Flood Risk Management Strategies for Delta Regions

Balancing resistance and resilience in unique contexts

Freek Kranen

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Thesis

By

Freek Kranen

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Supervisors

University of Groningen :	*Dr. Johan Woltjer*
Royal Haskoning, NL :	*Dr. Ir. Bas Jonkman*
Royal Haskoning NL :	*Drs. Stefan Nijwening*
Haskoning Inc., NOLA, USA :	*Dr. Ir. Mathijs van Ledden*

Preface

The Paper presented here consists of two sections: A case study report as a result and conclusion of a two months internship at Haskoning Inc. in New Orleans, and the main thesis as part of the requirements for the masters degree program Environmental and Infrastructure Planning at the Faculty of Spatial Sciences, University of Groningen.

Main goal of the research is to add to the discussion of flood risk management. As my interest for water and all issues that connect to it already came out at high school, the choice for this subject is no surprise to anyone who knows me.
Still, it is the chance to go abroad offered to me by Bas and Mathijs from Royal Haskoning that made this research so valuable for me personally and hopefully for you as a reader as well. The research turned out to be a rollercoaster ride through and across the worlds of spatial planning, water management and flood risk management, forming and reshaping my personal vision throughout the writing of this report.
The many discussions and interviews I had with professionals in the fields of planning, water management, architecture, governance and politics were a main contribution to this process that lead to a whole new view on flood risk management.

The focus of this thesis is on the usage of resilience based measures to mitigate flood risk. This approach is still young and needs to be shaped and reshaped in the coming years. Hopefully this thesis adds to that ongoing process.
As I noticed along the way, a major future role is reserved for spatial planning in achieving a sustainable development in flood prone regions. My background as a spatial planning student combined with my personal interest in water related issues turned out to be a valuable angle to start this research from.

I strongly believe that international comparison and learning is invaluable for flood risk management effectiveness and efficiency at any given location. By sharing worst failures and best practices students and professionals can develop their vision on how flood issues in complex deltas should be handled.
The *Delta Dialogues*, an initiative by Royal Haskoning Netherlands, offers a good example of how such international discussion and cooperation can be given meaningful content. From my position as a graduating student I am thankful for the chance that is offered me to join this program.

With special thanks to

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Johan, *Mathijs, Bas* and *Stefan*, for the time invested in reading and commenting on my report, and for discussing the contents and focus of the research with me. Without these people I would not have been able to proudly present you this thesis.

Summary

Worldwide flood risk in deltas is increasing, putting sustainable development in these vulnerable regions under severe stress. The traditional way of dealing with flood risk more and more proves to be not suitable in present times. The complexity and interrelationship of issues in deltas does not allow solely structural measures anymore, but calls for adaptation and flexibility of society. A key word in this new approach is resilience.

In this thesis the delta and its occupation are analyzed from a systems approach point of view. This approach offers a clear insight in the specific parts of the city as a system embedded within its unique context. In this thesis resilience is used more as an overarching term for a set of desirable system attributes, rather than one concrete system part.

By applying the right set of measures a preferred balance between resistance and resilience within a flood risk strategy can be obtained. Through this a delta can fit its flood protection strategy to the local context and the specific flood risk characteristics.

Integrated spatial planning plays an important role in this process. Through the design of comprehensive long term spatial plans the preferred balanced flood risk strategy can be implemented into built environment, supporting a more sustainable development of the region.

Through analyzing two case studies a suitable set of measures is identified that can be applied to increase the resilience of a socio-physical system. A method is suggested to score the level of resilience of a delta by using clusters of measures, different weight sets and a score card for visualization. Using this method enables generating insight in the preferred future actions to be taken to mitigate flood risk in flood prone deltas.

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1 Introduction

1.1 Deltas and Flood Risk

Throughout history floods have been part of daily life in deltas. Flood exposed societies learned to benefit from this phenomenon, as floods bring widespread environmental and economic benefits (see Blaikie *et al.*, 1994). Even for a country like the Netherlands, where the possibility of flooding is reduced to a minor factor nowadays, floods had a function up till a few decades ago. Floods fertilized agricultural lands, supported biodiversity and offered strategic opportunities in times of war. In this perspective floods were part of the socio-physical delta system. This two-faced impact of floods on society partly founded policies like 'living with water' (e.g. V&W, 2004; 2009)
From halfway the 20th century the world experienced a vast increase in population size, accompanied by major transformations in development patterns, economic conditions, and social characteristics. The greater part of these socio-physical transformations are concentrated in urbanized delta regions along the continental coastlines and the big rivers (Goudarzi, 2006). This results in a high increase of large flood disasters throughout the world. Climate change adds to the problem and is likely to cause global shifts in patterns of flood occurrence and intensities (Few, 2003; IPCC, 2001; Mitchell, 1999). Also coastal erosion and soil subsidence are important contributors to the growing flood risk.

The World Water Forum reported that in the year 2000 large deltaic floods occurred in Mozambique, South Africa, Indonesia, China, Bangladesh, Japan, Cambodia, Vietnam, and the United Kingdom (WWF3 Secretariat, 2002, referred to by Few, 2003). New Orleans flooded in 2005, as did large parts of the UK in 2007, Bangladesh in 2008, and Turkey in 2009.
The potential value of damage and the number of casualties caused by floods is gigantic and is likely to keep on growing during the coming decades. Nowadays flood disasters account for about one third of all natural disasters in the world (Berz, cited in Burrell *et al.*, 2007).. These trends stress the importance of research on, and a growing call for new flood risk mitigation strategies (Godschalk, 2002; Vis *et al.*, 2003; Burby *et al.*, 2000). This thesis attempts to answer this strong call by exploring the possibilities to design and evaluate a more hybrid flood risk management strategy that combines several sets of measures of different types.

Recent discussion in flood risk management concentrates mainly around two strategies; the so-called 'traditional' <u>resistance</u> strategy and the upcoming <u>resilience</u> strategy. Both of them consist of a variable package of measures that determine the effectiveness of the strategy. By choosing the right set of measures based on the local situation and

international experiences, decision makers can balance the costs and effectiveness of the strategy, and determine the time span and sustainability of it.
Whether it is about offering resistance against floods, or about upgrading the resilience of the socio-physical system, without good cooperation and coordination between the local regional, and national authorities, market parties, interest groups, water managers and spatial planners it is difficult to achieve this in the most effective or efficient way.

