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Long-term coastal management strategies: useful or useless?

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ABSTRACT

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Climate change impacts are expected to increase pressure upon coastal defenses worldwide. However, most adaptation measures for coastal defenses (if any) are still triggered by today's local problems, rather than addressing the expected long-term climate change. This gives rise to the question whether long-term strategies might bring advantages over continuing present coastal management practice during the next 200 years. Comparing long-term coastal management strategies is surrounded by both physical and sociological uncertainties, impeding this comparisons straightforwardness. A new assessment methodology has been set up, accounting for these uncertainties in impacts of optional long-term coastal management strategies. Applying this new assessment framework to a case study for the Dutch coast shows that assessments of long-term coastal management strategies differentiate sufficiently for comparison, despite all uncertainties involved.

ADDITIONAL INDEX WORDS: *integrated assessment, multi-criteria analysis, cost benefit analysis*

INTRODUCTION

Protecting low elevation coastal areas from flooding by the sea is a long-standing challenge that is faced in many places. However, the impacts of climate change are adding to the vulnerability of these low-lying coastal zones. Rising sea levels and increasing intensities of hurricanes and typhoons are among the impacts of climate change increasing the vulnerability of coastal populations [MEEHL *et al.*, 2007]. At the same time, about two-thirds of the world's largest cities are located in low elevation coastal areas (with elevations less than 10 meters above sea level) and about 10% of the world's population is living in these low elevation areas [MCGRANAHAN *et al.*, 2007]. It is even foreseen that about 80% of the world's population will live in coastal areas and deltas by 2050 [NETHERLANDS WATER PARTNERSHIP, 2004].

The above mentioned developments raise the need for an adequate adaptation policy for coastal areas and deltas. However, a recent study of the EUROPEAN ENVIRONMENT AGENCY [2006, p. 47] indicates that "research into the theory and practices of adaptation is still in its infancy and is not yet in the position to guide the adaptation decision process". Moreover, the same study states that adaptation measures are often triggered by today's problems and by extreme events during recent years. A long-term perspective is generally missing in coastal adaptation strategies or, if present, is considered to be beyond the scope of coastal management strategies.

Next to the absence of long-term perspectives, a large-scale perspective is also missing in present coastal management practice. The European study on coastal erosion [EUROPEAN COMMISSION, 2004] points out that in a considerable number of cases, measures have solved coastal erosion locally, but exacerbated problems at other locations up to tens of kilometers away. It also indicates that a small-scale approach to coastal management might be conflicting with the general aim of developing effective, sustainable adaptation strategies for the long term.

A major difficulty for developing a long-term coastal adaptation policy is the presence of (large) uncertainties in predictions of future circumstances and impacts. The following major uncertainties can be identified in the development of long-term coastal management plans. First, there are major uncertainties in the future magnitudes and rates of the impacts of climate change [MEEHL *et al.*, 2007]. These rates have a direct impact on the hydraulic boundary conditions for the coastal defenses, but their uncertainty limits confidence in predictions of climate change impacts. Next, the unknown extent of future impacts of long-term coastal management strategies also introduces uncertainties to the policy development process. Systematic studies into adaptation measures for coastal zones are at an early stage and it is still unclear how new measures may relate to present coastal management practice [TOL *et al*., 2008]. In addition, it is unknown how future insights might change preferences for certain measures. Criteria that are now thought of as very important or even decisive may lose significance over the next decades to centuries.

Until now, major questions on appropriate temporal and spatial scales for adaptation plans in the coastal zone are not addressed. This raises the question what assessment method and which criteria should be applied in evaluating potential adaptation strategies and whether the uncertainties inherent to long time spans prevent a proper comparison of alternatives. The goal of this paper is to start answering these questions and to explore whether assessments of various long-term coastal management strategies differentiate sufficiently (given uncertainties involved) for comparison.

This paper starts with an introduction into the features and shortcomings of present assessment methods. Subsequently, a newly derived assessment framework is introduced. The next section applies this assessment framework to a case study on the central part of the Dutch coast. The final sections present a discussion on three major issues in applying the findings of the case study (uncertainties, international validity and public participation) and some general conclusions.

