Towards a Comprehensive Framework for Adaptive Delta Management

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Executive Summary

Deltas are dynamic landforms at the boundary of land and sea, involving intricate mazes of rivers and small waterways, wetlands, estuaries and coastal barrier islands. They are home to over half a billion people. Deltas are also home to rich ecosystems, such as mangroves and marshes. They are economic hotspots, supporting much of the world's fisheries, forest products, and extensive agriculture. Yet, delta systems are under threat from sea-level rise, cyclones, river flooding, storm surges, rapid urbanization, agricultural over-use and pollution, salinization, sediment starvation, coastal erosion, and natural and man-made subsidence.

One of the missions of the Delta Alliance is to support the development and proliferation of new approaches in delta management through research, exchange of best practices and outreach of concepts and ideas.

This report provides an overview of new approaches emerging in several deltas that can be labelled under the heading of Adaptive Delta Management. Adaptive management can be defined as a structured, iterative process of robust decision making in the face of uncertainty, with an aim to reduce uncertainty over time via system monitoring. Applying adaptive management to deltas is relatively new and one of the first explicit uses is by the Dutch Delta Program. The Dutch Delta Program formulates Adaptive Delta Management (ADM) as phased decision-making that takes uncertain long-term developments into account explicitly and in with transparency towards society. Adaptive delta management encourages an integrated and flexible approach to land and water management with to aim to reduce vulnerability limit the risk of over- or underinvestment in future challenges such as flood risk management and freshwater supplies. This report shows that ADM is developing rapidly into a fascinating new type of decision making under an uncertain future. The reasons for using the new approach are convincing, the theoretical foundation is growing and the results on the ground are promising.

Adaptive Delta Management can be captured as a cyclic process of which the overall design does not differ much from traditional planning steps. However, the approach and methods within each step contain new elements, such as long term scenario building, adaptation pathway developments, signposts and triggers. In this report we distinguish the following building blocks for ADM:

Connecting short term investments with long term challenges

As part of ADM a planner should create a strategic vision of the future, commit to short-term actions and establish a framework to guide future actions. Typical in ADM is that such a vision has a longer time horizon than usual in planning activities (e.g. a century), in order to capture the long term processes of climate change. So instead of focusing on short-term 'trial and error' actions and projects, the idea is to keep the long term vision in mind while prioritizing short-term 'no regret' actions. Scenario development is an important tool in this process, against which strategies can be tested to see how robust these strategies are.

Path dependency and adaptation pathways

The history of deltas shows developments which, once started, cannot easily be changed or adapted to new conditions. This is what we call path dependency: the extent to which a policy action is limited by actions implemented in the past or by actions planned anterior in the pathway. Learning from the past and knowing that we cannot predict the future this leads us to the ambition to avoid

such lock-ins. One way to do this is to use adaptation pathways: i.e. a sequence of policy actions over time that is able to achieve a set of objectives.

Avoidance of over- and under investments

Insight in the adaptation pathways is not only relevant for the required flexibility of measures, but also in view of the risks of over- or under-investments. Under-investment occurs if it turns out that the solutions are not adequate. Over-investment on the other hand happens when measures are over dimensioned, which proved unnecessary and therefore too expensive.

Connecting public and private (investment) agendas

Another building block for ADM is to actively search for windows of opportunity to combine different investment agendas, either within the public domain or between public and private investments. This way measures may be easier (and cheaper) to implement and yield more added (societal) value.

The way forward

Three phases can be defined in applying ADM. The first phase focuses on identification of current and future problems and challenges based on relevant future scenarios. In the second phase options are explored which might enhance the sustainability and/or reduce the vulnerability for both current threats and longer term uncertain futures. The last phase focuses on integrating the adaptation options into viable management strategies and ensuring their proper implementation.

Until now the first two steps are gaining momentum, although more knowledge is needed on how deltas as complex dynamic systems work. How to link the second and the third step, where financing arrangements, public (infrastructure) procurement strategies, implementation constraints and opportunities as well as durable maintenance arrangements play a decisive role, is yet to be explored. We can potentially learn much by analyses of best practices which take into account the diversity in social and cultural dimensions. These practical experiences can thus generate a larger body of knowledge on delta planning and management.

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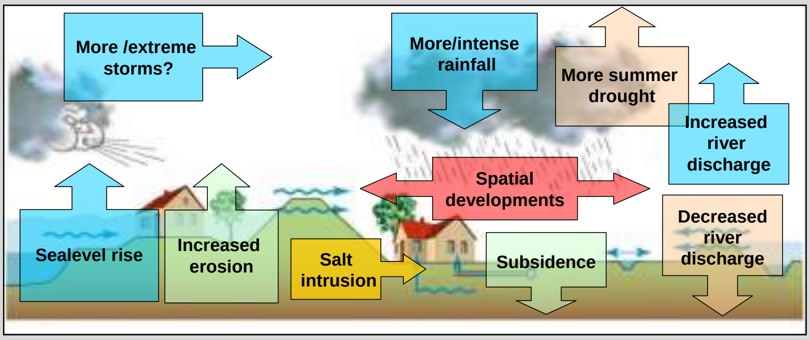
Chapter 1 Introduction

1.1 Why this report?

Many of the world's deltas face serious challenges when it comes to accommodating economic progress under future uncertainties such as climate change, global fluctuating markets and socio-cultural dynamics (Box 1). Historically, deltas have constantly evolved adapting to natural geological processes and human interferences. Deltas are dynamic complex systems whose behaviour is driven by different feedback mechanisms that could accelerate the pace towards reaching tipping points, thereby requiring continuous adaptation. In the past, efforts have been made to manipulate these natural and socio-economic dynamics by various means of spatial planning, engineering works and designs which made many deltas major hubs of economic prosperity. The past two centuries saw an increasing incorporation of deltas into centralized policy of planning and control encapsulating them into national economies. However, this situation is changing towards a decreased involvement of national institutions and increasing responsibility of local authorities, communities and civic society to define new futures of deltas (Meyer & Nijhuis, 2014). New approaches in planning, design, technology and governance are therefore needed. Improved delta management is not only needed because of the changing context of delta governance, but also because of the potentially significant changes in the conditions on which the prosperity of delta economies are based.

Box 1. Deltas under threat

Deltas are dynamic landforms at the land-water boundary, involving intricate mazes of rivers and small waterways, wetlands, estuaries and coastal barrier islands. They are home to over half a billion people – over 250 million people are living in the three deltas of the Ganges-Brahmaputra-Meghna, Mekong and Nile rivers alone. Deltas are also home to biodiverse and rich ecosystems, such as mangroves, reedlands and marshes. They are economic hotspots, supporting much of the world's fisheries, forest products, and extensive agriculture, and they are the venues of significant growing cities and ports/harbours. At the same time, worldwide delta systems are under threat from sea-level rise, cyclones, river flooding, storm surges, rapid urbanization, agricultural over-use and pollution, salinization, sediment starvation, coastal erosion, and natural and man-made subsidence (Foufoula-Georgiou et al. 2013).



The Delta Alliance intends to develop and promote new, integrated approaches by focusing on the policy concept of ***Adaptive Delta Management***. This concept was put forward by the Dutch Delta Programme as a way to deal with the uncertainties of climate change and socioeconomic developments in delta areas. This report provides an overview of recent new approaches emerging already in several deltas that could be labelled as Adaptive Delta Management. The description of this approach will be illustrated with best practices and we will identify knowledge and tools to support these approaches. The overall objective is *to review and combine recent experiences with delta development under the uncertainty of climate change in the Netherlands and other deltas around the world, and to develop building blocks for a generic framework for long-term integrated climate change adaptation in delta regions.*

1.2 Who should read this report?

The publication is relevant in (early stages of) delta planning, e.g. in Bangladesh, Mekong Delta (Vietnam) and the Irrawady Delta (Myanmar). Therefore, readers include all those who are active in the process of delta planning. They could be members of Delta Alliance Wings around the world, urban planners, NGO's, government officials, but also scientists, consultants and staff members of international donor agencies, UN agencies and the Global Water Partnership.

Chapter 2 The need for adaptive delta management

2.1 Path dependencies and regime shifts

Many deltas show a history of early settlement, growing economic activity leading to well-known centres of regional or even global importance (e.g. New Orleans, Rotterdam, Jakarta, Bangkok), and historic flood events. Despite the occurrence of these flooding events, favourably everyday conditions in the deltas have given them a significant role in the national economies. The economic development is often accompanied by the harnessing of natural deltaic processes through infrastructural works in order to maximize productivity in the primary (agriculture, aquaculture, fossil energy etc.), secondary (industry) and tertiary (trade) sectors. Delta societies became more and more dependent on these infrastructural works. But path dependencies also became visible in many deltas and are often the result of similar feed forward mechanisms:

- Drainage of peat soils leads to soil subsidence which leads to more drainage requirements;
- Dredging of navigation channels leads to more sedimentation requiring even more dredging;
- Flood protection makes deltas more attractive to live and work in, investments in housing, industry and infrastructure grow, which increases flood risks, which requires higher safety levels etc.

These essentially non-linear mechanisms are often combined with governance systems that are ‘locked-in’ into a prevalent solution strategy which one is not able to diverge from. For instance, in the Netherlands flood risk management was identical with flood protection for a long time, implying the building of dams and dikes. Wetlands, such as marshes and intertidal areas were considered as wastelands. To *dredge, drain and reclaim* was the prevailing paradigm for centuries. Because many of these ideas are firmly rooted in cultural traditions (‘embedded’, cf. Williamson 1998) of the pioneers who colonized the harsh delta environments, it is not surprising that it takes decades to gain momentum for alternative views.

Because of the harnessing strategies, physical and ecological processes were disturbed in the Dutch delta. Natural accretion of intertidal areas was reduced, industrial pollution contaminated the sediments (leading to serious concern where to put the dredged material), saltwater-freshwater gradients disappeared and self-purification capacities of water bodies became overloaded. The first environmental awareness movement, started in the late sixties, produced the initial cracks in the bastion of traditional engineering solutions and the half open storm surge barrier in the Eastern Scheldt is a nice example Of the alternative strategies that were developed. But it took another twenty years, when rising concern about climate change was reinforced by several events both in the Netherlands (high river waters in 1995) and the USA (Katrina 2005). . Although such extreme events cannot be directly linked to climate change, they acted as wake up calls. There is concern that such events could become more frequent. In combination with sea level rise and environmental degradation (e.g. wetland loss in Louisiana, ecosystem degradation of estuaries of the Rhine and Elbe), the usual engineering reflex seems no longer adequate. Traditional centralized planning and control with dominance of civil engineering measures seems no longer appropriate. A more adaptive approach which makes use of (or increases) the intrinsic resilience of the delta system seems to ring in a new regime shift.

2.2 What is adaptive delta management?

Living in such a dynamic environment, people in deltas have always been able to adapt in one way or another to the whims of nature. So what's actually new in adaptive delta management (ADM)? And how is it defined?

Indeed, the general idea of adaptive management and planning is not new and the seeds for this planning paradigm were planted almost a century ago, as Dewey in 1927 argued that policies should be treated as experiments, with the aim of promoting continual learning and adaptation in response to experience over time (Dewey, 1927; Haasnoot, 2013). Adaptive management can be defined as a structured, iterative process of robust decision making in the face of uncertainty, with an aim to reduce uncertainty over time via system monitoring (Wikipedia, 2013). Later on in this report we will frequently encounter elements from this definition, such as robust decision making, uncertainty and monitoring.

