed below, but in this section we'll describe the methodological design.

The PBCA Methodology has 5 different steps which can and should be completed in approximately one hour by groups of diverse stakeholders. The methodological steps are presented at the beginning by a session facilitator, which cannot be also a group focalizer. The objective of the session is also presented at the beginning, clarifying that the purpose "is not to calculate the "right" decision, but no help improve the understanding for decisions involving risks, multiple criteria, and multiple interests."(Bell et al, 2003: 2) as Michelle Bell, Benjamin Hobbs and Hugh Ellis have argued for participatory MCDM. The 5 Methodological Steps are:

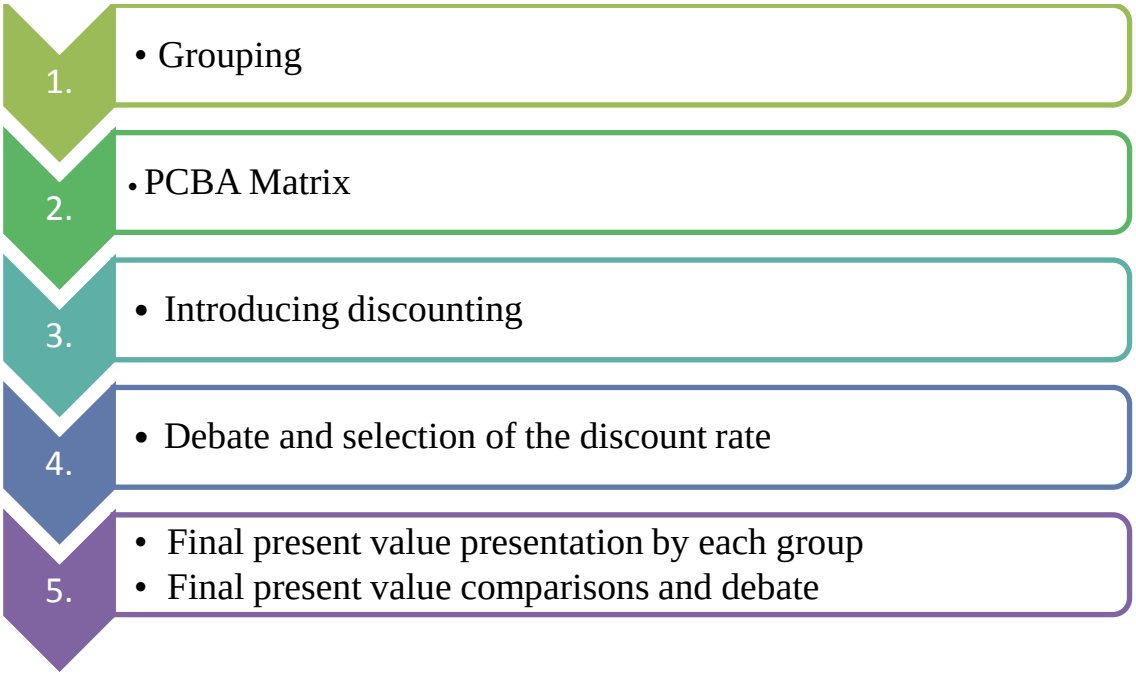

Figure 8 - PBCA methodological Steps

Step 1: Organize participating stakeholders into mixed groups of [3min-9máx; 5 is optimal], where each group is given one Adaptation Measure/Project to assess and one focalizer[16]. It is extremely important to guarantee heterogeneity in the constitution of

[16] We use the term 'Focalizer' because more than facilitating, the purpose and mission is clearly to bring focus (time and subject wise) to the group, thus enhancing the efficiency and effectiveness to the work. The focalizer is briefed beforehand.

the groups, so as to foster rich debates from multiple perspectives. The adaptation measure to be analysed can come from a previous exercise and be selected by the group or it can be a new measure suggested by the facilitator of the session according to the groups' interest and motivation.

Step 2: Each group is given the PBCA Matrix (explained below) and 30 min to fill it according to sub-step 1 - name the impacts – sub-step 2 - value each impact according to the given scale – sub-step 3 - calculate ratios.

Step 3: The session facilitator presents the concept of discounting and offers different alternatives for the participants' consideration. Doubts are clarified.

Step 4: The participants are given 15 min to debate the discount rate to apply in each group. Group Discussion on which Discount factor to apply and net final value calculation

Step 5[17]: Each group selects a representative group speaker which presents in 1-3 minutes the final net value, the discount rate choice and the overall discussion regarding the costs and benefits of the adaptation measure under scrutiny.