PRESENT ASSESSMENT METHODS

Until now, there are two major schools in assessing coastal management plans (and infrastructure projects in general): cost benefit analysis (CBA) and multi-criteria analysis (MCA). CBA's produce an objective summary of present and future advantages (benefits) and drawbacks (costs) of a plan, all measured in monetary units. Those impacts that can not be expressed in monetary units are included as Pro-Memory items in the CBA. Calculated costs and benefits are added into a final balance that can take several forms like a (positive or negative) project profit or a cost-benefit ratio. Two variants within the CBA methodology are the socio-economic CBA and the pre-feasibility CBA. The main characteristic of the socio-economic CBA is that its scope is relatively wide; it accounts for all changes in societal welfare (also including the environment) by quantifying and monetarizing them as much as possible [RUIJGROK *et al*., 2006]. The prefeasibility CBA aims to identify costs and benefits from rough estimates of potential project effects (based on previous studies) and is thus very well suited for decision making in the preliminary project phases [EIJGENRAAM *et al*., 2000]. Note that the pre-feasibility CBA can still also account for socio-economic impacts.

MCA, on the other hand, compares project proposals on a series of explicit criteria by use of their natural units, which can be both quantitative (e.g. monetary) and qualitative (e.g. grades). All these different impact assessments are subsequently standardized before being summarized into a final assessment. This procedure facilitates the use of weights accounting for the importance of the different impacts that are considered.

Of these two particular assessment methods, CBA is more often legally prescribed than MCA for public decision making on infrastructure plans [GAMPER & TURCANU, 2007]. However, there are many indicators for MCA being a notable alternative for these processes, overcoming some of the shortcomings of CBA. First, coastal management plans are in need of an integrated assessment concerning economic, social and environmental impacts. However, social and environmental impacts are often not monetizable or even not quantifiable and therefore they can only be accounted for artificially in CBA. Different types of information cannot be included in the final balance resulting from the CBA, while MCA is appropriate to cope with this incommensurable information [BROUWER & VAN EK, 2004; MUNDA, 2006; ROCA *et al*., 2008]. The ability of MCA to represent other assessment perspectives next to the economic perspective of CBA makes the two methods complementary [BROUWER & VAN EK, 2004]. Second, MCA is better suited to address the inherent complexity and uncertainty in assessing extensive coastal management projects. In CBA, the only way for expressing the role of individual costs or benefits and uncertainties therein is a sensitivity analysis which is only a partial approach. This is avoided by MCA, separating the assessments for the different criteria throughout the assessment process and presenting them in an accessible framework [JOUBERT *et al*., 1997; GAMPER & TURCANU, 2007]. Together, this makes GAMPER & TURCANU [2007, p. 305] say that "MCA tools have the ability of addressing interdisciplinary issues in a pluralistic way, resulting in a valuable body of knowledge and leading to a transparent and more robust decision making".

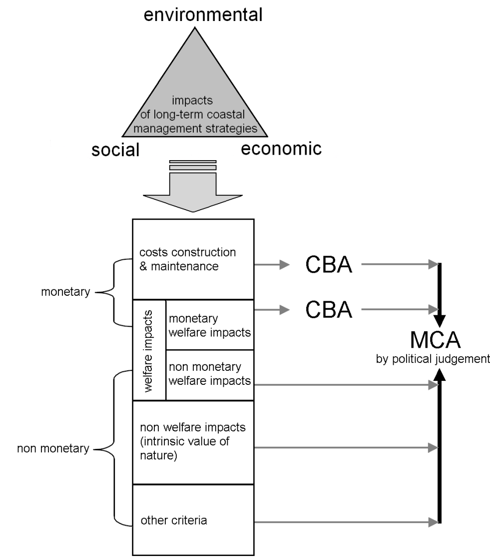

Figure 1. General set-up of the assessment method that is developed in this study. Partial results of CBA are integrated in a MCA framework.

This dilemma of CBA being the method most often prescribed by law and MCA being better for incorporating social and environmental impacts is nicely illustrated by comparing the UK approach and the Dutch approach to public decision making. The UK approach aims at a full MCA comprising all impacts in one assessment. The Dutch approach, on the contrary, summarizes all welfare impacts (including social and environmental impacts) in a CBA. The non-welfare impacts concerning the intrinsic values of nature and some governance values are introduced respectively in an environmental impact assessment and in the final political judgment (which is more or less the same for MCA) [RUIJGROK & KIRCHHOLTES, 2006].