Every delta's flood risk management system - hereby I refer to the total of interconnected systems of weirs, dikes, sluices and additional structures, as well as measures like flood insurance, evacuation schemes, and information and education that are used for flood protection and mitigation - is especially equipped for the unique local conditions. It is designed to the dated vision and considerations of local policy makers and spatial planners.
These local strategies are strongly shaped by their dependency on a wide variety of influential factors embedded within the local socio-physical system and its environmental and institutional context. Each delta region has its own history of major failures and best practices and it is important to share these experiences. Taking the design of a strategy out of its local context and comparing it to a similar situation somewhere else can lead to valuable new insights about how to cope with the local challenges (see also Brooks *et al.*, 2005; Dolowitz and Marsh, 1996). An example of doing could be, amongst others, 'the Delta Dialogues'. This concept, created by Royal Haskoning, is designed for facilitating a dialogue between deltas from all over the world.

1.2 The role of spatial planning

In most deltas built environment is not adjusted to the limitations and potentials of their dynamic natural environment and the risks that are part of this environment, causing billions of dollars of damage a year. Land and water use development in deltas is for a great part not sustainable, which is reflected in the current issues in deltas worldwide (NWP and Deltares, 2009).
As we can see in the Rhine Delta, the lack of integrality in past flood risk management policy caused major environmental problems in recent years, sometimes leading to the costly reversing of measures like in the Oosterschelde area (Nienhuis and Smaal, 1994). Such like consequences of unsustainable decisions from the past can be recognized world wide (USACE, 2006; Liu Xiaoyan *et al.*, 2006), stressing the importance of well formulated, adaptive solutions.
Such unsustainable situations can occur for several reasons. At first, in many deltas there has been a lack of sufficient and accurate information and technologies to assess the potential future risk in early days (Colten, 2006). Secondly, there was minimum communication amongst planning professionals, authorities and other parties like water

managers and environmental specialists during the process of plan development. Furthermore, the modernistic idea of the makeable society in the fifties and sixties was also reflected on water management and spatial planning, resulting in mainly structural and technical solutions to flood risk.

The actual flood risk, and the most adequate strategy for coping with it, is also determined by the characteristics of and developments in the area concerned (de Bruijn, 2004). The fixed character of buildings and infrastructure makes it difficult to undo unsustainable developments from the past that add to the risk in present conditions. Radical and costly changes would be needed to adjust built environment to the actual risk on the short term. Not only such interventions would be too costly and intrusive for the community, it is defendable either.

Sanderson (2000) says that: ‘at policy level, gaps between disasters and urban planning need to be closed’. A solution to the risk issue is to adjust built environment gradually. Godschalk (2004) states that land use planning, or spatial planning in this report, has ‘the power to divert spatial development away from the most hazardous areas and/or to regulate the use of such areas, and can thus contribute to a less hazardous environment’. Burby *et al.* consider land use planning as ‘the single most promising approach for bringing about sustainable hazard mitigation’ (Burby *et al.*, 2000, referring to The Second National Assessment on Natural and Related Technological Hazards). It is clear that he role of spatial planning within flood risk management is of great relevance.

Burby *et al.* (2000) distinguish a variety of advantages for integrating flood risk mitigation into spatial planning. At first, spatial plans are formulated through participatory processes aimed at *consensus building*, the forming of a *community-wide definition* of the problem (e.g. flood risk), and the *possible strategies* to solve it are generated. Spatial planning, thus, provides a platform for stakeholder consultation. This process is essential because risk is for the greater part a judgment rather than a fact (Aven and Kristensen, 2005) and is perceived from a subjective point of view; judgment of risk can differ significantly between experts, politicians and the public (Renn, 1998; Weber and Hsee, 1998). As risk is constantly changing with socio-physical developments and changes in the context, constant monitoring and re-evaluation of the risk assessment is needed (see also Davar *et al.*, 2001). Once defined the actual problem, a review of the alternative strategies to solve it helps *resolve conflicts* and *build commitment* to the adopted policies (Burby *et al.*, 2000).
Second, plans *coordinate* community agendas, integrating risk mitigation with economic development, environmental quality, housing development, and infrastructure programming. Through this, uncoordinated actions are avoided and possible conflicts in

actions and policies are limited, offering a good chance for sustainable development in risky areas.
Finally, a spatial plan offers political and legal policy *defensibility*, and encourages public and private parties to follow the articulated strategy, enhancing the community's resilience. Spatial planning is considered to form an essential part in flood risk management practice.

The moderator's kick off speech by prof. dr. ir. de Vriend at the Aquaterra Conference in Amsterdam (2009) gave a strong impulse for further research on flood risk management strategies (de Vriend, 2009). The subsequent presentation on the Mississippi River Delta case, given by Colonel Lee, Windell Curole and David Waggonner was only a confirmation that the case of New Orleans is an important part in this.
At this conference, professionals from deltas around the world agreed on a statement that deltas should be adaptive to future changes in climate and demographics, and that this can only be done in a centrally coordinated, integral way and through good governance. Formulating a suitable comprehensive spatial plan and an integrated flood risk management strategy for the long term is part of this. This knowledge is applied and built upon in this report.

Incorporating spatial planning into a flood risk management strategy or, in reversed words; to incorporate a flood risk management strategy within built environment and the regulative institutions that shape it by use of spatial planning is an essential aspect of effective flood risk management. The integration of water management and spatial planning is a major challenge for land use planners and policy makers in delta regions (Woltjer and Al, 2007).
This thesis adds to that discussion and offers some new approaches for the application of spatial planning with the objective to reduce the socio-physical vulnerability in deltas.

1.3 Objectives

In the field of international flood risk management there are two main strategies to be recognized: the resistance strategy and the resilience strategy. Both are polarized strategies that have the same goal: protecting the socio-physical system from severe disruption, and minimizing the damage and casualties through the use of structural and nonstructural measures. In section 2.4 the advantages and disadvantages of both strategies are discussed.