The fundamental structure of the PCBA is presented to the participants in Step 2, and it serves as the underlying matrix for the discussion that will follow. The PBCA Matrix was developed having as the starting point the SPCBA Matrix proposed and tested by the Climate Resilient Network, while bringing into the exercise both time differentiation (short-term; long-term) and the possibility of unequal weighting of the criteria (Economic, Social and Environmental). This was a conceptual possibility but it was never truly explored in our participatory workshops, mainly due to time limitation. In Figure 9, you can find an example of the SPCBA[18][19] done in Da Nang, Vietnam, in a participatory workshop held with local stakeholders – Da Nang's People's Committee and Women's Union Households -, by the Climate Resilience Network regarding

[17] If relevant, a 6th Step can be added for Sensitivity Analysis regarding both the use of different discount rates and/or different weighting criteria in order to challenge the group's decision and promote debate about assumptions in the decision-making process.

[18] Find out more about it here: *http://training.i-s-e-t.org/module-series-3/*)

different resilience actions to be undertaken by the local community using a 0-5 scale where the lower the number, the lower are the relative costs or benefits.

	COST (0-5)				BENEFIT (0-5)				
ACTIVITIES	ENV	ECON	SOC	TOTAL	ENV	ECON	SOC	TOTAL	B/C
Promotion of minimum tillage operation	0	2	1	= 3	5	4	4	= 13	4.33
Plantation in the degraded and eroded land	0	3	1	= 4	5	5	5	= 15	3.75
Construction of check-dams	1	5	3	= 8	5	4	4	= 13	1.62
Protection of water sources	0	4	3	= 7	5	5	5	= 15	2.14

Figure 9 - an example of the SPCBA matrix

In figure 10 you can find the summary example of a PBCA Matrix filled by a group of 5 participants from different institutions and organizations of Cascais after being presented with a summary dossier, prepared by the Municipality and BASE, with the adaptation measure description, budget, impacts and responsibilities, in a workshop held in our BASE case-study of Cascais for the Adaptation Measure Green Corridors. The participants came into a consensus regarding the main positive and negative impacts in each dimension and valued them according to a subjective scale of 1-5. Partial Benefit-cost ratios were calculated out the mean average from each block to allow for partial comparability regarding each dimension as well as short-term and long-term impacts.

After their initial valuation for each impact and each dimension, and the presentation of the Discount factor, this particular group consciously opted for a negative interest rate to apply to the Long-term ratio, ending-up with a final value of 1.76. It is important to notice that the aggregation of the different criteria was done directly, i.e., considering equal weights for environmental, social and economic effects of the implementation of the adaptation measure.

[19] Unpublished data collected by Li-Bird through the CADP project under ISET's direction. Method design by ISET.

ADAPTATION MEASURE: Green Corridors

	ENV			SOCIAL			ECONOMIC				
	Effect Description	Short-term (2014/6)	Long-term (2050)	Effect Description	Short-term (2014/6)	Long-term (2050)	Effect Description	Short-term (2014/6)	Long-term (2050)	Short-term (2014/6)	Long-term (2050)
BENEFITS	Biodiversity hubs and channels	1	4	Shadow, heat-relief spaces	1	3	Real-estate valorization	1	4	4,5	8,5
	Flood control; Erosion control	1	2	Meeting point	1	2	Job creation	4	2		
		1	3		1	2,5		2,5	3		
COSTS	Negative impacts in fauna dynamics	3	1	Social resistancedue to traffic changes	4	1	Investment	5	1	9,5	4
	-			Social resistance due to biodiversity increase	2	1	Maintenance	2	3		
		3	1		3	1		3,5	2		
Rácio B/C		0,667	3		0,167	2,5		0,714	1,5	0,47	2,13
										FINAL NET PRESENT VALUE	1,76248586

FUTURE PRESENT

-5%	-1%	0%	1%	5%
6,3379	1,4359	1	0,6989	0,1726

$PV(X_t) = (X_t)*[(1+i)-t]$

X_t = Rácio B/C t = time frame (36)

i = Discount rate

Figure 10 - example of a PBCA Matrix filled regarding the adaptation measure 'Green Corridors'

Still regarding Step 2, filling-up the PBCA Matrix has 3 Sub-steps:

1) **Name them**!! Each group has to come to a common agreement on the 2 most important effects (positive and negative) for each of the three 'criteria' based on their expert knowledge and synthetically describe them. If necessary, more than 2 can be named and valued, if the group agrees. In the end you should have 12 important impacts identified for your Climate Adaptation Measure
2) **Value them**!! Each group has to come to a common agreement for a scale-valuation (1-5) for each effect named before. In the end you should have 24 single valuations
3) **Time for Math**: Add and divide by two for each 'criteria box', add all Benefit means as well as Costs means and by now you should have 4 final sums (Short-term Benefits; Short-term costs; long-term benefits and long-term costs) and 8 partial Benefit/costs ratios

Uncertainty can be internalized if the participants don't reach a common agreement for a certain valuation by allowing for intervals, let's say for example [3-5]. This was the

case within one of the groups were consensus was not reached and the facilitator suggested intervals. The scale can also be adapted for [1-10] if necessary, for better distinction between adaptation measures. Bigger, proportional scales [1-100] can also be used. Nevertheless, in our view they add substantial complexity without improving dramatically the overall conclusion. Although the final value is a ratio a unique scale should be decided prior to the use of the PBCA in any context, in order to guarantee perfect comparability between results and final ratios. Based on our experience within BASE, explored in chapter 6, we recommend the use of [1-10] scale.

5.2 Applying the Discount Factor

"A key result is that the interest rates IA[20] experts recommend for discounting future impacts depend strongly on what type of impact is being discounted, as well as upon the exact phrasing of questions used to elicit rates from the experts."

(Bell et al, 2003: 289)

One of the crucial added-values of the PBCA regarding SPCBA is time differentiation. As we separate between short-term and long-term impacts, we allow time dynamics and future expectations and valuations to come into being. We also allow for uncertainty, technological advancements and all of those things that we know we don't know, to come into our exercise. By doing so, we either not introduce discounting and assume a 0% discount factor on future impacts – which as we've seen before its quite a strong assumption – or, we are forced to introduce discounting into the Methodology – see section 2.4. For the PBCA we've decided to introduce the concept and the exercise regarding discounting and in Step 3, a brief presentation of the basic fundamentals of discounting takes place using common demonstrative examples found in the discounting literature and the presentation of the Ramsey equation and its parameters. Although discounting and the Ramsey equation are both used mainly for monetary values, we've assumed time-preference as a form of multi-criteria weighting on time which reflects mainly a value judgment that can be applied to non-monetary valuations (Bell et al, 2003). The session facilitator then introduces the five discount rate possibilities for this exercise and their meanings. The five possibilities, as one can

[20] [Impact Assessment]

observe in Figure 7 are: -5%; -1%; 0%; 1%; 5%. The selection of these possibilities had into consideration the following elements:

i) Clear differentiation of alternatives – both positive, negative and neutral – in order to allow deeper ethical, political and economic debate over time preferences
ii) Reasonable scale of intervals for better result differentiation and reading
iii) Maintaining the scale of intervals within commonly agreed rates in the literature (see section 2.4)

The option to give the opportunity for negative interest rates was supported by the work of Bell et al, in which, and for a MCDM participatory workshop, more than a third (41.6%) of the participants chose negative interest rates when asked - directly and indirectly (Bell et all, 2003).

The results of the PBCA as well as the choice regarding the discount factor will be further developed and analyzed in chapter 6.

6. The case of Cascais

In 2010, the Municipality of Cascais, together with Center for Climate Impacts, Adaptation and Modelling (CCIAM) from the Faculty of Sciences of the University of Lisbon, elaborated the Strategic Plan of Cascais for Climate Change (PECAC). This strategic document was the first of its kind ever done in Portugal. Its contributions were integrated modestly in the City Urban Planning Map Review of 2012/2013 but besides this, the PECAC was never fully internalized in the Municipality procedures, planning and strategic design, communication, and properly used as a tool for better decision-making processes regarding future investments.

In 2013, a team from CCIAM, within the framework of the European action-research project BASE took the lead to use Cascais as one of its case studies for the period 2013-2015. The key starting point was an in-depth analysis of the PECAC and, in a first cycle of research, different stakeholders were invited, namely the City Technical body to contribute with not only their perception of the concrete implementation of the proposed Adaptation Measures in the PECAC but, above all to bring in their knowledge and critical view regarding what are today's main priorities, vulnerabilities, opportunities and barriers regarding climate change adaptation measures implementation in Cascais.