Applying adaptive management to deltas is relatively new. One of the first explicit uses is by the Dutch Delta Program (see box 2). The Dutch Delta Program formulates ADM as a phased type of decision-making that explicitly and in a transparent manner takes uncertain long-term developments into account. Adaptive delta management encourages an integraed and flexible approach to increase resilience, reduce vulnerability and limit the risk of over- or underinvestment in future flood risk management and freshwater supplies.

The path dependencies which we encountered in the previous section are of special relevance for deltas. Draining, dredging and diking were adaptations and modifications of the natural landscape, but with little flexibility. Modern adaptive delta management envisages elucidating these *and* alternative pathways under a series of future scenarios in order to make robust decisions. This supports sustainable development, which can be defined as a development that is able to achieve environmental, social and economic targets now and in the future by being robust and/or flexible. Robustness is defined as performing satisfactorily under a wide variety of futures. Flexibility means that it can be easily adapted to changing (unforeseen) future conditions. (Haasnoot, 2013).

One can thus formulate adaptive delta management as a form of uncertainty management of dynamic complex human-environment systems aiming for sustainable delta development. Clearly the challenge is to find strategies which avoid over- and under-investments now and in the future.

The Dutch Delta Program identified four key points of adaptive delta management:

- linking short-term decisions with long-term challenges around flood risk management and freshwater availability;
- incorporating flexibility in possible solution strategies (where effective);
- working with multiple strategies that can be applied alternatingly depending on the developments (i.e. adaptation paths);
- linking investment agendas from different policy fields.

Adaptation does not necessarily imply gradual, step-wise change. Both in nature and societies we encounter drastic events causing rapid changes after which periods of relative stability and slow change follow (Brugge 2009). Indeed, an adaptation measure could consist of a radical change in policy, but the essence in ADM is that a decision to take such a measure is made while acknowledging the uncertainty of long term changes in the future.

Box 2. **The Dutch Delta Program**

The Dutch Delta Program is a national program in which the central government, provincial and municipal governments and water boards work together, also involving social organizations, knowledge institutes and the business community. The objective is to protect the Netherlands against flooding and to secure a sufficient supply of freshwater for generations ahead.

The Delta Program works on the Delta Plan for the 21st century. It aims for a safe and attractive Netherlands, now and tomorrow, where flood risk management and freshwater supplies are organized effectively. That is a key condition for the Netherlands' continued existence and a strong economy. All of the parties involved in the Delta Program are working towards a robust Dutch delta, for which an innovative approach is of paramount importance.

Chapter 3 Principles of Adaptive Delta Management

3.1 How to find robust and flexible solutions?

How can we find the solutions that will not only solve our current problems but also those of possible futures? Besides the inherent uncertainties that shroud a clear answer there is also the issue of legitimacy. Hence, as is common in planning domains, there is a distinction between 'process' and 'content'. Agreement on the planning process is essential for good governance and for getting legitimate results.

Adaptive Delta Management can be captured as a cyclic process which does not differ much from traditional planning steps. However, the approach and methods within each step contain new elements, such as long term scenario building, adaptation pathway development, signposts and triggers, etc. (see Figure 1). It is not our intention to elaborate extensively on each step in this publication, but we will highlight the innovative elements of ADM. We will call them building blocks and explain them in the next section.

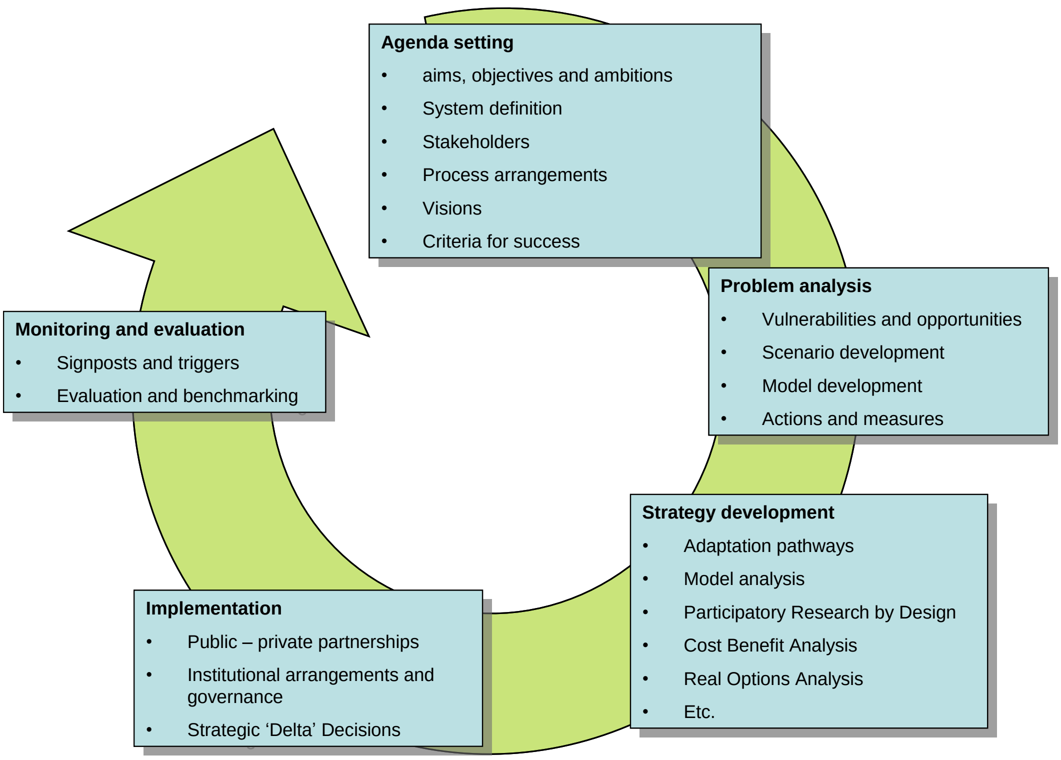


Figure 1 Adaptive Delta Management and the planning cycle

3.2 Building blocks for ADM

3.2.1 Connecting short-term investments with long term challenges

Any planner or manager will work with a certain ***vision or perspective*** that motivates his or her actions, recommendations or plans. This is also the case for planning under conditions of deep uncertainty, in which a planner should create a strategic vision of the future, commit to short-term actions and establish a framework to guide future actions (Haasnoot, 2013). Typical in ADM is that such a vision has a longer time horizon than usual in planning activities (e.g. a century), in order to capture the long term processes of climate change. Instead of focusing on short-term ‘trial and error’ actions and projects, the idea is to keep the long term vision in mind while prioritizing short-term ‘no regret’ actions. By forecasting and back-casting this leads to more adaptive management (see Figure 2).

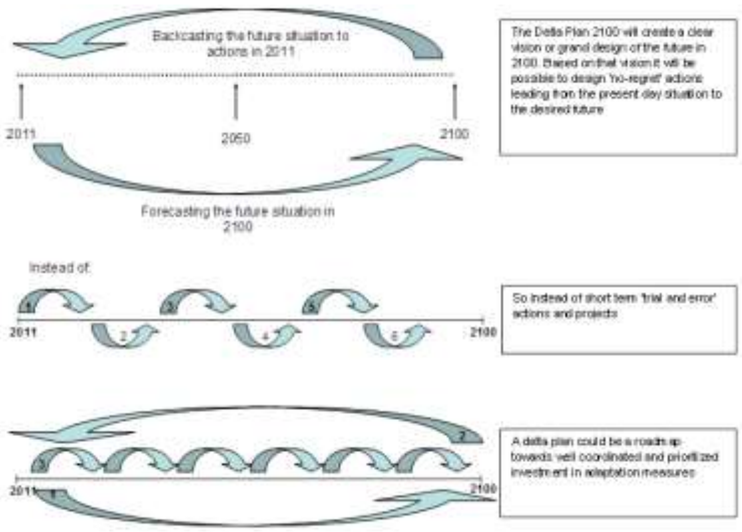


Figure 2 Back-casting and forecasting (Source: Choudhury et al., 2012)

The long term perspective can be defined as a more or less coherent vision of the desirable delta development and the activities needed to realize it. Such a vision can e.g. be a climate proof delta, a competing delta or a sustainable delta. Since they are a complex adaptive system, for deltas such a perspective is more likely a direction than an end-picture (Meyer & Nijhuis, 2014).

Of course, it should be borne in mind that such a long term perspective itself should be interpreted flexibly: indeed, in such a long time frame the values, needs and desires of society surely will be different from the present. But this is an intrinsic problem with planning anyway: we can only use our present valuation system to evaluate planning actions which affect the future.

Scenario development is an important tool for ADM. Scenarios are descriptions of plausible futures. Hence, they are not predictions, as it is extremely difficult to attach probabilities to them. Instead, we use them to test our array of measures and strategies. Therefore, it is important to choose scenarios in such a way that together they form a canvas of all possible futures. It is advisable not to develop three scenarios – e.g. a worst case, a best estimate and an optimistic scenario, as people tend to limit further analysis based on the middle scenario – but to have a least four, each at a corner of the canvas (see Figure 3)

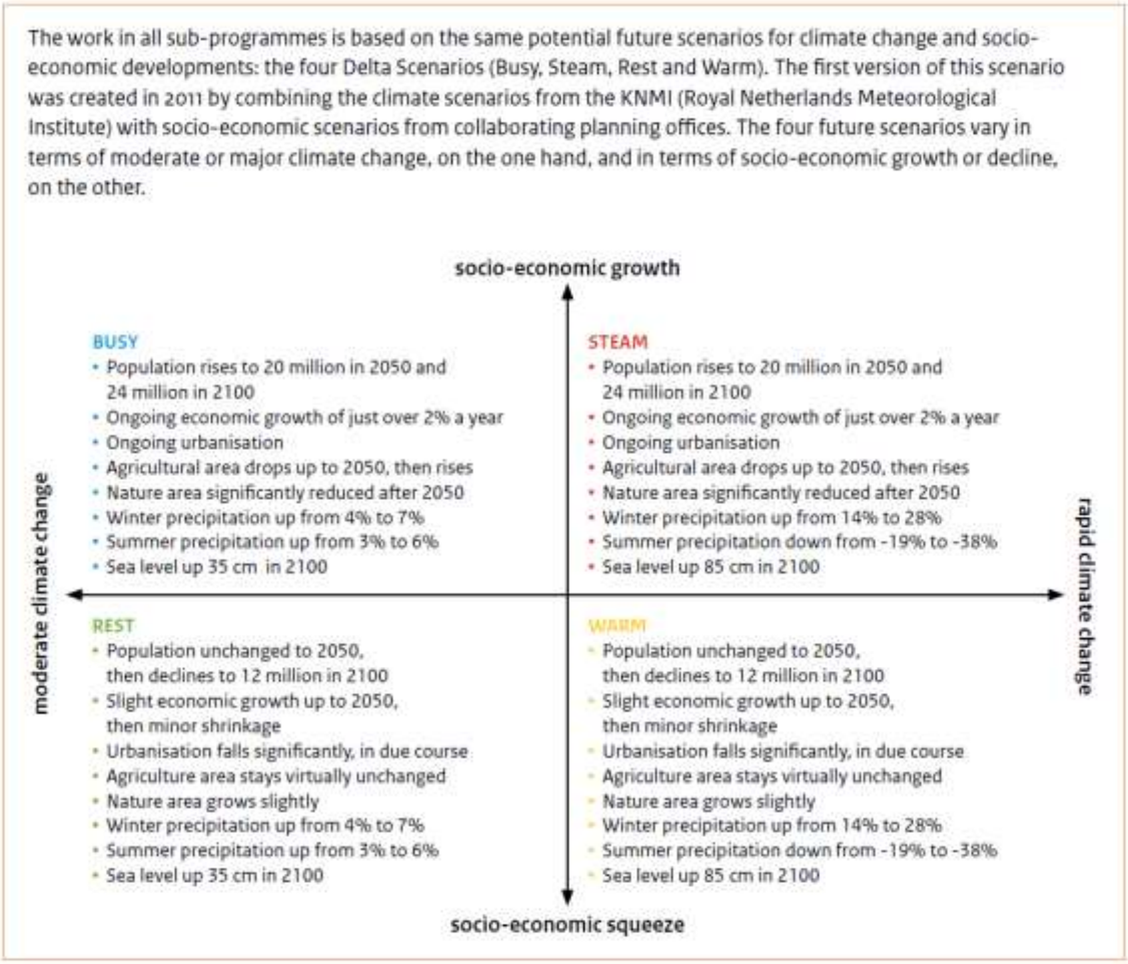


Figure 3 Example of scenarios used in the Dutch Delta Program

Testing of measures or strategies against scenarios can be done in various ways. One recently developed method is the use of so-called ***Adaptation Tipping Points***. These are defined as points where the magnitude of change due to climate change or sea level rise is so big that the current management strategy will no longer be able to meet its objectives. This method provides information on whether and when a strategy may fail and other strategies are needed (Kwadijk, Haasnoot et al. 2010). Another way of testing measures is the use of exploratory modelling and ***robust decision making*** (RDM) techniques. RDM identifies robust strategies, being the ones that perform relatively well, compared to the alternatives, across a wide range of plausible future states of the world. RDM uses computer simulation models, not to predict the future, but to create large ensembles of hundreds to millions of plausible future states that are used to identify candidate robust strategies and systematically assess their performance (Groves and Lempert 2007).