The first objective of the research is to understand the *vulnerability of the socio-physical system* in order to determine the effects of floods. This analysis is done based upon literature studies and field observations, and is applied in practice to generate an insight

in the fundamental parts of a socio-physical system. If the assets of vulnerability are identified, spatial planning can focus on these critical parts in order to increase the effectiveness of a flood risk management strategy.
The second and main objective is to identify specific measures that enhance the resilience of a socio-physical system. The identified measures are clustered in several compilations to gain insight in the weight of specific measures. Based on these pre-determined clusters this report suggests a vulnerability assessment method that is applied and tested in two case studies. This generic framework for vulnerability assessment is based on literature studies contents analysis of policy and working documents, in-dept interviews with experts and professionals from various fields, and on-location analysis.
The introduction and evaluation of a '*balanced strategy*' for flood risk management is a direct result from the findings of this research. Such a strategy takes a position in between both main stream strategies, and leans over to either one of the both extremes. This balance within a flood risk management strategy is strongly dependent of the local context and can be determined particularly by the combination of structural and nonstructural measures that are being implemented in built environment.
The third objective of this study is to determine *the role of spatial planning* within the assignment of flood risk management, and to offer recommendations on how spatial planning can offer a contribution in solving flood risk challenges worldwide.

This research is concluded by a short evaluation of different approaches that can be used to bring comparable regions that are situated far apart closer together. The exchange and comparing of local experiences is considered an important part in gaining valuable information on international flood risk management.

1.4 Research Questions

To reach the objectives formulated above, a series of questions are used to guide the research. The main question encompasses all three objectives: the systematic analysis of urbanized deltas, the introduction of the balanced strategy, and the application of spatial planning in flood risk management:

How can a balanced flood risk management strategy be applied through the use of spatial and regulative measures, with the goal to reduce the vulnerability of a socio-physical system within its unique context?

By using the following sub-questions all separate parts of the main question are answered. These answers will form the basis for the final conclusion and recommendations.

Answering the first sub-question will create an insight in the two main flood risk management strategies, and how a balance can be created between both extremes, using spatial planning as a main tool. The second sub-question will focus on the analysis of the socio-physical system, often called the city or urban area of a delta:

1 a) Which indicators for resilience can be distinguished, and can those indicators be recognized within a socio-physical system of a delta?
b) How can spatial planning add to a well-considered balanced flood risk management strategy?
c) What is the role of the local physical and institutional context in the choice for a preferred strategy?

2 What are the main fundaments and the primary functions of a socio-physical delta system, and what is their role within a flood risk management strategy?

As main case study New Orleans is chosen, situated in the Mississippi delta. This case is compared to the situation in the Rhine delta (Netherlands) with the goal of comparing strategies and determining the value of the proposed vulnerability assessment method. The Mississippi and Rhine deltas are very similar in many aspects, but are both coping with a different type of flood risk making a comparison very interesting.
The similar challenges with which both case-studies are struggling offer a basis for comparison. For both deltas the solution lies in both structural and nonstructural measures that together form the preferred flood risk management strategy.

For the case studies the following sub questions have been designed:

I What is the present state of the case study, and how does the presence of flood risk affect the development process of the socio-physical system?

II To what extent is flood risk management incorporated in spatial planning in the case study area?

III To what extent can the resistance and resilience concepts be recognized within the case study, and what does this imply for the general vulnerability?

As a comparison between deltas and other flood prone regions is considered highly valuable for gaining insight and generating knowledge on flood risk management, a final set of questions aims at the differences and similarities between both cases:

3 What are the spatial and institutional disparities between the New Orleans and The Netherlands case studies?

4 Which best practices or worst failures in respect to spatial planning and flood risk management can we distinguish for both deltas?

5 What are the learning moments for both deltas, and how can they be communicated between the two?

1.5 Methodology

For answering the above mentioned research questions first a literature study is executed to place this research within the contemporary flood risk management and planning theory discussions.

In this thesis two case studies are discussed. The first is the case of New Orleans, situated in the Mississippi delta in the South of the USA. Research takes place at location in the form of a two months internship at Haskoning Inc. During this internship field observations are done, and professionals from several disciplines are interviewed (Waggonner, 209; Curole, 2009; Nance, 2009; Evans, 2009; Marchal, 2009). Additional literature research, and contents analysis of policy and working documents and research reports is done. This internship is concluded by the writing of an extensive case study report called 'New New Orleans' that is handed over to the supervisors from Royal Haskoning. The most relevant information obtained during the New Orleans internship is derived from this case study report and applied as input for this thesis to support the research.

The second case is the Netherlands. This country forms the greater part of the Rhine delta in Western Europe. The research here is done based on discussions and interviews with professionals in spatial planning and water management, a literature study and contents analysis, supplemented with information derived from a previous research on resilience in the Netherlands (Kranen, 2008).

One of the strongest factors that influence urban development is the institutional context, consisting of all stakeholders including authorities at all levels, NGOs, and other involved parties as well as the rules, regulations, legislation and cultural aspects of a society. To get a good insight in the institutional context, the power balances and extent of interaction and cooperation between involved parties are analyzed by having several interviews and discussions with representatives at all levels of authority as well as other involved parties.

In addition, some literature effort has been put in the analysis of the socio-physical system and the environmental and institutional context of the case studies. It is considered to be essential to gain full knowledge of the present situation of a case study before an opinion on future developments can be formed.

In this thesis the flood risk management assignment is studied from a *systems theory* based approach. This implies that the subject of research, the occupied delta, is approached as a complex of interconnected variables and sub-systems. The need for such a holistic view is underlined by Takeuchi (2002) who says that '…devastating floods can only be managed in a holistic manner with a wide spectrum of engineering, societal and institutional measures'.
Three more arguments found this choice. At first, the two main used strategies for flood risk management - the resistance and resilience strategies - are in essence characteristics used in ecology to define the vulnerability of ecosystems (Holling, 1973). Working with these characteristics then, as a result, is preferably done systematically.
Secondly, resilience, as used in water management, seems to be derived from the scientific discipline of 'systems ecology' (Klijn and Marchant, 2000). Since this thesis mainly focuses on the resilience of society a system's approach is preferred.
Third, the focus of systematic functional thinking lies on 'control' characteristics, in contrast with common science that mainly focuses on explanatory characteristics (Noordzij, 1977). In addition, systematic functional thinking approaches the subject of research as a whole and sees the contextual environment as a separate, but influential aspect (Kramer and de Smit, 1991); in this thesis the context is considered to be an important aspect of flood risk management as well.

In summary, the systems theory approach offers a foundation for a comprehensive and integrated analysis of flood risk management strategies in deltas, and includes the influence of the interfering contextual environment of the subject of research.

In order to get insight in the resilience of the case studies a score card is developed based on various indicators for resilience applied in flood risk management strategies. The analyses of the two cases are then used to test the proposed methods and to offer some recommendations on a preferred flood risk management strategy that considers the local contextual conditions. The recommendations are placed in the perspective of the contemporary discussion on planning theory and water management.