NEW ASSESSMENT FRAMEWORK

Integrating Cost Benefit Analysis in Multi-Criteria Analysis

This study proposes to integrate the objective method of accounting for future monetary costs and benefits through CBA within a MCA framework. Monetary impacts (like construction costs and user values) can be inventoried separately from the non-monetary impacts (like safety perception and robustness). Figure 1 shows that all monetary impacts can be calculated by applying CBA methodology, making use of (authorized) values of costs and benefits which are sometimes derived from previous projects (both socio-economic and pre-feasibility CBA). The amounts that are found for each of the monetary impacts (e.g. construction costs and safety benefits) are subsequently included in the MCA method together with all remaining assessments that are either qualitative (ranging from -- for very negative impacts to ++ for very positive impacts) or quantitative (like an acreage of nature area gained).

One of the problems faced in MCA is adding up different types of incommensurable information. Here, we propose a method for translating all quantitative and qualitative impacts into qualitative impact scores by comparing the impact score of the alternative to the impact score of the basic scenario, in this case defined as prolonging present coastal management policy. For the monetary impacts, the most extreme scores (-- or ++) are awarded if costs or benefits are an order of magnitude smaller/larger than those of the basic alternative and slightly differentiating scores (- or +) are awarded if costs or benefits deviate at least with a factor two from those of the basic alternative. This comparative qualitative assessment strategy is introduced for three reasons: (I) comparative assessing is common practice in infrastructure projects; (II) the presence of some large amounts of costs/benefits for one criterion does not impede the distinction of smaller amounts of costs/benefits on the same criterion due to the applied conversion of monetary impacts into qualitative scores and (III) major uncertainties in e.g. future sand prizes or future policies for developing newly gained land do not affect the relative assessment scores.

BROUWER & VAN EK [2004] state that this integrated application of MCA and CBA is very rare in a water related context and they present a first attempt to do so. The general set-up of the assessment method presented in this paper resembles their method, although processing incommensurable information on impacts and uncertainties therein is enhanced by this new method.

Coping with uncertainties

The need for enhancing coastal defenses and the impacts of potential strategies to do so are surrounded by uncertainties. These are caused by changing hydraulic boundary conditions (physical uncertainties), inherent uncertainties in the future impacts of the strategies (socio-physical uncertainties) and unknown preferences for weighting the impact scores within the MCA (sociological uncertainties). In order to cope with the changing hydraulic boundary conditions, climate change scenarios are developed, representing the range of potential local impacts of climate change on hydraulic boundary conditions. This scenario-approach is the best way for coping with this fundamental uncertainty [BRUGNACH *et al.*, 2007]. The proposed strategies for coastal management can be tuned to and assessed for each of these climate scenarios, enabling a comparison of the strategies for different potential future circumstances.

Accounting for physical and socio-physical uncertainties in future impacts of the strategies is partly implemented by the comparative assessment method translating the incommensurable impacts into qualitative impact scores related to the impacts of the basic alternative. However, estimating monetary impacts of proposed strategies on the basis of preliminary designs incurs large uncertainties. For the non-monetary impacts, the potential disturbance by uncertainties is much smaller and supposed to be of minor importance. A sensitivity analysis should be applied to the final results of the study in order to account for the uncertainties in the monetary impacts. The sensitivity analysis is based on the analysis presented by VAN DER KLEIJ *et al*. [2003]: costs and benefits are assumed to contain an uncertainty of for example a factor two (which is applied in the case study presented in this paper). All monetary impacts are varied according to this assumed uncertainty factor and the resulting financial values are translated into (a range of) potential qualitative assessment scores for each of the proposed strategies on every criterion. An example: construction costs of strategy A might be two times higher/lower/remain unchanged while at the same time the construction costs of the basic alternative might be two times higher/lower/remain unchanged too, which could result in a qualitative assessment range for strategy A on this criterion being

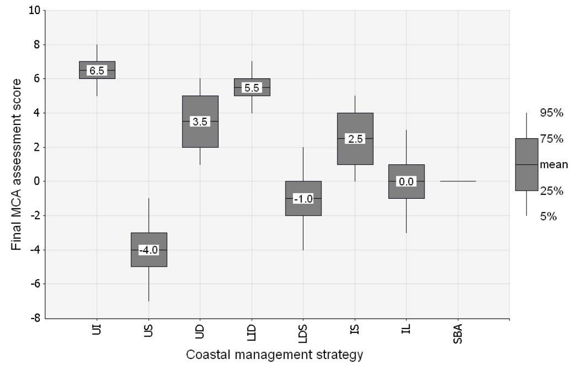

Figure 2. Results of a random simulation accounting for the effect of uncertainty in monetary impacts in the final MCA assessments of several coastal management strategies. The strategies range from very large-scale (left) to continuation of the small-scale present approach (right).