Although it may seem rational to select the measures that are the most robust, there is a chance of over-investment. For instance, building new dikes which can withstand a one meter sea level rise seems a robust strategy, but it may not be necessary for the next decades. And the dikes would have to be maintained in that period anyway. Hence, timing and flexibility play a role too. This aspect will be further elaborated in section 4.2.3.

One of the first studies using tipping points was the Thames Estuary 2100 pilot, in which various options for flood risk were compared. It included an assessment of the useful life of existing defences such as the Thames Barrier as well as an understanding of the drivers of change in the estuary, including climate change, urban development, social pressures and the dynamic natural environment. Figure 4 shows a number of strategies in relation to the projected sea level rise.

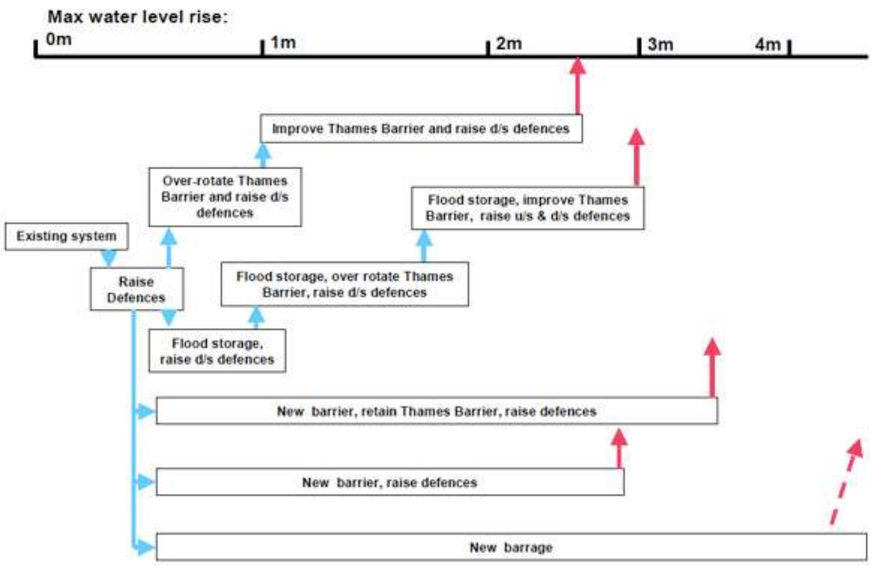


Figure 4 Example of tipping points for the Thames Estuary (Source: Environment Agency, UK)

3.2.2 Path dependency and adaptation pathways

As already mentioned in Chapter 2, the history of deltas shows developments which, once started, cannot easily be changed or adapted to new conditions. This is what we call ***path dependency***: the extent to which a policy action is limited by actions implemented in the past or by planned future actions. Learning from the past and knowing that we cannot predict the future this leads to the ambition to avoid such lock-ins. One way to do this is to use ***adaptation pathways***: i.e. a sequence of policy actions over time that is able to achieve a set of objectives (Haasnoot 2013).

When formulating such adaptation pathways a picture emerges which shows tipping points, dead ends and 'transfer stations' (Figure 5). Which pathway to follow depends on several factors, such as the cost of a strategy or action, but also the cost of shifting to another strategy once a tipping point has been reached. For instance, it seems robust to follow Action A in the example since this does perform well over the next hundred years, but it may also be an expensive one. Perhaps it is better to go for Action C if it is cheaper and then shift to another strategy later, if necessary at all.

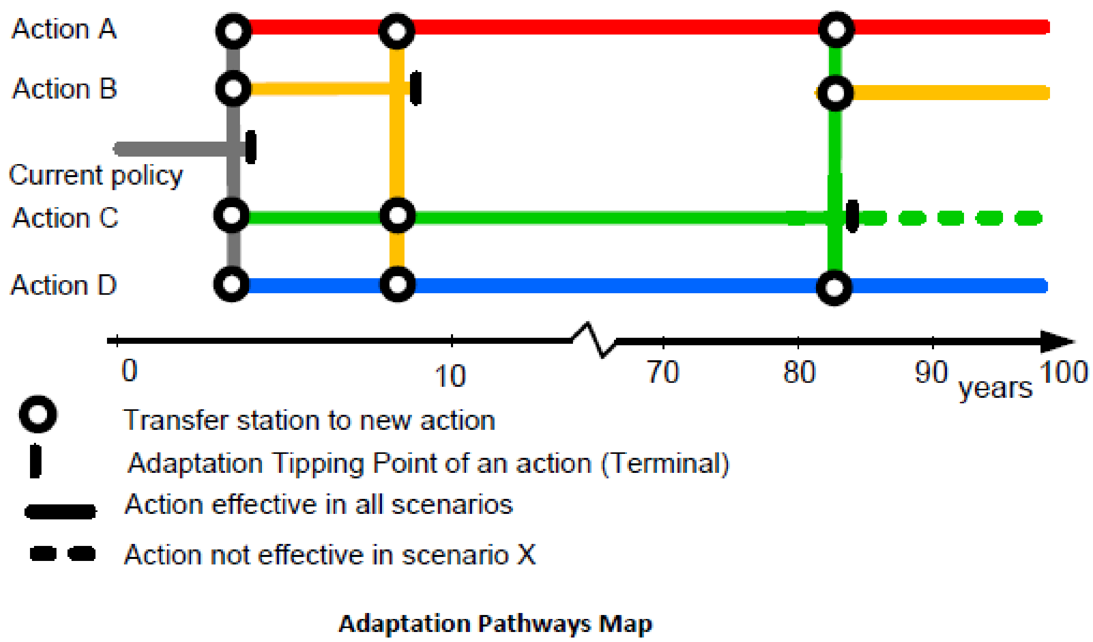


Figure 5 Principle of adaptation pathways (Source: Haasnoot, 2013)

3.2.3 Avoiding over- and under-investments

Insight in adaptation pathways is not only relevant for the required flexibility of measures, but also in view of the risk of over- or under-investment. Under-investment occurs if it turns out that the solutions are not adequate to protect society against damages in an extreme event. Over-investment on the other hand happens when measures are over dimensioned, which proves to be unnecessary and therefore too expensive.

Delaying a measure reduces the risk of over-investment, because over time more information becomes available regarding climate change and economic development, which reduces the uncertainty. However, care should be taken that measures are not taken too late. Some measures require a considerable lead time for planning and implementation before they become effective (Van Rhee, 2012). A hurried implementation will reduce the possibilities of involving different stakeholders who might have contributed their knowledge of the system, and therefore may lead to less smart solutions.

3.2.4 Connecting public and private (investment) agendas

Another building block for ADM is to actively search for windows of opportunity to combine different investment agendas, either within the public domain or combining public and private investments. This way measures may be easier (and cheaper) to implement and may yield more added value to society (Van Rhee, 2012). For example, when infrastructure such as a sluice or dam requires maintenance, potential climate change impacts can also be taken into account and a climate adaptation action can be implemented earlier than strictly necessary (Haasnoot, 2013). Huq and Reid (2004) assign the label 'mainstreaming' to such actions that incorporate potential climate change impacts into ongoing developments and plans.

Chapter 4 Knowledge, Tools and Methods

Chapter 3 gave an overview of the most important concepts for adaptive delta management. In this chapter we will explain the methods that apply these concepts in more detail.

4.1 Building scenarios

4.1.1 The need for scenarios

To formulate strategies and make decisions about future investments, policy makers in water management have traditionally focused on forecasting methods and tools. For the biophysical systems 'stationarity' was assumed. This implied that long term variability in freshwater availability and flood risk could be estimated based on historical observation. In reality this is not the case; water availability and flood frequencies will likely change due to global warming (Milly et al. 2008; Ludwig et al. 2014). The magnitude of the expected changes in climatic and hydrological variables is highly uncertain. This uncertainty poses a set of new challenges for water management. Although climate change information has improved over the last decades and many climate impact studies have been carried out in deltas, water managers still struggle how to cope with the impacts of climate change.

Not only the future climate is uncertain: future socio-economic changes also depend on many different factors. Historically, socio-economic predictions were often based on the extrapolation of past trends. It was assumed that it was possible to predict the future and decisions were often based on a single future scenario. This might be a good approach for well-understood problems with low uncertainties, but for complex issues with large uncertainties it is impossible to predict the future.

Adaptive delta management aims to develop strategies which are flexible and can deal with multiple futures. Scenarios play a central role in defining future adaptive strategies. By developing multiple scenarios it becomes easier to anticipate to future developments and to take uncertainties into account. Scenarios provide a way to be more explicit about important long term uncertainties and therefore scenarios facilitate the development of long term strategies such as delta plans. Scenarios also assist in identifying which decisions and investments should be made in the near term and which options should be reserved for later decisions.

4.1.2 What are scenarios?

Scenario analysis is used for dealing with uncertain futures. It aims to assess the possible impacts of important drivers and to assist in the design of policies (e.g. Carter et al., 2007). A scenario can be a sequence of events resulting into a particular future condition. A scenario can also represent a story of a specific future or a specific future event. A scenario is neither a forecast nor a prediction but it should be considered as a plausible story about the future. Within the delta plans of the Netherlands, Vietnam and Bangladesh sets of scenarios are or will be adopted which aim to explore the most import range of uncertainties in future projections. They reflect different perspectives on future developments and serve as a basis for future investments (Van Notten, 2005).

4.1.3 Drivers of scenarios

Scenarios for deltas should be based on plausible changes, which represent critical uncertainties. Within the scenarios for the Dutch delta plan the first step was to formulate the focal question(s), such as: *Which (external) events, circumstances and (autonomous) developments are critical for water management, in particular for flood protection, fresh water supply and water quality?* Next an evaluation was done on the major drivers of change by classifying them according to their impact and uncertainty (Figure 6). Drivers which both have a major impact and are highly uncertain represent the "critical uncertainties" which should be included in the delta scenarios. The Impact-Uncertainty Matrix was developed for the Dutch Deltaplan scenarios and also during a recent scenarios building workshop in Bangladesh.