2 Theory

2.1 A Conceptual Approach for Delta Development

To underline the author's opinion that the socio-physical system is inseparable from its context (see also Swyngedouw, 1996; Kramer and de Smit, 1991; de Roo, 2001), and to better understand the development of deltas, it is decided to adopt a *layer approach* to describe the subject of research, which is in fact the inhabited delta in general.
The layer approach was first introduced in the Fifth Policy Document on Spatial Planning (VROM, 2001) and later adopted by NWP and Deltares (2009). Linden and Voogd have modified this approach and referred to it as the *environmental layer concept* (Linden and Voogd, 2004). This layer approach divides space into three 'physical planning' layers as visualized in figure 1.1. Adopting this approach does not only allow the description of the urban or socio-physical environment, but pays attention to the natural environment as well; which is the theoretical base layer for the socio-physical system.
Moreover, this approach offers a base for comprehensive planning in a logical order, starting at the base layer, which is the most fixed and thus should be planned carefully before switching to the next level (Figure 1.1). The usage of the three layer approach offers the potential to determine the role of the natural environment in urban development and spatial planning as a whole. This possibility turned out to be essential in understanding the historical and present developments in, for example, the New Orleans case study.

The base layer consists of *the natural system* with all its dynamics e.g. soil subsidence and marshland growth, coastal erosion and water flows. The natural system is always in some form of stable situation and is largely adaptive to changing circumstances.
Water is one of the most important component of the base layer because it influences the infrastructure and occupancy layers, both in generative (drinking water, irrigation, transport, recreation) as in threatening (drought, flooding) ways. The natural system itself is not vulnerable to flooding thanks to its extremely high resilience, although it is under high influence of the subsequent two layers instead.
The normal rate of change within this layer is between 50 and 500 years. This is translated in for example a shift of the main stream of the river, the formation of new land mass, or the erosion of coastal areas.

The second layer is called the *infrastructure* layer in this report. It consists of the total man-made infrastructure that supports socio-economic activity on the occupancy level. The speed of change within this layer is 25-100 years. Infrastructure has a 'hard' character; roads and railroads are historically fixed to their location and cannot be (re)moved without considerable effort. A problem we witness in many deltas nowadays is

ageing of infrastructure; it reflects one of the major safety issues of modern cities nowadays.
The effect of flooding on this layer is two-fold. At first it directly disrupts the functioning of the infrastructure system; for example the presence of water keeps the transportation infrastructure from functioning, affecting the occupational layer as its user. Secondly flooding can damage parts of the infrastructure layer disrupting its functioning even after the water is gone e.g. through road subsidence or a breach in the flood protection system.

The third layer is the *occupancy* or the *land and water use* layer that contains all socio-economic activities. The occupancy level is very dynamic, changing every 10 to 25 years. This layer is totally dependent on the previous two as it needs these facilities to function normally.
On this level the disruption of a flood is felt the strongest, as casualties and economic damage strongly affect the socio-physical system for a long time in terms of demographics and development. It is this layer that has to be protected by incorporating the previous two in spatial plans and flood risk management strategies.

Prof. dr. Arts (2009) suggested to add a fourth layer to this concept, the so-called policy layer. It is important to realize that all previous layers are highly influenced and shaped by the practiced development policy, local legislation, and rules and regulations that are embedded in spatial planning and national politics.
In this report this suggested fourth layer is mentioned being the institutional context.

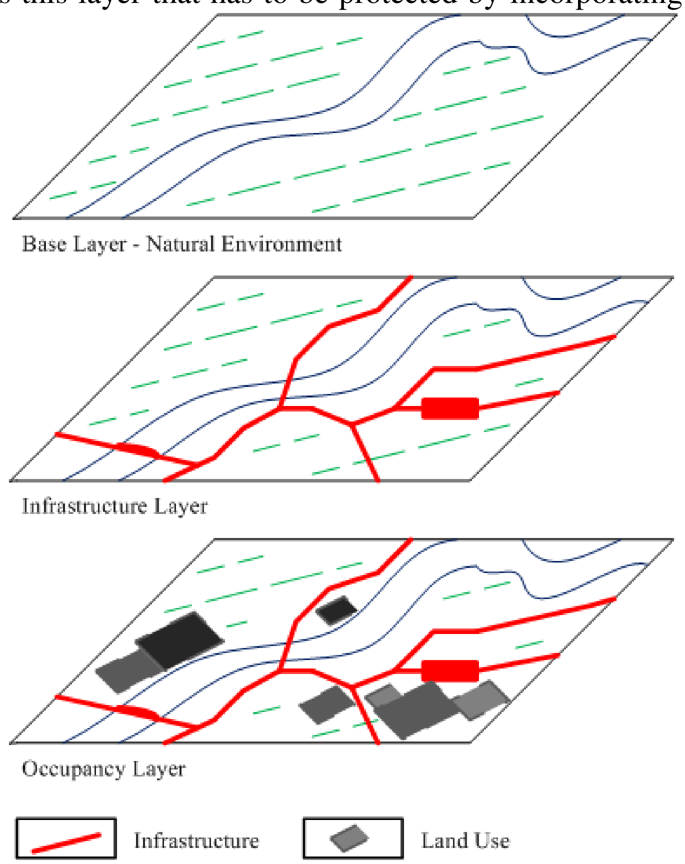


Figure 1.1: The Three Layer concept

2.2 Vulnerability and the Socio-physical System

2.2.1 *The socio-physical system*

Socio-physical systems are the complex and dynamic mix of human activities, functions and inter-relationships that are all supported by and strongly dependant on the physical environment. In this report the combination of the two top layers of the three layer concept, the infrastructure and occupancy layers, are together considered as the socio-physical system.

To be able to define the socio-physical system of a delta, it is important to set some strict boundaries and definitions. According to drs. T. van der Meulen, spoken to in preparation of this research, a city or socio-physical system has two specific kinds of boundaries; physical and administrative boundaries. For each case study both boundaries are defined to prevent vagueness and to be able to focus on that one specific area.

The ability of individuals and social systems to cope with the impact of floods is often correlated to general socio-economic indicators. Such indicators embrace general information on age, structure, poverty, gender, race, education, social relations, institutional development, proportion of population with special needs (children, elderly) and the like (Messner and Meyer, 2005, referring to Blaikie *et al*., 1994; Smith 2001). During the case studies these indicators are considered as well in order to estimate the vulnerability of the socio-physical system.