0/-/--. Subsequently, equal probabilities are awarded to the occurrence of the probable qualitative impact scores for every single strategy-criterion combination, resulting in a discrete probability distribution for the identified range of impacts. Random simulations covering all impact scores of both the uncertain monetary impacts (a range of impact scores with a discrete probability distribution) and the certain non-monetary impacts (one impact with hundred percent probability) then show the effect of these uncertainties within the final MCA outcomes (see figure 2). The random simulations were carried out using @RISK software (Latin Hypercube sampling; 5000 iterations per simulation). Only those strategies that have no overlap with the score of the basic alternative (=0) in the 5^{th} to 95^{th} percentile range are considered to be significant outcomes that should be included in the final comparison.

Finally, the distribution of weights over the various criteria will be subject to personal and political preferences (sociological uncertainty) and hence may vary over time. In ideal situations, these weights should be distributed according to stated public preferences [GAMPER & TURCANU, 2007]. At present however, weights are often determined by political debates. In the case study presented below, several perspectives are applied to the distribution of weights among the criteria within the MCA.

CASE STUDY

To test whether taking a long-term (i.e. 200 year) perspective in developing optimal coastal management strategies will result in alternatives that, given the inherently large uncertainties, can actually be differentiated from continuing today's practice, we carried out a case-study for the central part of the Dutch coast. The Netherlands stand out as having the most vulnerable coastal zone of the EU [NICHOLLS & DE LA VEGA-LEINERT, 2008], as 9 million of its inhabitants are living in areas below mean sea level and 70% of its gross domestic product is being earned in these areas. The coastal defenses of the central part of the Dutch coast have a total length of 118.5 km and consist of coastal dunes that are only locally interrupted by short sections of sea wall. These coastal defenses ensure the protection of the hinterland at the legally prescribed probability of flooding of 1:100,000 per year.

In this study, long-term coastal management strategies are developed for four different spatial scales, of which only two will be presented here: 'small-scale' and 'uniform coast' (full results

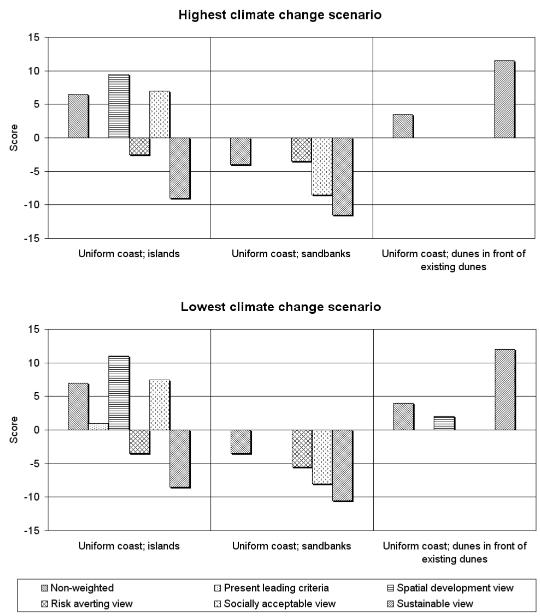

Figure 3. Assessment results for three 'uniform coast' strategies. The various views reflect a different importance of the applied criteria in the MCA. Only scores that significantly differ from the basic alternative score (=0) are shown.

are presented in [HORSTMAN, 2008]). The small-scale strategy, being the basic alternative, divides the study area into many short sections of only several kilometers length. This division is based on local land-use characteristics, the type of coastal defenses present and the long-term safety of these defenses (defined as areas that will (not) remain safe during the next two centuries). This strategy resembles present coastal management practice. Long-term local plans for enhancing the coastal defenses are derived from present local plans for short-term safety enhancing measures. The uniform coast perspective considers the entire study area as one section. Three different strategies are proposed for this large spatial scale perspective: (I) constructing islands in front of the coast with safety levels that are considerably lower than at the mainland coast; (II) creating a series of sandbanks at 1.5 to 3 km off the coast and with a moderate inclination to the coast and (III) creating a continuous row of new dunes in front of the existing dunes.

The above strategies are assessed on twelve criteria comprising all impacts and characteristics to be thought of in assessing coastal management plans. These criteria have been abstracted from an inventory of criteria applied in previous coastal enhancement plans within the study area. The assessment procedure explained in the previous section is subsequently applied for both a minimum and a maximum climate change scenario. These scenarios affect the dimensions of the measures within the proposed strategies that are needed to cope with the change of the boundary conditions coming with these scenarios: 0.95 m sea level rise for the lower scenario; 3.15 m sea level rise, 0.4 m storm surge level increase and 5% wave height increase for the maximum scenario. Figure 3 presents the significant impact scores of the three uniform coast strategies according to various policy views (represented by a different distribution of weights over the criteria in the MCA). The small-scale alternative (not shown) always scores zero impact because it is the reference case to which other alternatives are compared.