Bearing this in mind and in tight cooperation with Agenda XXI Cascais, eight participatory workshops, one horizontal survey of the technical staff of the Municipality with 99 valid answers and a population survey with 1885 valid answers were successfully organized.

In three of these workshops we were able to test the PBCA tool which was applied for 8 different adaptation measures by a total of 40 people concerning three clusters of adaptation measures: Biodiversity; Health; Water.

The PBCA tool was used in the end session of our workshop agenda as the workshops were designed to build up knowledge and group coherence along the day. The workshop agenda consisted in three different sections:

- Section I consisted in PowerPoint presentations by the Municipality representative Eng. João Dinis regarding the municipality PECAC and by

CCIAM representative Dr. Gil Penha-Lopes concerning the new IPCC AR5, new scenarios and the agenda for adaptation at the E.U., national and local scale;

- Section II consisted in a participants analysis of the PECAC adaptation measures - level of implementation, adequacy to today's needs and scenarios, coherence with the Municipality's strategy and focus, prioritization;
- Finally, Section III consisted in a multi-criteria analysis of the cluster-specific adaptation measures according to complexity of implementation – social, technical and institutional – and importance, urgency and no-regrets[21], culminating with each group selecting a different adaptation measure over which they would do a PBCA.

Overall, the eight adaptation measures, their final net value and selected discount can be seen in Table 7, together with time and discount rate sensitivity analysis. There are many important conclusions one can draw from the observation of table 7, namely:

- All groups considered that the partial benefit-cost for the present (short-term) impacts of the measures is lower than future expected impacts with the exception of the adaptation measure "Bioclimatic legislation";
- Present benefit-cost regarding three of the measures – all in the biodiversity cluster – were considered to be below 1, i.e., the short-term costs are bigger than the short-term benefits and the measure would not be advisable;
- No group selected either 0% nor 5% as the appropriate discount rate, as three groups selected a negative rate and five groups decided for a 1% discount rate;
- If only the final NPV from the PBCA was taken into consideration in the decision-making process, Reforestation of the Sintra-Cascais Natural Park and Bioclimatic legislation would be the adaptation priority actions for Cascais;
- If we change the time horizon regarding future expected benefits to 2050, while maintaining all other factors constant, we witness that a small difference in the rate makes a great difference in the NPV (see for example the measure: Reforestation)

[21] According to IPCC AR5, section 7.3.4.2: "No regrets options are by definition GHG emissions reduction options that have negative net costs, because they generate direct or indirect benefits that are large enough to offset the costs of implementing the options". In terms of adaptation the key concept remains the same, ie, actions in which we have net negative costs.

- If we assume a 3.5% discount rate and a time horizon for 2050 for all adaptation measures, the overall NPV conclusions are significantly different from the original NPV, namely for the biodiversity cluster adaptation measures.

The results from the 3 workshops summand in the first columns of table 7 were presented by each group representative and discussed with all the workshop participants. Interestingly the focus of the debate was mostly not about the results themselves but rather about the assumptions that each group made to arrive at each result. However, the results, when taken into consideration to rank possible priorities of action for Cascais, show us a coherence with the MCDA, the implementation analysis and prioritization made in prior sections of each workshop, and an inconsistency with the TOP 15 prioritization made in 2010 with scientific experts. The divergences and inconsistencies between the non-participatory expert-based methodology from the PECAC 2010 and the participatory, stakeholder-based methodology of BASE, regarding climate adaptation actions for Cascais Municipality are not the focus of this master thesis but deserve future deeper research mainly in order to better understand not only how can science better serve society but also how can participatory, non-expert, stakeholder-based processes contribute to a scientifically-sound outcome for local adaptation strategies and actions.

After running the PBCA tool in three separate workshops with more than 40 participants the key findings regarding the methodology were:

- **It's more about the process than the result itself** as people engaged seriously in technical and also ethical/moral debates with great sharing but then disregard the final present value;
- **It can lead to counter-literature**, but intuitive, **results**, such as the selection of negative discount rates for some particular adaptation measures in some groups;
- **Simple to use and understand**, mainly if there is good facilitation/focalization of the debate.
- The introduction of the time-factor and the inherent use of a **discount rate enriches the debate** and contributes significantly to the usefulness and maturation of the tool;