As in all systems the socio-physical system consists of many parts and sub-systems, and has a number of main functions. The system is in essence stable but constantly developing and each part is functioning as a part of the whole. The many parts of the socio-physical system are interrelated to a high degree, and are supported by and under influence of the system's environmental and institutional context. This context assures an internal balance by providing resources, physical facilities, legislation, and social norms and values to the system.

In essence the system works well if the occupancy level (section 2.1) is able to live, work and recreate in a normal manner. For this, functions as transportation, communication, commerce, industry, service and administration are essential. It is priority to protect or prepare these supporting facilities from severe disruption like flooding to assure they remain functioning, even under disturbing (high water) conditions.

2.2.2 *Vulnerability and exposure*

The increase of damage and casualties of floods worldwide is not only caused by an increase of flood hazards, but by growing vulnerability as well, mainly due to unsustainable development and rapid urbanization of flood prone areas (Barredo *et al.*, 2005; Goudarzi, 2006). This trend in world population migration (Figure 2.1) underlines the need for new flood risk mitigation strategies. Possibly 2.75 billion people will live in coastal zones by 2025, and will thus be exposed to coastal threats from global warming such as sea level rise and stronger and more frequent hurricanes (Goudarzi, 2006; IPCC, 2001).

'Vulnerability' in this thesis, in accordance with the definition used by Blaikie *et al.* (1994), is defined as the total of characteristics of a system that define its capacity to anticipate, cope with, resist, and recover from the impact of floods.
In other words, vulnerability is seen as an expression of the system's capacity to cope with and its potential to be harmed from the impact of floods (see also Messner and Meyer, 2005). Varying from an individual to community-wide scale these capacities are influenced by the physical as well as the social environments (Parker, 2000).
Hence, the actual amount of flood damage of a flood event depends on the vulnerability of the affected socio-physical system (Cutter, 1996), regardless of the severity of flooding. The same event can, thus, have differential effects on communities and even households (Blaikie, 1994; Cutter, 2003). The influence of the constantly interfering and changing context is much more decisive (see also Green, 2004).

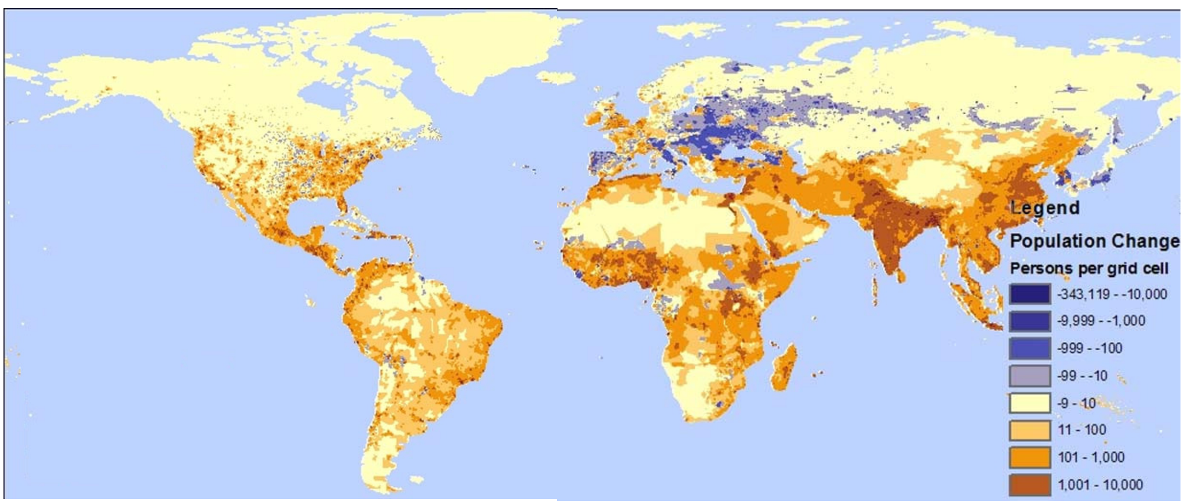


Figure 2.1: Population migration trends towards 2025. Map created by the Center for Climate Systems Research. *Source: Goudarzi (2006)*

Following the previous mentioned, flood risk management strategies should focus on reducing the vulnerability of the socio-physical system. It is the main goal to offer society the capacity to cope with external disturbances like floods by maximally reducing the potential damage and the number of casualties, and minimizing the recovery time.
In ecology the vulnerability is composed of two main characteristics, the so-called imbedded *resistance* and *resilience* of ecosystems (Holling, 1973). The combination of

those two strategies makes a biological system less susceptible to external disruptions, making them less vulnerable and more sustainable. Pelling (1999) adds a third component to vulnerability: 'Vulnerability (…) has three components; *exposure*, resilience and resistance, (… these are …) the products of political and socio-economic structures and the capacity of individual actors and social institutions to adapt…'
It is from this perspective that this thesis will approach flood risk management, although exposure is considered to be partly an outcome of the level of resistance and resilience of a community because a higher level of resistance (through a higher protection level) or resilience (e.g. through increased awareness or preparedness) reduces exposure of structures and individuals.

2.3 Flood Risk Management

The next step before the research will focus on the preferred strategy for flood risk management is to give a clear definition of risk in the context of flooding.

2.3.1 *Risk assessment*

The most commonly used equation to express risk is hazard probability multiplied by the (negative) consequences (Helm, 1996):

$$\text{Risk} = f\ (\text{Hazard probability} * \text{Consequences})$$

In addition to this classic risk assessment approach, many more definitions with other combinations of probability and consequence are available in literature (Blaikie *et al*., 1994; Green, 2004). Others say that risk is not a fixed condition or something that can be measured in hard numbers, but that it should be considered as to be a judgment or a social construction rather than a fact (Aven and Kristensen, 2005; Steinfuhrer, 2009).
This raises the question how flood risk should be approached. Flood risk can be estimated based upon statistical occurrence or extreme tide tables and by counting the economic value and lives that are at stake. It is also possible to estimate risk based upon the judgment of scientists, politicians or individuals.
When you estimate risk based on perceptions it is mainly the dread risk and the unknown risk that are influencing the call for risk reduction (Kraus and Slovic, 1988).