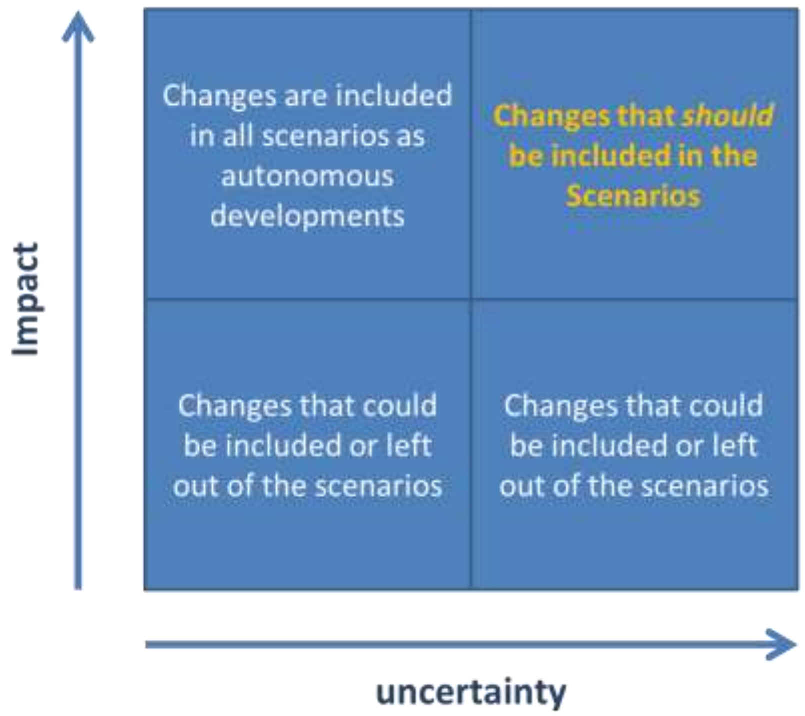


Figure 6 Impact-Uncertainty Matrix

The major changes which were considered within the Dutch Delta-scenarios were climate change and socio-economic development. For socio-economic development the major uncertainties are demographical development and economic growth (Bruggeman et al, 2011). In Bangladesh similar drivers were identified during a scenario development workshop in Dhaka in October 2013. Here, socio-economic development and climate change were also seen as the drivers with the highest uncertainty and impact. Additional important drivers identified for water management in Bangladesh were international cooperation and upstream development.

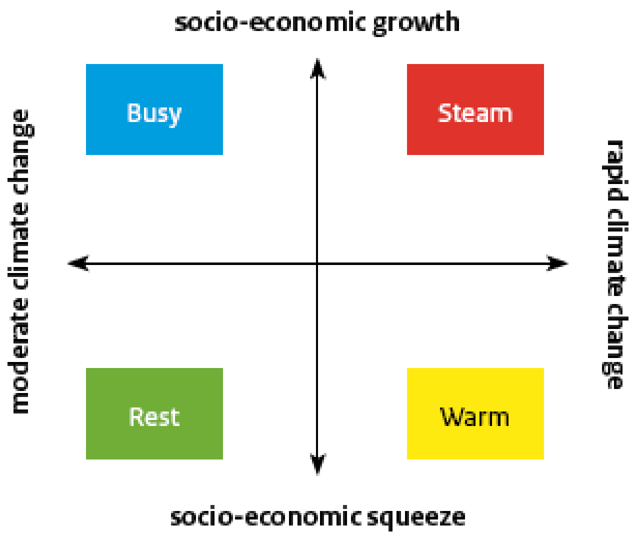


Figure 7 The scenarios for the Dutch Deltaplan structured in a four quadrant matrix (Bruggeman et al., 2011)

By integrating the two driving forces with the strongest impact and highest uncertainty a four-quadrant matrix can be developed which then results in four different scenarios. For example, in the Dutch Delta programme four different scenarios were developed which were a combination of high and moderate climate change and socio economic growth and socio economic "squeeze" (Figure 7). Once a more detailed narrative has been developed and key variables have been quantified for each scenario, the scenarios can be used to define and evaluate the specific water related implications for different time horizons. Within the Dutch delta plan land use maps were developed for the different scenarios. This way the scenarios are also used to assist in future land use planning which is often necessary in a delta plan.

Within the Mekong delta plan three different drivers of scenarios were defined: (i) Socio-economic land-water-use change, (ii) Climate change and (iii) Upstream developments. For the Mekong delta four different socio-economic scenarios were developed along two axes (see Chapter 5, Figure 16). The first axis is on spatial planning, assuming either controlled or uncontrolled spatial development. The second axis reflects the industrialization process. Two scenarios assume a focus on agro-business while the other two focus more on manufacturing. The characteristics of the scenarios are given in Figure 17 (in Chapter 5).

4.2 Dynamic adaptive policy pathways

As already mentioned in Section 3.2.2 one of the building blocks for Adaptive Delta Management is the development of adaptive pathways. How to develop these has only recently been explored. There is not yet a large body of knowledge or experience. However, we can define a number of steps (see also Roosjen et al., 2012 and Haasnoot, 2013).

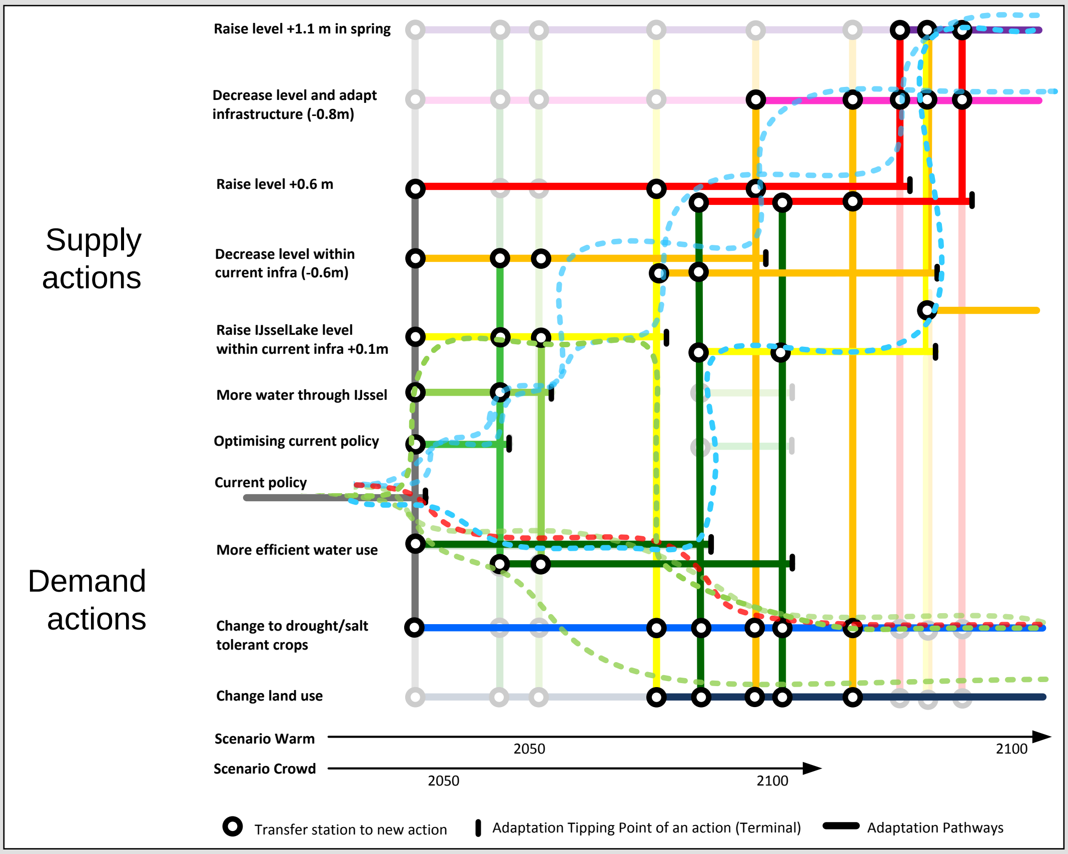
First objectives and bottlenecks are identified, both present and in the future, using scenarios. Next, a number of contrasting solution strategies are defined, based on a certain vision, philosophy, or principle. For instance, a strategy could be based on the principle that (individual) users have to adapt themselves as much as possible. A contrasting principle could be that the government should guarantee meeting the (water) demands of users as much as possible. The idea is to have a number of such basic strategies that together encompass the entire 'solution domain'. For each strategy pathways are formulated consisting of measures that solve the problems and bottlenecks identified earlier. The basis for these pathways are the tipping points which show under which conditions a measure is not feasible any more (e.g. a certain measure is able to cope with a 1 meter sea level rise, but not more). At such a tipping point a new measure needs to be chosen, which suits the overall principle of the strategy best.

Working with Adaptation Tipping Points as a function of a (physical) condition means that the actual time when they occur ('sell by date') depends on the scenario. For instance, under one scenario a 1m sea level rise could be expected 80 years from now, whereas in another scenario it may take 140 years.

Having sketched out all different measures with their tipping points ('transfer stations'), one or more adaptation pathways can be followed. Again, the route to be taken into the future also depends on the vision or principle one chooses: e.g. a large role for the government or a more market driven society. (see Box 3 for an example).

Box 3 **Adaptation pathways for the management of Lake IJssel**

The adaptation pathways map was developed to provide management options for Lake IJssel (Haasnoot, Kwakkel et al. 2013). Measures were grouped vertically, based on whether they influence water supply or water demand. Subsequently the measures with a long durability – of which the tipping point lies far in the future – were placed on the top and bottom of the list. Tipping points for all possible measures were estimated based on results of the Dutch Freshwater Programme and this determines the length of the horizontal line for each measure. In reality the exact time of these tipping points cannot be given as they will differ for each scenario. After each tipping point, all options are considered. This way a network of paths is created. Less logical pathways requiring drastic changes are presented only in the background (lightly coloured).



Preferential pathways are displayed (dashed lines) for three cultural 'perspectives' (Thompson, 1997): blue for the *Hierarchist* perspective (large role of government, maximum control), green for the *Egalitarian* perspective (protection of the environment and equity) and red for the *Individualist* perspective (market driven society, small role for government). For example, the Hierarchist believes in controlling water and nature, while assigning major responsibilities to the government. This means a preference for actions related to managing water levels and water use. The Egalitarian focuses on the environment and equity, resulting in strategies for decreasing water demands by adapting functions to their environment (drought tolerant crop types or crop relocation). The Individualist adheres to a liberal market and a high trust in technology and innovation. This means a preference for facilitating technological developments for more water availability in the growth season.

As can be seen in the picture, parts of the preferred pathways are similar. The point at which the paths start to diverge can be considered as a decision point. In this case, there are three decision points: (1) after 'current policy', (2) after 'raise the Lake IJssel level within current infrastructure', and (3) after 'more efficient water use'. The preferred pathways could be a start of a discussion on an adaptive plan. In addition, combinations of these pathways could be drawn as paths that have support from more than one perspective. For example, starting with 'more efficient water use in the regional areas' could be followed by a small rise of the Lake IJssel water level (+0.1 m), and, if needed, that water level can be raised more, or the water demand could be reduced by changing to other crop types. The short-term action is one that all perspectives could agree upon, making a decision easier ((Haasnoot, Kwakkel et al. 2013).