Adaptation measure	CB Short term	CB Long term	Discount rate	Final present value (original, 2013-2020)	Final present value (original 2013-2050)	Final present value (3,5% 2020)	Final present value (3,5% 2050)
Green corridors	0.5	2.25	-1%	1.445	1.8653875	1.13425	0.575125
Reforestation of the Sintra-Cascais Park	0.8	6.5	-5%	4.755	20.998175	2.9545	1.33925
Action plan to manage invasive species	0.79	3	-5%	2.404	9.90185	1.574	0.8285
Eliminate water pollution points	2	2.42	1%	2.14	1.84579	1.95106	1.34969
Raising awareness in households regarding good sanitation practices	2.25	3.5	1%	2.7	2.34825	2.5005	1.63075
Legislation towards bioclimatic construction norms	5.25	4.5	1%	4.74	4.19775	4.3935	3.27525
Vector surveillance system in the municipality	3.5	5.5	1%	4.34	3.67225	3.9115	2.54475
Awareness raising campaigns for heat waves and heat stress	1.25	2.2	1%	1.68	1.3939	1.4896	0.9429

Table 7 - Selected adaptation measures with their NPV, discount rate choice and sensitivity analysis for different discounting time periods and rates

- The impact measurement scale (1-5) was considered too short to clearly distinguish between adaptation measures and a (1-10) scale has been proposed for future workshops;
- **Inexpensive to use and implement** as it can be applied in the context of an existing workshop and represent a 1-hour add-on to the program with minimum marginal costs
- It allows stakeholders **to point you in the right direction** regarding the most important effects of an action if deeper CBA is needed for quantitative valuation

The PBCA also received feedback from the participants, Agenda Cascais XXI and the organizing researchers involved, and the key findings were that:

- Too Simple: One possible criticism regarding the tool is that it's too simple to draw serious, scientific conclusions from its use in different contexts as the participants might not be completely truthful in their valuations as they face it as a mere 'game' and value upon their subjective principles/values and not their real behavior.

- Too abstract: concepts like the Discount factor might be rather complex to explain and integrate consciously within the discussion of a group and lead to misleading results, such as the use of a negative discount rate. Although the use of a time differentiation is clearly a plus added-value for the tool itself and for the discussions it promotes, careful sensitivity analysis regarding different Discount Rates is obviously necessary in order to robust the results and analysis.

- Too short: the time given for group discussion might be too short to allow for deeper debates on the impacts as well as their valuations keeping the overall exercise in 'shallow waters'. Further in-depth CBA methodologies might balance this weaker point.

7. Conclusion

Cost-benefit analysis is indisputably an important and central economic appraisal tool, both for public and private projects, which has grown significantly in the last 200 years not only theoretically and in its practical use but also in its political recognition. However, CBA is also strongly criticized by academics, decision-makers and planners for being politically biased, theoretically weak, too expensive, unfair to future generations or even for poor people and limited in its scope of reality. Many authors claim that a CBA on CBA would be negative or below 1, depending on which criteria we would consider the NPV, and argue for its dismissal. Still, CBA is expected to continue its path in becoming ´the' economic appraisal tool in the E.U. and the U.S. in upcoming years.

From the recent trends not only with CBA but mainly with MCDA and CEA we argue that not only complementarity between different tools but also the use of participatory methodologies is fundamental when dealing with uncertainty, with complexity, with growing demand for transparency in public decision-making processes and with sustainability. Dealing with such challenges as Climate Change, where complex interdependencies both in time and space exist and impacts can occur over long-time periods, policy-makers and decision-makers should not rely in a single tool trusting that that by itself will give us the correct answers. Only when combining several different tools, stakeholders and approaches in a scientifically sound, robust and coherent manner, while allowing for constant iterative processes, can we aim to achieve the socio-economic-political support to build resilient societies to deal with the challenges that we will all face in times to be.

We believe that the PBCA as a hybrid methodology can be an effective, low-cost, easy to implement and adapt tool, easy to complement with MCDA as we've tested in our case study or with CBA as we argue in chapter 6, which can allow us to involve stakeholders, assess different options, create meaningful debates over such important assumptions as the discount rate and point us in the right direction regarding more quantitative valuation of impacts.