> 'The conventional method of risk analysis - with risk as a product of probability and consequences - does not allow for a pluralistic approach that includes the various risk perceptions of stakeholders or lay people within a given social system' (Raaijmakers *et al.*, 2008)

Taking these critics into account, it is necessary to assess risk differently within the aim of this research - reducing vulnerability of delta regions through the application of flood risk management strategies (section 1.4 and section 2.2.2).
It is needed to consider vulnerability and exposure as part of the total risk (Gwilliam *et al.*, 2006):

$$\text{Risk} = f\ (\text{Hazard} * \text{Exposure} * \text{Vulnerability})$$

The advantage of such an approach is that it allows composing a flood risk management strategy that reduces risk by either reducing the level of exposure of the region (through improving capacities) or reducing the vulnerability (through resistance and resilience increasing measures).

This divergence in risk assessment approaches goes hand in hand with a shift in flood risk reduction strategies from structural solutions towards a more adaptive approach. The former mainstream approach mainly consisted of technical interventions such as river channel modifications and embankments, and risk was approach technically, based upon statistics and calculations.
Although this structural approach is prominent in the history of flood management, it has achieved mixed success (Few, 2003). Often such solutions proved to be costly in environmental terms, or failed due to misuse, operation failure, mismanagement, malfunction, poor maintenance or changing environmental conditions. Some even exacerbated flood impacts (Blaikie *et al.*, 1994; Blackmore and Plant, 2008; Robert *et al.*, 2003).
We can clearly recognize a shift in the Netherlands, where increasing economic of the areas 'behind the dikes', the change in discharge regimes of the Meuse and Rhine rivers, and the foreseen sea levels rise provided arguments for reconsidering the Dutch strategy.
Recently the main focus of the national strategy shifted from maintaining our national embraced, often technical, strategy of offering resistance against high water levels to a more adaptive approach (Messner and Meyer, 2005; Schanze, 2002; Wiering and Driessen, 2001; NWP, 2007). The new discussion is still in its primary phase and mainly concentrates on 'key-words' as *sustainability*, *nonstructural measures, adaptation*, *integration, natural value* and, more recently, *resilience*.

There is a growing awareness amongst policy makers that a solution for the current issues is not only to be found in structural, technical measures (Vis *et al.*, 2001; Kundzewicz, 2000). Nonstructural approaches that focus for example on human adjustment, public awareness, land use controls and good governance of deltas are gaining more and more attention (Smith, 2001; Parker, 1999; Burrell *et al.*, 2007).
It seems that, in following of spatial planning (de Roo, 2001), also flood risk management is saying goodbye to the idea of the 'makeable society' and the willingness

to control. Adaptation to the dynamics of the environment in deltas is now being regarded as the key to success for sustainable development on the long term (Sanderson, 2000); there is a clear shift recognizable from flood protection to flood (risk) management (see also Messner and Meyer, 2005).

2.3.2 *Flood Risk Management Strategies*

Flood risk management involves all activities that enable an area to maintain or improve the way it copes with flood waves, storm surges, peak discharges or excessive rainfall (de Bruijn, 2004; Parker, 2000; Smith, 2001). There are many different measures to consider for flood risk management in urbanized deltas (Roggema, 2008; Parker, 2000; Few, 2003; Takeuchi, 2002). For example, authorities can reserve space for water, restrict city expansion into flood prone areas, or flood-proof buildings and infrastructure. Other measures can be raising the awareness of the public, offering financial support (e.g. insurance or funding), monitoring weather events, and organizing emergency exercises.

Raaijmakers *et al.* (2008) see one clear choice for delta authorities: they have to make a choice between a voluntary agreement of limited economic consequences with a high damage probability on the one hand, and protection by flood defense structures with a small probability of failure on the other.
This polarization is too restrictive for the wide array of measures available for flood risk management, since protection does not inherently imply a smaller risk and not building defensive structures does not inherently imply high damage probability.
Robert *et. al.* (2003) see the presence of flood defensive structures as being a trigger for an increase in influx of socio-economic activity and values in a flood prone area, actually increasing the potential risk. In other regions it is the absence of defense structures that made society adapt to floods, reducing damage during these regular events (NWP and Deltares, 2009; Chan and Parker, 1996).

As mentioned before, each community adopts its own strategy to cope with flood risk (see also Blaikie *et al.*, 1994), based upon and influenced by the local contextual conditions. While comparing different delta regions across the globe, Oosterberg *et al.* recognize three main strategies to deal with the conflict between urbanization - in this thesis referred to as the socio-physical system - and flood risk (Oosterberg *et al.*, 2005). These three applicable approaches are:

1. Keeping flood away from the urban environment
2. Preparing urban environments for flooding
3. Keeping urban environment away from flooding

The first strategy can, because of its defensive characteristics, be seen as a resistance strategy that is based on mainly structural measures within the scope of this study. The second mentioned strategy is comparable to the resiliency approach as it focuses on adaptation.
The latter one, although it is the most effective one in reducing flood risk, is the hardest strategy to implement. Main reasons for this are that many cities are already located in flood prone areas and urbanization processes are particularly difficult to steer. In addition, relocating cities is generally considered too costly and too complicated (Mitchell, 1999). Installing non-development policy in flood prone regions might be a successful way of implementing the third approach mentioned by Oosterberg *et al.*, but in many cases it proved to be very difficult to maintain such a policy. Still, land development regulations can prevent areas from urbanization, as is shown for example in the Netherlands where *the green* heart is still open, while situated in the *fringe city* ('de randstad'), a region under high urbanization pressure.
Summarizing the three main strategies suggested here: offering resistance, upgrading resilience, and moving away from flood prone areas. In this report a combination of the three is proposed, considering the latter one as part of the resilience measures because it can be implemented through nonstructural, regulative tools and does not aim at flood control.

2.4 Resistance and Resilience

In the past the Dutch mostly lived on high grounds to protect themselves from floods. But as population and demand for space grew by the hands of economic development they built dikes, weirs and sluices to prevent flood waters to enter their lands. This strategy has proven to be effective for a long period in history, but it also showed its weakness at other moments.
After the flood of 1953 in the Southwest of the Netherlands a technical rational approach to establish safety levels was adopted; a perfectly normal reaction to crises (de Roo, 2009). The desired safety level was defined as the acceptable probability of flooding, i.e. dike heights should exceed water levels related to a discharge with a certain occurrence probability, the so-called 'design discharge' (Committee River Embankments, 1977).
River controlling and the construction of embankments and levees are measures that aim to reduce the flood hazard, or in other words, the frequency of flooding. Flood risk management strategies based on this approach are called *flood control* strategies or resistance strategies.