4.3 Integrated impact modelling systems

To develop adaptive water management plans policy makers need information on future changes on issues such as future water availability, water quality, flood risks and agricultural production. This information is often derived by the use of different impact models such as hydrological, hydrodynamic and agricultural production models. The models are driven by climate models to assess future climate change impacts. The output of these impact models is also used for the climate adaptation atlas (see next section). Due to the complex dynamics of many delta systems it is often necessary to use a range of different models to quantify the main impacts. Figure 8 shows an example of such a modelling framework which was developed for the Bangladesh Delta. This framework consists of four types of models. First of all regional climate models are used from which bias corrected climate data are prepared as inputs for basin and delta modelling. Climate data need to be corrected due to the large biases/errors in especially precipitation. Secondly a basin scale hydrological model is used to simulate changes in the discharge of the major rivers, the Ganges and Brahmaputra. The output of the basin scale model is used as boundary conditions for regional models. River flows and water levels are simulated using a hydrodynamic model. This model uses climate data and sea level rise as input. Finally, to assess future saltwater intrusion a salinity model is used which simulates the salinity in coastal rivers based on hydrodynamic conditions.

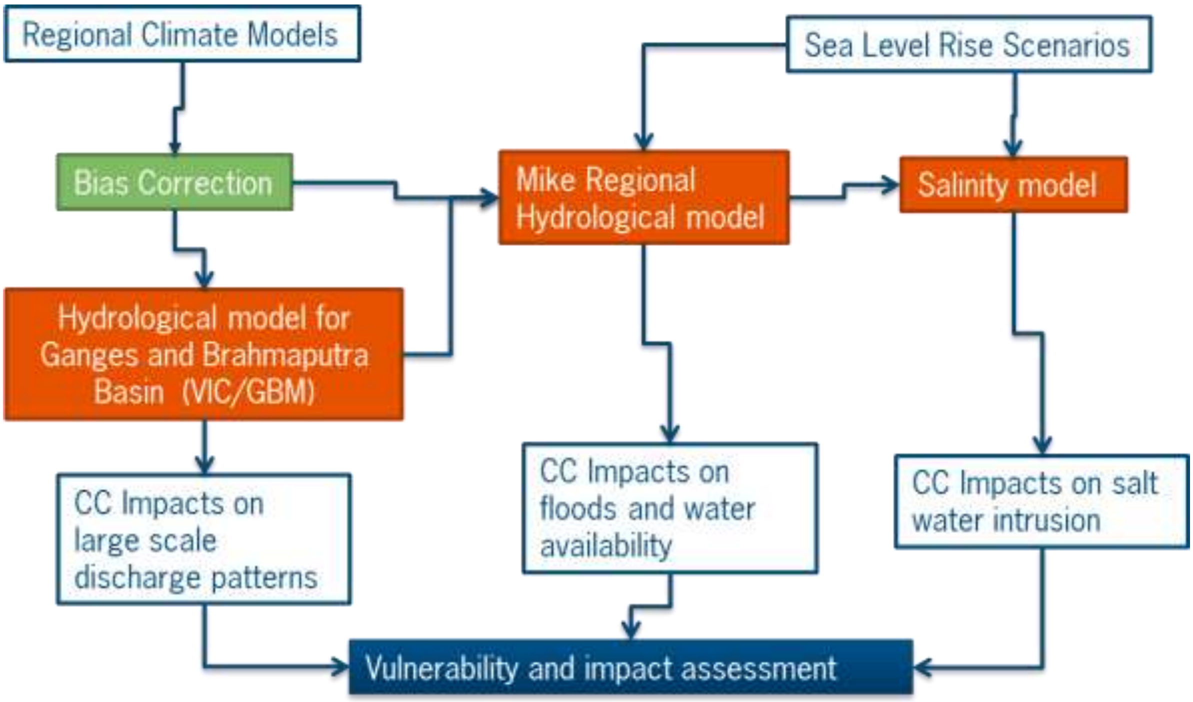


Figure 8 Climate impact modelling framework for the Bangladesh delta developed with the Impact2C EU FP7 project.

4.4 Climate Adaptation Atlas

Long term land use or spatial planning is important for adaptive delta management. To address this issue in the Netherlands the Climate Adaptation Atlas (CAA) was developed to bridge the information gap between climate change information and spatial planning (Goosen et al. 2013). The CAA was initiated by different provinces in the Netherlands to respond to their needs for spatial information about climate change impacts and adaptation.

The Climate Adaptation Atlas platform provides an integrated perspective on climate change by putting together dispersed information on different climate change impacts such as: flood risk, salinity, urban heat island effect and the sensitivity of agricultural crops to droughts. The different aspects of climate change are integrated with scenario-based outlooks on socio-economic change (reflected in land-use patterns) in the Atlas. The results can be visualised on a web-based portal and with interactive devices such as a touch table. Such devices are applied in workshops with local stakeholders to discuss the information and to harvest local knowledge about impacts and vulnerabilities. The Climate Adaptation Atlas and touch table device provide a valuable one-stop-shop for planners, water managers and other decision makers. The included maps on climate impacts and vulnerability help users to identify key adaptation challenges in their area of interest. The tools raise the awareness for climate adaptation issues and highlight areas where proposed investment policies may face future damage. Opportunities due to climate change can also be identified. The maps can be used in interactive and multidisciplinary workshops where scientists, policy makers and spatial planners meet to jointly design and discuss adaptation options based on the local impacts of climate change.

The Climate Adaptation Atlas approach described by Goosen et al. 2013 distinguishes five different steps (see also Figure 9). In the first three steps the primary, secondary and tertiary climate change impacts are identified and spatially visualised. In step four the major challenges are assessed and in the final step there is an identification and integration of adaptation options and strategies. The primary impacts are changes in meteorological variables such as temperature and precipitation. These data are produced by downscaling climate models. Secondary impacts are assessed through different impact models, often focussing on hydrological change such as flood depth and frequency, storm surges and ground and surface water availability. The tertiary impacts focus on the vulnerability of different user functions such as agriculture or urban living environment.

The Climate Adaptation Atlas has been widely applied in the Netherlands. In the Hoar region in Bangladesh the Climate Adaptation Atlas was used to study the impacts of climate change on flash floods and how this affects future rice crop production and urban expansion (CAS 2013). The project focused on a joint problem analysis and on gaining joint support for action. This pilot project showed the potential use of the touch table in the participatory design of adaptation options. The project also highlighted the need for reliable information on future climate change and impacts and the need to develop methods to involve local stakeholders.

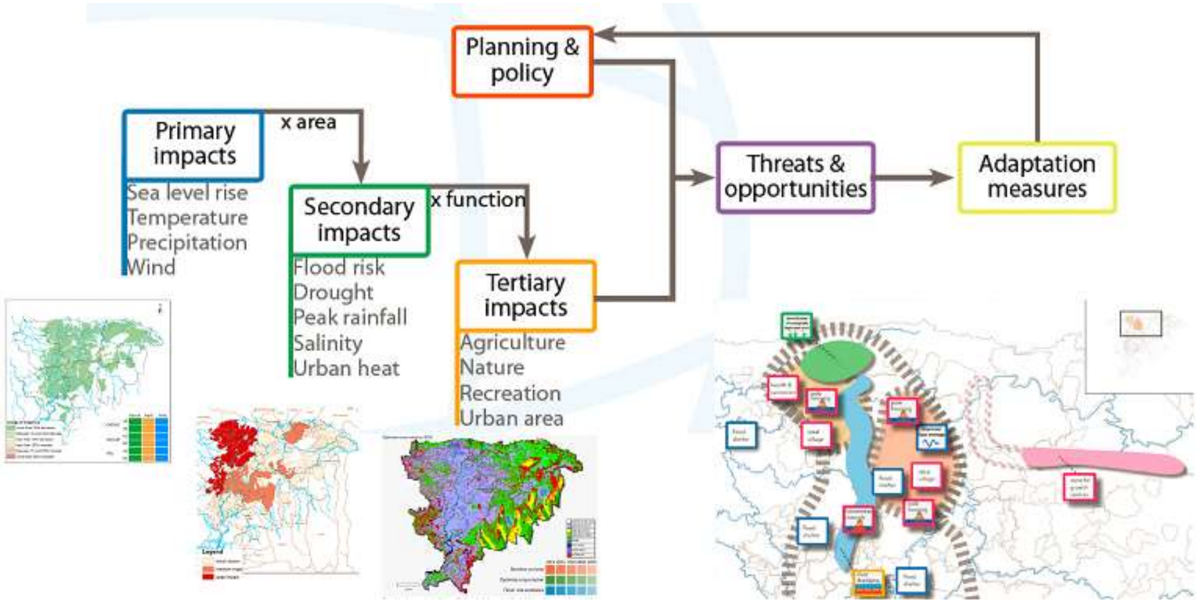


Figure 9 Climate Adaptation Atlas for the Haor Region, Bangladesh

4.5 Planning concepts: deltas as complex adaptive systems

In recent planning practices, deltas are regarded as complex adaptive systems (CAS). Essential for a CAS is:

- It contains many elements and mechanisms, which are not limited to the physical and ecological environment, but also explicitly include the artificial networks and human society;
- Many relations between the elements are non-linear;
- The current and future state of both the elements and relations are uncertain.

Because of these characteristics, complex systems are difficult to fully understand, their behaviour is difficult to predict and they are manageable only to a limited extent. Relations between system elements are often in a dynamic equilibrium and evolve over time. This brings us to the adaptive capacity of a CAS. Since a CAS includes human society, the governance is part of it as a sub-system. Actors in this sub-system react to each other and on changing external conditions.

One way to derive some order in such a complex system is to use a layer-approach, in which three sub-systems are distinguished. This Layer model recognizes three physical planning layers (Figure 10): the **Base layer** (water and soil), the **Network layer** (infrastructure) and the **Occupation layer** (zoning of land use functions), each with different but interrelated temporal dynamics and public-private involvement. The model indicates a physical hierarchy in the sense that the Base layer influences the other layers through both enabling and constraining factors. For instance, the soil type determines to a large extent the type of agriculture that can be performed in the Occupation layer.

Unfavourable conditions (constraints) posed by the Base layer can be mitigated to a certain extent through adaptations in the Network layer or Occupation layer. For example, farmers can use agrochemicals to improve soil conditions, or dykes can be constructed to protect low-lying land from flooding. But these adaptations to the original physical geography of an area require investments and need to be managed.

The essence of the Layer model is the difference in dynamics and vulnerability between the layers, which results in a logical order in planning for the various layers. The model can be used for analysing the physical interactions between the layers: each layer enables and/or constrains activities in the other layers. Besides The model is also useful in positioning the roles of different actors, such as government agencies, private entrepreneurs and stakeholders. The development and maintenance of infrastructure in the Network layer is traditionally the responsibility of the government. The government also has a main role in the protection and management of the Base layer. Moving towards the Occupation layer, the role and influence of the government becomes more restricted and the influence of private parties and citizen's organizations become more dominant.

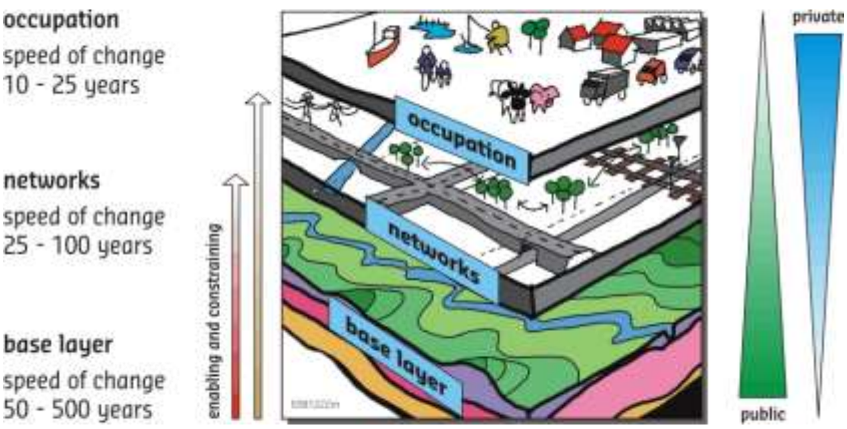


Figure 10. The spatial layer model

The Layer model is largely compatible with other well-known approaches, such as the ecosystem functions approach (De Groot, 1992; De Groot, 1994; De Groot et al., 2002). The Base layer provides the enabling conditions for humans, which can be split into function categories, such as regulation, habitat, production, information and carrier functions. An important advantage of the Layer model is that it explicitly takes into account human alterations to the natural ecosystem. Indeed, many deltas are no longer in a pristine state and should be described as modified or highly modified ecosystems. The Layer model describes these modified ecosystems in terms of the Base layer *and* the Network layer.