The results of the study show that, not withstanding the large uncertainties involved, impacts of various long-term strategies can be differentiated from continuing current small-scale coastal management practice. Furthermore, it can be concluded that the small-scale basic alternative will not be the best strategy for managing coastal defenses up to the year 2200 for most of the applied policy views. On the long term, strategies developed at a larger spatial scale appear to create better chances with enhancing the coastal defenses and for managing its spatial consequences. Compared to the proposed uniform coast strategies, the basic alternative is ranked relatively high on the risk averting and leading criteria views (compared to scores of other strategies on these views). These two views for coastal management emphasize construction and maintenance costs and the possibility for a phased implementation. This is quite well in line with present coastal management policy's preferences (as would be expected for present practice). From other viewpoints however, two of the three uniform coast strategies show some significant advantages over this small-scale basic alternative. It should be noted that the uniform strategy with sandbanks is assessed rather bad due to lack of knowledge on its long-term effectiveness and persistence.

DISCUSSION

Situational and fundamental uncertainties

According to BRUGNACH *et al.* [2007] there are two types of uncertainties: situational and fundamental. Situational uncertainties are uncertainties that, at least in principle, can be reduced by further research. Within this research, major situational uncertainties are related to the impacts of proposed long-term coastal management strategies. These are inherent to long-term perspectives and are coped with by the proposed assessment methodology. Fundamental uncertainties, on the contrary, refer to uncertainties that are persistent with respect to the problem that is investigated. Two fundamental uncertainties to long-term coastal management are climate change impacts (coped with by applying scenarios) and the dynamic development of natural coastal defenses over time (as predicting the occurrence of specific meteorological events is impossible). These fundamental uncertainties stress the need for flexible coastal management strategies that can be adapted to the development of the hydraulic requirements and the coastal system over time. Particular examples of flexible strategies are those that are based on the principles of building with nature. The development of new dunes, as proposed in the case study, may comply with these principles.

International validity

As has been stated in the introduction, problems in protecting low-lying coastal areas are omnipresent and may become very pressing on the longer term. So, next to the study area of our case study, there will be many other countries that will face similar problems in climate proofing their coastal defenses. Unfortunately, the results of the case study presented in this paper cannot be simply transferred to other locations, since they are largely dependent of the specific situation of the coastal defenses and of the hinterland within the studied area. However, the principles and methods presented in this paper are quite well applicable to other locations, so the analyses included in the case study could be repeated for other vulnerable coastal regions to develop sustainable long-term coastal management strategies.

Nonetheless, the finding of this research that coastal management might benefit from long-term strategies applying a large-scale perspective might still be internationally valid. This thought is underpinned by the observations presented by McNamara & Werner [2007] and the European Commission [2004] that major problems with present coastal management stem from focusing on short-term problems and small-scale solutions.

Public participation

Finally, an important advantage of the assessment methodology proposed in this paper is that MCA provides extensive possibilities for public participation [Gamper & Turcanu, 2007]. Stakeholders can be involved for example for determining social impacts (e.g. safety perception) and for awarding weights to the criteria involved in the assessment process. This would improve the representation of public knowledge, feelings and preferences in the decision making process, resulting in a common understanding of public and political opinions and increasing consensus on the final decision [Brouwer & van Ek, 2004; Gamper & Turcanu, 2007; Hommes, 2008].

CONCLUSIONS

The main conclusion of this paper is that uncertainties in long-term coastal management do not preclude the comparison of these strategies. Otter & Copabianco [2000] state that coastal managers are increasingly forced to take decisions based on information that is surrounded by uncertainties due to the increasing need to act in a pro-active way. Applying the assessment methodology as proposed by this paper shows that, although information on future requirements for and long-term impacts of coastal management strategies is rather uncertain, significant (dis-)advantages can be discerned. This enables the selection of those long-term strategies that suit best to specific socio-political preferences.

Next to that, applying this assessment methodology to a case study on the Dutch coast also shows that coastal management strategies based on larger spatial scales might create better opportunities for long-term coastal management than their equivalents based on confined temporal and spatial scales.

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