Another strategy to lower flood risks, instead of reducing the flood magnitude, is minimizing the consequences of flooding. In this approach flooding is allowed in certain areas, while at the same time the adverse impact of flooding is minimized by adapting the land use pattern and by applying nonstructural measures. Such strategies are called 'resilience strategies'. They rely on adaptation, coping capacity and flood (risk) management instead of on flood control (Blaikie, 1994; Few, 2003; Takeuchi, 2002).

As flood risk management is all about reducing vulnerability, the main goal can be considered to be strengthening the socio-physical system by upgrading its resistance or resilience or limiting its exposure, or both. The new paradigm for flood risk management specifically includes the economic analysis of costs and benefits[1] of flood protection and mitigation measures. Here, not only the safety of a defense system and its associated costs are considered, but also the damages to be expected in case of its failure (Sayers *et al*., 2002; Schanze, 2002). These damages can be reduced by upgrading the share of resilience based measures in a flood risk management strategy and of the socio-physical system as a whole. As Roger Few (2003) states:

> 'Further theoretical and applied research is important to understand the nature of impacts, people's perceptions of the risk, their responses and the means to strengthen their coping capacity as a complement or alternative to structural means of flood mitigation.'

2.4.1 *The Pros and Cons*

Both of the previously mentioned resistance and resilience strategies have their advantages and disadvantages. These aspects are discussed shortly for the both of them.

The main advantage of the classical resistance strategy is that it prevents water from entering a city, protecting it from any disturbance or damage, or at least reducing the probability of a flood (Burrell *et al.*, 2007). The level of protection can be calculated and 'built', offering a direct, physical and psychological result. Despite of these well appreciated advantages this strategy has many disadvantages as well. Most of them are mainly linked to the sense of safety that flood protection structures evoke:

1.) Conventional (structural) risk reduction measures carry the assumption of predictability whereas the empirical reality is that defense systems are inherently unpredictable because it is interlinked with other systems (e.g. the socio-physical system, the communication system, the natural environment). The performance of the strategies relies on the interaction with the surrounding and interconnected systems, rather than on the physical stability of its components (Blackmore and Plant, 2008; Hollnagel *et. al.*, 2006). Technical, resistance-

[1] In calculating possible damage caused by floods, also benefits should be included as floods may increase agricultural production by fertilizing lands, and sometimes offer the potential to trigger a more sustainable recovery and rebuilding of society, possibly generating a more effective and beneficial situation in the post-flood period. See also the part on 'ecology resilience' in section 2.5.3.

based structures do not calculate in malfunctioning, misconstruction, misuse, or operational failure.

2.) Another major disadvantage of a resistance strategy is that if the line of protection fails, a sudden and uncontrolled flood will occur in the area that was assumed to be well protected (de Bruijn, 2005), and thus had no incentives to minimize the vulnerability of a socio-physical system to flooding by appropriate land use planning (Vis *et al.*, 2003). This happened in many cases already, with the failure of the levees in New Orleans in 2005 as an extreme example.

3.) Because levees create a common sense of safety little attention is given to the consequences of possible floods. As a result of socio-economic development, the exposure to loss increases when a protection system is put in place (Takeuchi, 2002; Robert *et. al.*, 2003; Burby *et al.*, 2000). The resistance strategy creates a sense of safety, explaining the large investments that are being made in highly flood prone areas. As a consequence the socio-economic value at risk of flooding increases rapidly while inhabitants and local governments may not be fully prepared for floods (Kundzewicz, 2000; Vis *et al.*, 2001).

4.) The recovery time of a socio-physical system that is protected by a resistance strategy is most likely to be longer than when a resilience strategy is used (de Bruijn, 2005). Structural damage to infrastructure and buildings that are not adjusted to potential flooding may slow down the pace of recovery, and damage to communication and power lines can severely disrupt each recovery effort and may increase the potential damage and the number of casualties.

5.) In calculating levee or dike strength and height, one design discharge is applied for a whole area or dike ring, implying that all land use types, e.g. residential area, industries, infrastructure, agricultural areas and nature reserves, have the same probability of flooding.
In addition, applying only one safety level contains the uncertainty which area will be flooded once the design discharge is exceeded or fails. Because all areas theoretically have the same probability of flooding, a large area must be evacuated in case of flood threat.

6.) Resistance strategies cause an endless need for maintaining, monitoring, strengthening and improving the water defense structures, further restricting the natural dynamics of a delta system.

Despite these disadvantages, resistance strategies have proved to be very popular. This is reasonable when we realize that offering resistance can work out fine for a very long period, while costs and implementation time of the technical measures are often limited.
A resilience strategy, on the contrary, offers less protection from the beginning, and damage may occur directly at the start of the high water event, increasing as flood severity does. This strategy has some advantages as well:

1.) Although the consequences increase with flood severity, they are likely to be limited because of the level of preparedness of the socio-physical system. Due to the flexible and adaptive character of resilient cities, people and property are safer when the resilience is high (see also Godschalk, 2002).

2.) In risk reduction recovery time plays a crucial role. The sooner the socio-physical system recovers from disturbance and reaches its new situation of stability, the lower the damage. Here resilience is a determinant aspect, since it is 'as a measure of the speed of recovery from an unsatisfactory condition' (Hashimoto *et. al.*, 1982).

3.) An important aspect is that a resilience strategy calculates in, and copes with a certain level of uncertainty (Godschalk, 2002). A socio-physical system consists of highly dynamic and complex parts, relations and processes, while the context plays an important role as well because of the openness of the system.
These characteristics, combined with the unpredictability of climate behavior, cause many uncertainties (see also de Roo, 2001) about the risk and the possible consequences when disaster strikes. Adaptive measures are crucial for tackling this uncertainty (Kundzewicz, 2002).

4.) A resilient community is not tied to a specific development pattern. The embedded flexibility allows responding to sudden changes and to the unique conditions of a locale (Godschalk, 2002).

As shown above, both approaches have their pros and cons. The theoretical reaction of a socio-physical system that applies either one of the both strategies on a severe disruption such as a flood event are reflected in figures 2.2a and 2.2b.
The resistance strategy offers full protection for a long time, but potentially induces major damage and a high number of casualties when the so-called threshold is reached, or failure occurs (Figure 2.2a). Research shows that heavy investment in structural measures reduces the total death toll caused by flooding, but at the same time increases economic losses (Takeuchi, 2002; Kundzewicz and Takeuchi, 1999).