The layer model is instrumental for so-called casco-planning (Sijmons, 1991) by which robust infrastructure and landscape elements are used to allow land use and urban development to evolve in an organic and flood resilient way.

4.6 Delta Program Evaluation Framework

Delta adaptation requires a long term vision how to adapt to plausible futures regarding climate change as well as socioeconomic development. Promising strategies and measures need to be assessed and evaluated, to provide essential information for decision making. However, relatively little knowledge exists how to design an assessment framework that can handle the inherent uncertainty which comes with the long term character of adaptation strategies. Most existing evaluation frameworks such as cost efficiency or cost-benefit analysis (CBA) are designed for investment plans and projects with a time horizon that is too short to encompass the effects of climate change. Furthermore, delta adaptation strategies are of a very diverse nature, including infrastructural investments, urban redesign, fiscal incentives, eco-engineering and green infrastructural design. The question is, therefore, how to design assessment frameworks that can grasp this diversity as well as long time horizons.

Recently an assessment and evaluation framework was prepared upon request of the Dutch Delta Program. The Framework was developed during 2011 and 2012 in close interaction with analysts and participants of the Delta Program and was tested in a number of regional trial sessions. The outcomes of these sessions were used to refine and improve the Framework.

The core of the Framework includes a semi-quantitative scoring method on main criteria: goal realization (flood risk reduction and/or freshwater supply), investment and maintenance costs as well as environmental, social and economic values.

The Dutch experiences were subsequently used to prepare an Assessment Framework for application in the on-going Rebuild by Design contest aiming at providing a more resilient and adaptive coastal development in New Jersey and New York after Hurricane Sandy. An initial framework was tested during a workshop with the designers (see Table 1 below).

Table 1 Evaluation criteria used for Rebuild by Design contest (USA)

Criteria	Sub criteria	Indicators
Life cycle costs	Investment costs	Dollar
	Operation and maintenance cost	Dollar/year
	Re-investment after … years	Dollar
Flood protection	(Reduction) of expected property damages due to flooding	Dollar/year Or Probability x number of assets Or Probability x number of persons at risk Or Length of (artificially) defended coastline (miles);

Criteria	Sub criteria	Indicators
	Reduction of expected casualties due to flooding	Same People at risk; Length of (artificially) defended coastline;
Environmental value	Ecosystem and biodiversity effects	Change of condition of habitats and species that have been identified as priorities for conservation;
	Energy efficiency	Share of renewable energy;
	Ambient (urban) environment / spatial quality	Green buildings; Collection of rain water / rain water harvesting for urban supply;
	Noise levels	Human exposure to harmful noise levels;
	Greenhouse gas emissions	Share of Biofuels in Transport; Energy Consumption;
	Air quality	Air pollution; Green areas;
Social value	Identity & Social cohesion	Attendance to festivals and public events, organized to strengthen the area's local identity; Local products;
	Crime and vandalism	Crime; Perception of safety; Safety provision; Poverty;
	Affordable housing	Provision of affordable housing;
	Recreational value for inhabitants	Green Land Area; Tourism Intensity;
	Cultural, historic, archaeological sites and landscapes	Visits to cultural and natural sites;
Economic value	Direct effects on local or regional economy (e.g. tourism, agriculture/fishery, logistics, energy)	Gross Value Added (per sector of economy, explicitly focusing on activities like fishing, aquaculture, tourism, port activities);
	Synergies or spin-off effects to other sectors' revenues (e.g. transportation)	Transport of goods;
	Economic competitiveness	Unemployment rate; Business with access to broadband;
	Substitution effects / damages	
	Local / regional employment	Employment by sector;
	Local / regional employment in construction	Employment in construction;
	Spin-off effects to other sectors	Expenditures and investments;
	Value of property	Re-use of urban and derelict areas;
	Mobility / Transportation	Transport usage; Vehicle ownership;

The Rebuild by Design scoring process was embedded in a step-wise approach that included defining a reference situation, stakeholder identification and robustness/flexibility tests as well as implementation and synergy opportunities

(Figure 11). This approach combines several methods presented previously in chapters 3 and 4 and places the evaluative assessment in step 5.

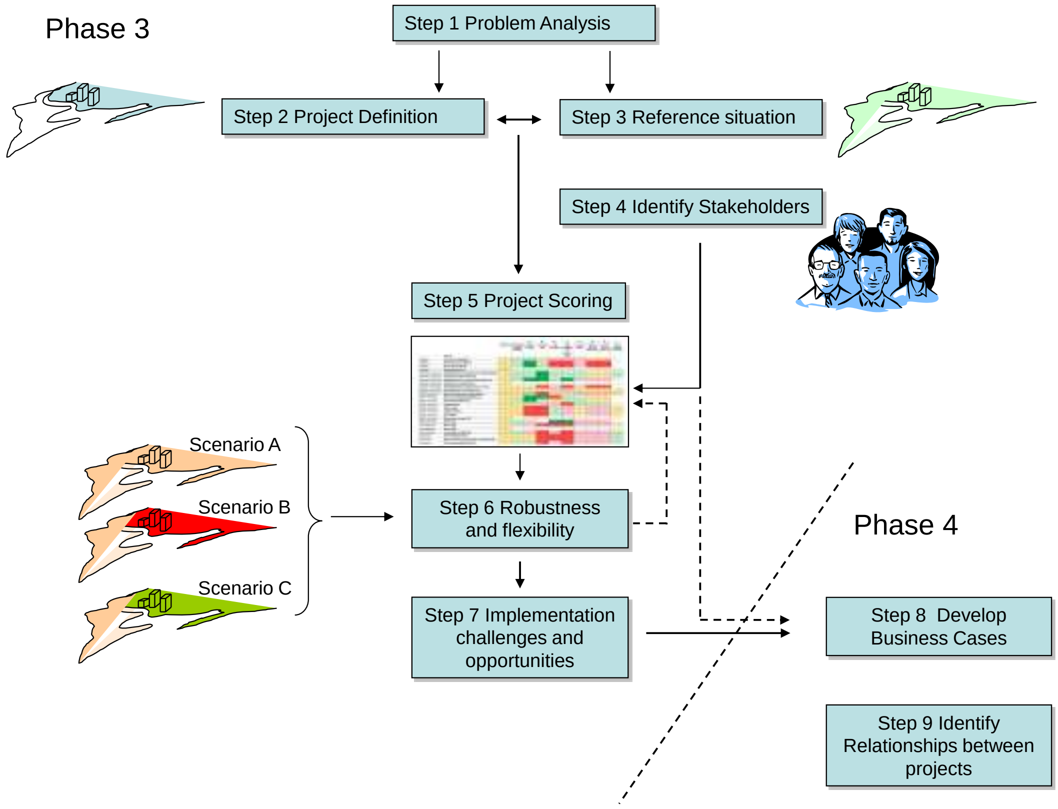


Figure 11 Stepwise evaluation approach (Rebuild by Design, USA)

4.7 Real options analysis

Real options analysis, as a discipline, extends from its original application in corporate finance to decision making under uncertainty in general, adapting the techniques developed for financial options to "real-life" decisions. It differs from other economic or financial methods in two ways: it takes uncertainties into account in the future evaluation of the parameters that determine the value of a project, and it acknowledges the management's ability to respond to the evolution of these parameters[1]. Since Adaptive Delta Management has everything to do with the ability to respond to future changes, the real options analysis seems well suited as a valuation technique.

Using the Net Present Value (as in most cost-benefit analysis) has the disadvantages that it considers future conditions as fixed and that it ignores the possibility of future decisions. Real options are for instance the option to expand a certain investment if new opportunities appear, or to abandon an investment, if conditions worsen. Also the option to delay an investment is considered, unlike the NPV method, which simply considers to do the investment now or never. Postponing the decision could be wise in situations where current information is too weak or too uncertain.

Using Real Options one could calculate the NPV's of the various future options, by using decision trees, but only if one assigns a probability to each of the options. For instance, there is a 75 % chance that there is a high demand of a product and a

[1] Wikipedia.org/wiki/Real_options_valuation (accessed 14 April 2014)

25% chance of a low demand. Similarly one could calculate the investment NPV under different climate conditions. Still, a problem is that it is difficult to put probabilities to each of the climate scenarios.

Nevertheless, the real options method is an improvement in guiding economic decisions under Adaptive Delta Management because it explicitly acknowledges the different options created by adaptation pathways.

Chapter 5 Best practices of Adaptive Delta Management

5.1 The Netherlands

Over the past decades the Netherlands have gained ample experience in delta management. In fact, Dutch water management is in the middle of a fundamental change process that started in the 1970’s towards a more adaptive and participatory form of water management (Brugge, Rotmans et al. 2005). Its latest development towards adaptive delta management is now taking place in the Dutch Delta Program. The essence of its approach is the long term vision, a broad societal involvement and a strong, interdepartmental governmental legitimacy. In this approach delta decisions are prepared which will be implemented in action plans and ultimately in practical measures, including public investments in infrastructure, and embedded in regional and local physical planning.

Although the Delta Program is not finished, experiences up till now show promising results (Van Rhee, 2012). For instance the method of tipping points and adaptation pathways has already been applied successfully in all sub-programs. Working with adaptation pathways facilitates making choices in regions where measures are already necessary on the short term. It also proved to be possible to link Delta measures with other investment agendas which elucidated win-win situations. Fine-tuning decisions in time using a cost-benefit analysis to find an optimal implementation sequence also proved to be possible but still requires to be worked out further.

5.1.1 Adaptive coastal management

One of the best practices of ADM in the Netherlands which has been on-going for more than 20 years now is the coastal policy of Dynamic Preservation. According to this policy coastline management is based on sand nourishments as the preferred method for protection. The idea of sand nourishments is basically to enhance the natural resilience of the sandy coast, by adding sand in the system where too much sediment has been eroded due to along-shore transports. Every year up to 12 million cubic meters of sand is used for this purpose. Only when this measure is not possible the alternative of hard engineering structures, such as groynes, breakwaters and sea walls is opted for. This policy has resulted in a safe, environmentally sound, sustainable and natural coastal defence system, consisting of dunes and beaches along the majority of the Dutch coastline (Mulder, Hommes et al. 2011).

Using the coastline position of 1990 as a benchmark, every year the government evaluates whether the actual coastline meets the standards and, if not, decides on nourishment. At first morphological developments at larger scales, e.g. sand losses at larger depths and long term developments such as sea level rise, were neglected. In 1995, the Dutch Government decided to implement an extended large-scale approach: additional compensation of sand losses at deeper water. Because the sand nourishments are a flexible measure, adaptation to climate change in the future is rather easy.

The general lesson learned from the Dutch delta Program is: a sustainable and adaptive solution to coastal erosion problems should be based on an understanding of the sediment dynamics, framed in a policy context with explicit objectives (such as maintaining the 1990 coastline benchmark). Furthermore, a good monitoring system should be in place, in order to decide when to act. Fortunately, the Dutch coast has been monitored each year for over hundred years now. This database is of great value for improving our knowledge, for validating numerical models and for informing the coastal manager when to apply a nourishment.