As for future research, two key debates arose during this thesis. The first concerns the adequacy and effectiveness of different tools at our disposal when dealing with

complex, uncertain, interdependent, world-wide issues such as climate change. The second concerns the underlying assumptions one has to take in order to use those tools. Ideally future research would allow us a better and clearer understanding regarding which tool or methodology to use when, how and for whom, bearing in mind that different projects in different sectors, in different contexts might translate to very different combinations of solutions and alternatives. A tree-choice model based on empirical evidence as well as supported by ethical and moral grounds would be of extreme usefulness to decision-makers, who instead of having a one-for-all tool or just following blindly a distant recommendation that just might not fit into their context, would have a 'find-yourself the appropriate mix" or find your recipe and adapt it to your specific and unique circumstances. Something like Emilio Padilla has envisioned for the evaluation process:

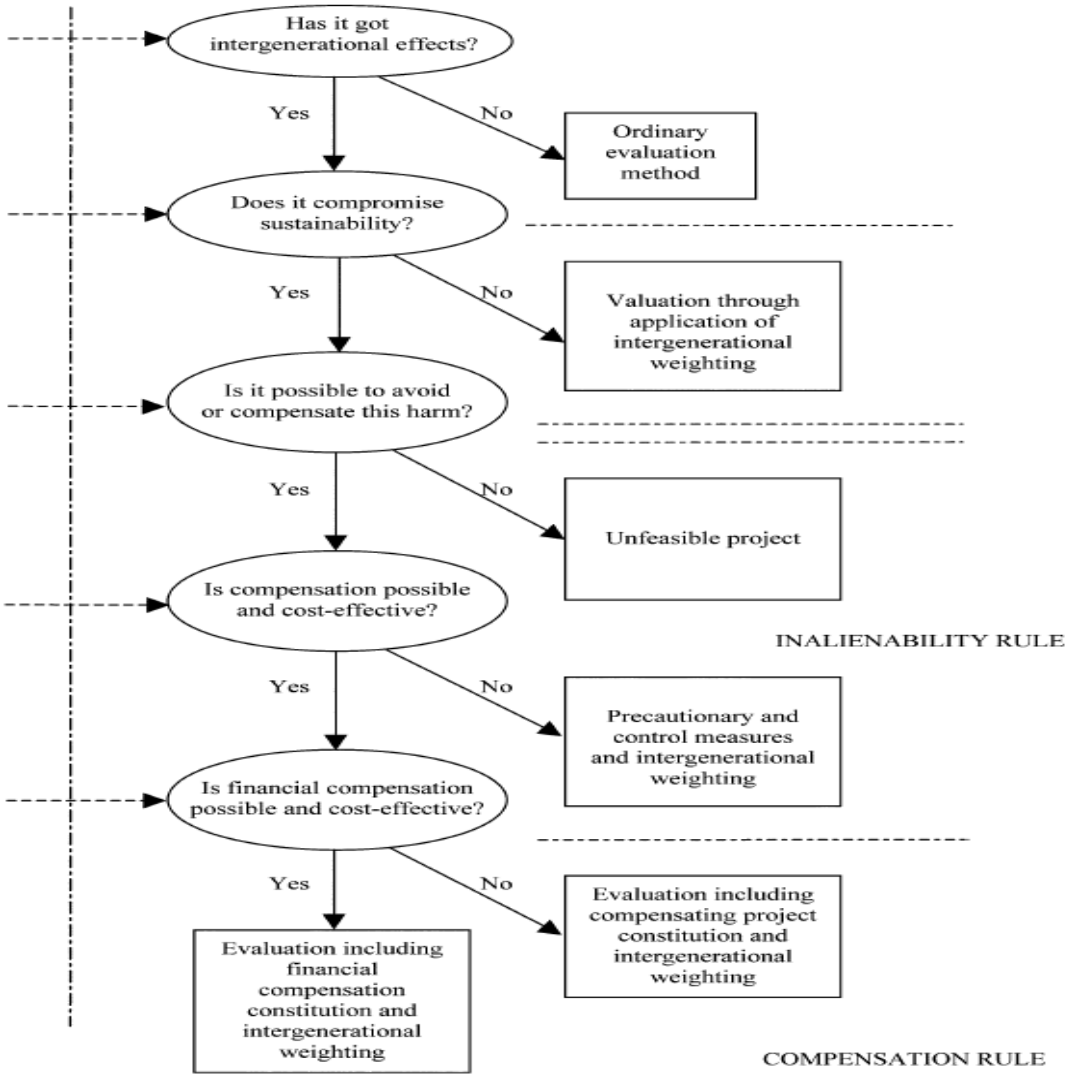

Figure 11 - Evaluation process (Padilla, 2002)

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