5.1.2 Room for the River Programme

Climate change could lead to a 30% increase in flood discharges in the River Rhine. The idea is raising the levees caused much societal resistance because it would destroy a lot of cultural heritage. Instead of raising the levees it was decided to give more room to the river. This would substantially lower flood levels and sustain a more attractive environment, both in urban and rural areas. The room for the river approach was officially adopted by the Dutch national government to achieve the required safety level for all river systems. It became the guiding principle for climate change adaptation along the major rivers.

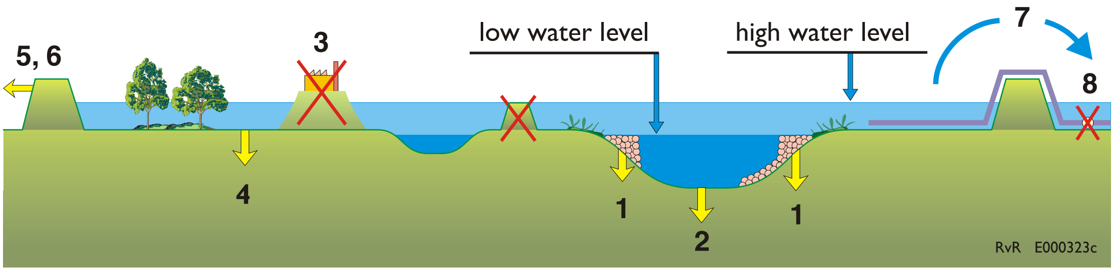
The main goal remains to maintain the safety of the land against flooding from the river with higher river discharges that are expected in the near future. Besides this goal the program also focuses on the spatial quality, amenity and nature values of the river landscape.

The Room for the River program consists of 39 different projects, located along all the main branches of the river Rhine. The first machines started digging in 2007 and the whole program will be finished in 2015. The map below highlights all the project locations of the program.

Figure 12 Map showing the locations of projects under the program

The Room for the River program consists of 8 basic types of measures to reduce the water levels in the floodplain (see Figure 12)

1. *Lowering groynes*: At high water levels groynes can hinder the river flow. By lowering the groynes the flow capacity increases.
2. *Deepening low flow channels*: Excavating the surface layer of the river bed increases the wetted area within the river channel, thereby increasing its flow capacity.
3. *Removing obstacles*: Modifying or removing obstacles such as old brick factories in the river floodplain creates more room and thus reduces the hydraulic resistance.
4. *Lowering floodplains*: excavating the floodplain lowers the water level during high river discharges.
5. *Dike relocation*: Displacing the dike landwards, increasing the width of the floodplain.
6. *Setting back dikes on a large scale ('de-poldering')*: By relocating the riverside dike, a previously reclaimed floodplain area can be restored so water can flood the former polder during high tides.
7. *Detention reservoir*: Additional place for temporary water storage during extreme events.
8. *Reduction of lateral inflow*: by preventing local water runoff (buffering water on the land), water levels are reduced.
9. *High-water channel*: creating a bypass to discharge water through a different route.
10. *Strengthening dikes*: Where creating additional room for the river is not an option, e.g. due to urban areas, the dikes are strengthened.



1 - lowering of groynes
2 - deepening low flow channel
3 - removing hydraulic obstacles
4 - lowering flood plains
5 - locally setting back dikes
6 - setting back dikes on a large scale
7 - detention reservoir
8 - reduction lateral inflow

Figure 13 Cross section of river floodplain with types of Room for the River measures.

Figure 14 Plan and realization of a Room for the River project

5.1.3 Bypass Kampen

An example of combining investment agendas is the construction of a bypass channel near Kampen, a town located at the downstream part of the river IJssel (Figure 15). In this case a bypass is a solution to maintain flood safety on the longer term, while it is not necessary in the short term. However, in the same area of the bypass other developments will take place, such as a planned new residential area, upgrade of a highway and upgrade of a railroad. By implementing the bypass earlier than strictly required for safety reasons it can be combined with these other developments. Because of this combined interest the regional government is willing to contribute € 94 million for the bypass. The costs for the water manager are therefore lower than would have been if the bypass was constructed in isolation later (Van Rhee, 2012).

Figure 15 By-pass Kampen (the Netherlands) (Source: H+N+S)

5.2 Mekong Delta

The Mekong Delta is located in southern Vietnam and has a population of about 17 million people. Traditionally the delta is used for intensive rice production but over the last decade land use and economic activities have become more diverse. The delta is vulnerable to climate change and sea level rise which cause reduction in dry season water availability, increased salt water intrusion and a higher flood risk. The autonomous socio-economic development, both inside and outside the delta, also causes challenges for sustainability. First of all the population is rapidly increasing while the delta is already densely populated. Partly in response to the increased salt intrusion, there has been a large increase in aquaculture. Many provinces in the delta also want to increase their industrial production, with a mixed level of success. Furthermore, upstream development will change the natural resources of the delta.

New dams and irrigation systems will affect the hydrological regimes and sediment flow of the Mekong delta. During the last few years there is an increasing awareness in Vietnam that it is necessary to develop integrated adaptation strategies to ensure a healthy future development of the delta.

One of these integrated strategies is the formulation of a Mekong Delta Plan. In October 2010, the Dutch and Vietnamese government decided to collaboratively develop an integrated long-term Mekong Delta Plan, to respond to the consequences of climate change and to ensure the sustainable socio-economic development of the Mekong delta. Currently a first draft of this delta plan has been developed (Mekong Delta Plan 2013). As a part of this plan four different socio-economic scenarios were formulated and for each of these scenarios different land and water management challenges and problems were defined (Figure 16 and Figure 17). Based on this assessment several key adaptation measures were designed.

The area used for triple rice cropping in the delta is increasing. As a result more flood defence structures are developed to facilitate the third season rice production during the flood season. Due to climate change the peak flow in the wet season could increase in the Mekong delta. This results in much higher flood risks in the lower delta. To reduce these flood risks the Mekong Delta Plan suggests three different measures. First of all it is needed to improve and expand controlled flooding in the upper delta to store more water during the flood season. To protect the urban region it is necessary to focus on local improvements of the urban flood protection systems. Thirdly, , it might become necessary to develop large flood diversion canals on the long term.

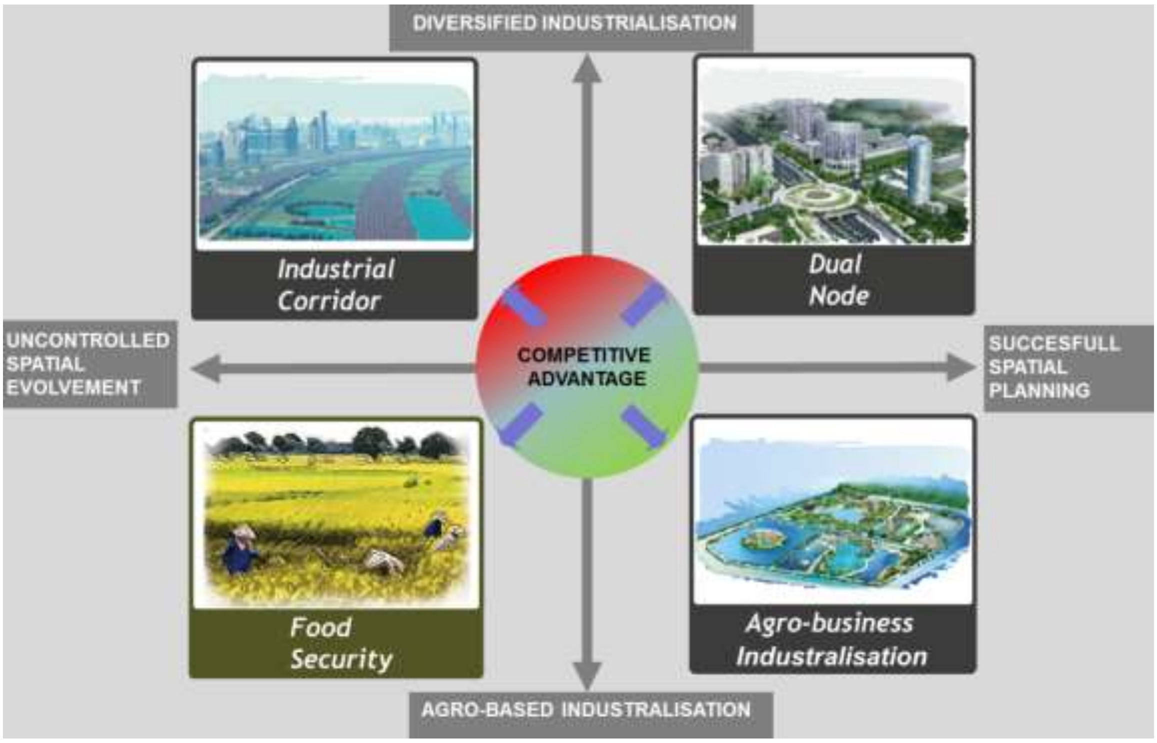


Figure 16 Four different socio-economic scenarios developed for the Mekong Delta Plan.

In the future, fresh water supply could become a major problem in the Mekong delta. Dry season flows could be reduced due to upstream development and climate change. At the same time, the demand for water is probably increasing due to intensification of agriculture, economic development and population growth. Due to sea level rise salt water intrusion will increase, affecting fresh water availability in the lower parts of the delta. To improve future freshwater availability two measures are suggested. First of all it is necessary to manage the flow diversion between the different branches of the river to ensure that enough freshwater reaches the different parts of the delta. Secondly, in the long term there might be a need for a dry season closure of different river branches. These structures could also protect the delta against storm surges.

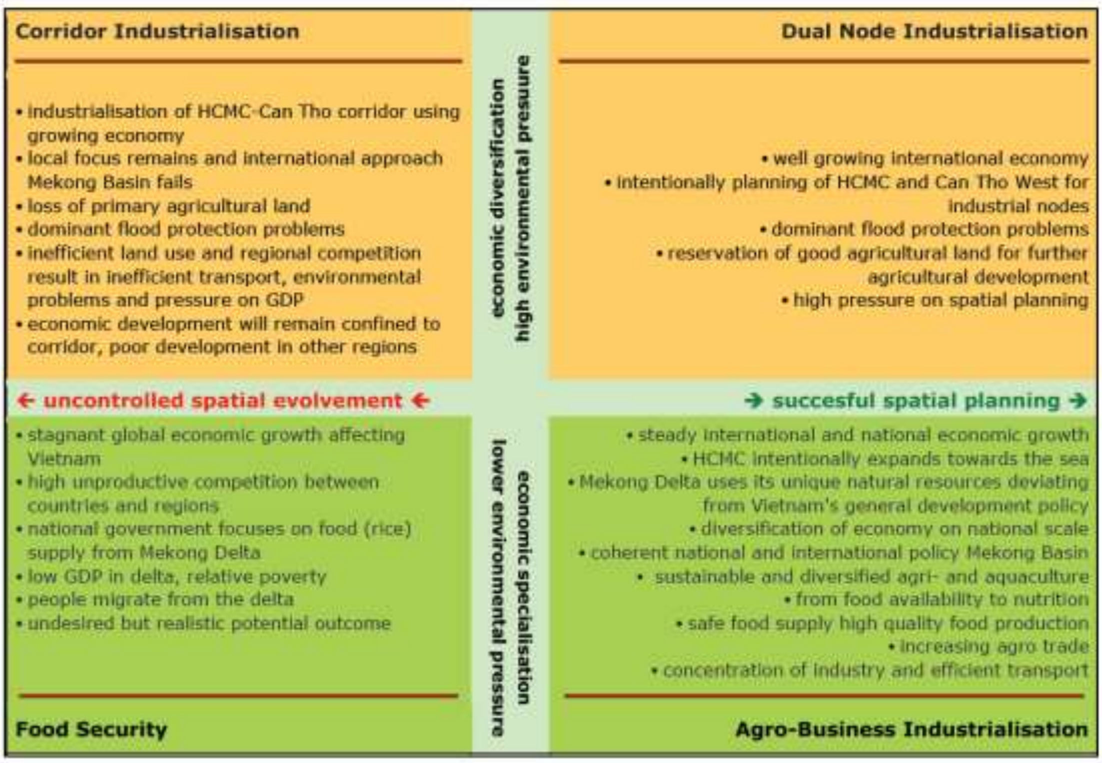


Figure 17 Characteristics of the different scenarios used in the Mekong Delta Plan.

The coastal zone of the delta possibly needs to deal with two important problems in the future: higher flood risk due to increased storm surges and increased salt water intrusion. To adapt to these changes and to ensure socio-economic development in the coastal zone a system needs to be developed which combines flood protection with brackish aquaculture and agriculture. Furthermore it is necessary to improve the water management in the coastal zone. Due to increased salinization of surface water and depletion of groundwater there is a need to expand saline agriculture in the coastal zone. In addition, the available freshwater resources need to be better managed and reserved for activities of high economic return and domestic water supply. Finally there is a need to improve the coastal flood protection system. Historically, many of the sea dykes have been constructed close to the shoreline. The natural flood protection such as mangrove forest has been managed badly. To improve the coastal flood defence it is necessary to decouple the road and dyke system and to improve the management of natural ecosystems along the coast.

The suggested adaptation measures discussed above focus very much on improvement of the biophysical system. However, the delta is not only impacted by biophysical change but there are also large scale governance problems. To improve adaptive water management in the Mekong delta it is therefore necessary to improve the governance system within the Mekong delta.

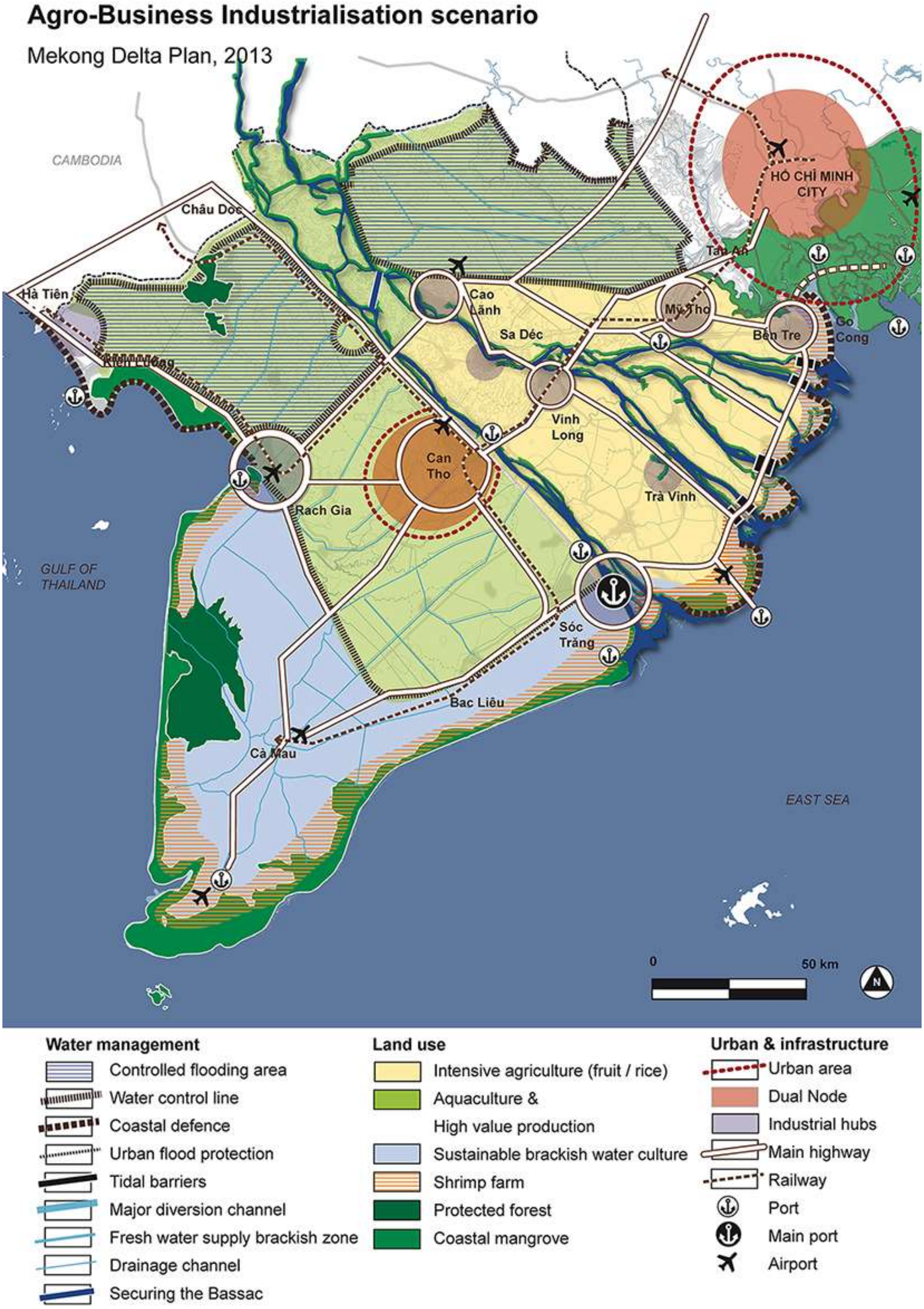


Figure 18 One of the scenarios of the Mekong Delta Plan (Source: MDP, 2013)

5.3 Mississippi River Delta[2]

In 2005 the Mississippi river delta was hit by Hurricane Katrina as a result of which large parts of the city of New Orleans flooded, two thousand people lost their lives and thousands of houses were destroyed. The case of New Orleans shows that rebuilding the city after the flood is not only a matter of repair or improvement of flood-defence constructions, but also a matter of combining water management with strategies for new spatial, social and economic perspectives for the whole region.

The floods of Hurricane Katrina functioned as an accelerator of the debate on a necessary change in the management of the Mississippi river delta and the spatial development of cities and urban settlements in the area. This comprises three elements. First, the reconsideration of the flood defence system of New Orleans in order to create safer conditions for urban development and for a closer relationship between the city and the delta landscape. Second, an effort to stop the decay of the wetlands, because of their role as a natural buffer between open sea and urbanized areas, and because of the environmental and ecological importance of these wetlands. Third, the improvement of the drainage system in the Greater New Orleans area, with special attention to the threefold role of the outfall canals in New Orleans: as essential elements in the drainage system, as open water bodies with flood defences, and as corridors in the urban system.

Citizens of the City of New Orleans took the initiative to reconsider the urban drainage system. This element is the main issue which was addressed by the Dutch American workshops 'Dutch Dialogues' (Meyer et al. 2009) and which has become an assignment for an 'integrated and comprehensive water management strategy', issued by the Greater New Orleans Regional Economic Alliance and implemented by a consortium of participants of the Dutch Dialogues workshops. The main ambition of this strategy is to change the existing drainage infrastructure to a new 'vascular' surface water system which will prevent on-going subsidence and store rainwater during heavy rainstorms. The introduction of this new system can also improve the urban fabric: next to the integration of surface water in public spaces like boulevards and parks and in private parcels, especially the transformation of the outfall canals plays a key role in this strategy. Instead of separating floodwall lined corridors between urban districts, which are oriented with their backs to the canals, the floodwalls will be turned down and the canals will be transformed into attractive public spaces, centrally positioned between urban districts (Figure 19) This is an important improvement of the spatial structure of the city, which was made possible by the construction of the storm surge barriers in the mouth of the canals by the USACE.

[2] Largely based on Meyer & Nijhuis, 2014

Figure 19 Outfall canal New Orleans – existing situation (top) and impression of the future situation (bottom). Source: Dutch Dialogues.

Chapter 6 Conclusions and way forward

6.1 Conclusions

The previous chapters show that adaptive delta management is rapidly developing into a fascinating new type of decision making under an uncertain future. The reasons for using the new approach are convincing, the theoretical foundation is growing and the results on the ground are promising. But we are not there yet.

Although the signs of a changing attitude towards adaptive delta development are visible, this does not mean that alternative solutions can be realized easily. It takes much effort to turn new ideas into practice. Surely, the last decade has shown a proliferation of new concepts and ideas, such as the Dutch Dialogues in New Orleans, eco-engineering, working with nature, climate proof cities etc. Some of them have actually turned into programs, such as the Room for the River program in the Netherlands, and the Louisiana Wetland Rehabilitation Program in the USA. Despite these successes, it is too early to say that the new paradigm of delta development has replaced the old one. Louisiana wetlands are still lost at a high rate and the enormous political and social turmoil around re-flooding the Hedwigepolder in the Scheldt estuary in the Netherlands (an area of less than 300 ha) shows how difficult it is to implement such ideas. There are at least two reasons for this:

1) *Lack of knowledge and experience*: the scientific evidence of alternative solutions is often shrouded by uncertainty. The effectiveness of traditional engineering solutions, such as a dike, can be calculated with tested and accepted methods, whereas reaching the same goal through a Building with Nature concept is not backed up by any evaluation methods yet. This requires applied knowledge on the behaviour of such essentially dynamic solutions. The protection capacity of a mangrove forest or salt marsh is also much more difficult to calculate. Another aspect to consider is that the behaviour of the complex delta system in itself is difficult to grasp. It often requires sophisticated models to predict changes under business as usual as well as under alternative solutions. Such models often have a wide margin of uncertainty (e.g. morphological models, climate change models). This uncertainty may easily become an excuse for not taking such knowledge seriously at all.

2) *Governance problems*: decentralization, privatization and increased public consciousness may lead to more complex and longer decision making processes. For instance, current governance structures in the Mississippi river delta make it difficult to establish linkages between federal, state and local planning initiatives. Vested interests in the engineering domain may form powerful counter forces. In the Mekong Delta, the ‘hydraulic bureaucracy’ is a factor to reckon with when suggesting alternative, non-engineering solutions. Financial and legal institutions are often designed around a specific type of solutions, which may cause the organizations benefiting from these institutions to discredit new solutions as less secure, more expensive and so on.

6.2 The way forward

One of the missions of the Delta Alliance is to support the development and proliferation of these new approaches in delta management through research, exchange of best practices and exchange of concepts and ideas. Several phases can be defined in such approaches, as was described before. The first phase focuses on identification of current and future problems and challenges, while in the second phase options should be explored which enhance the sustainability and/or reduce the vulnerability. The last phase focuses on integrating the adaptation options into viable management strategies and ensuring their proper implementation.

Until now the first two steps are gaining momentum, although still much can be learned from research into the coupling of science and governance for understanding how deltas as complex dynamic systems can be managed. Linking this understanding to the third step, where financial arrangements, public (infrastructure) procurement strategies, implementation constraints and opportunities as well as durable maintenance arrangements play a decisive role, is yet to be explored. Here we can potentially learn much from analyses of best practices which take into account a diversity in social and cultural dimensions. These practical experiences can thus generate a larger body of knowledge on delta planning and management.

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