The resilience strategy initially offers no protection and the damage increases along with flood severity. But, the eventual damage is most probably lower since people in such an 'open' environment are more aware of the risk, and adapted to it. After the peak inundation water leaves the city and damage and recovery time are minimal because of the level of adaptation and preparedness of the socio-physical system, as is shown in figure 2.2b. The Department of Human Services, quoted in UNU-EHS, (2006) states that 'the higher the resilience, the less likely damage may be, and the faster and more effective recovery is likely to be.'

The eventual consequences can, thus, be influenced by the chosen strategy. It has to be mentioned, though, that the local environmental context is an important determinant in the design and composition of a flood risk management strategy, while the institutional context plays an important role in the applicability of the preferred strategy. Whatever the strategy may be, the context should always be considered to ensure it is effective (see also Green *et al*., 2000).

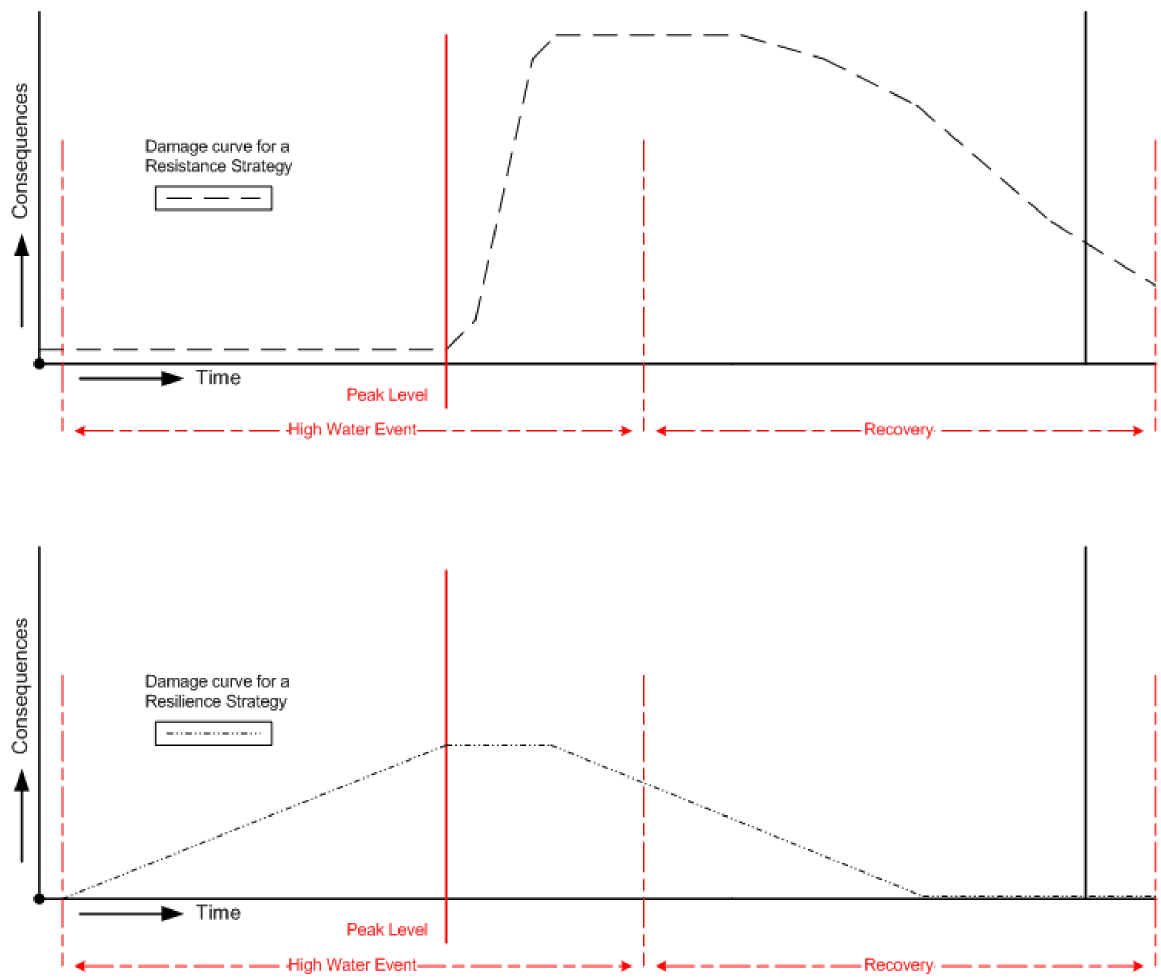


Figure 2.2a en 2.2b: A reflection of the moment and extent of occurrence of negative consequences of a flood event, and the recovery time afterwards when using a resistance strategy (a) and a resilience strategy (b)

2.4.2 *A Balanced Strategy*

Taking the characteristics and the pros and cons of the previously discussed two main strategies into account it might be valuable to combine them in order to collect the best aspects of both in one strategy. The US Army Corps of Engineers draws the same conclusion in their study on the coastal restoration and protection of South Louisiana: 'While structural components of the system are intended to provide a reduction in damages from storm surges, a complementary system of nonstructural measures can facilitate post-storm recovery in the event that the structural components are exceeded.' (USACE, 2009)

Because the risk of flooding has many uncertainties, systems should be made resilient to the unknown rather than reliable against the known (Blackmore and Plant, 2008). Focusing on reliability is not enough anymore, as experience from, for example, Japan showed (Kundzewicz and Takeuchi, 1999).
A combination of structural and nonstructural, or technical and nontechnical measures is preferred (Kundzewicz, 2002). In addition to this, recent research and experience prove that the focus of the chosen strategy should be on increasing resilience of the socio-physical system (e.g. de Bruijn, 2005; Blackmore and Plant, 2008; Klijn and Marchant, 2000; Remmelzwaal and Vroon, 2000; Roggema, 2008; Vis *et al.*, 2001)

An approach that combines both strategies theoretically offers resistance to disruptive water events and ensures that the socio-physical system is adapted to the possible occurrence of such an event, resulting in a minimization of the ultimate consequences. In figure 2.3 the damage curve of this balanced strategy is displayed.
Theoretically this strategy is applied to such an extent that the initial damage of a flood event only occurs when the first line of defense gives way. In other words: damage occurs when the peak water level exceeds the threshold value of the defensive measures.
After breaking the structural defensive measures damage increase will be almost equal the flood increase because the socio-physical system is adjusted in such a way that it can receive flood waters now and then.
When the inundation period is over, the recovery time will be limited to a maximum since people, buildings and critical infrastructure did not suffer severe disruption. In the end, the socio-physical system preserves its major functions and attributes, and returns to a new state of (post-flood) stability from which it develops further in a normal way.

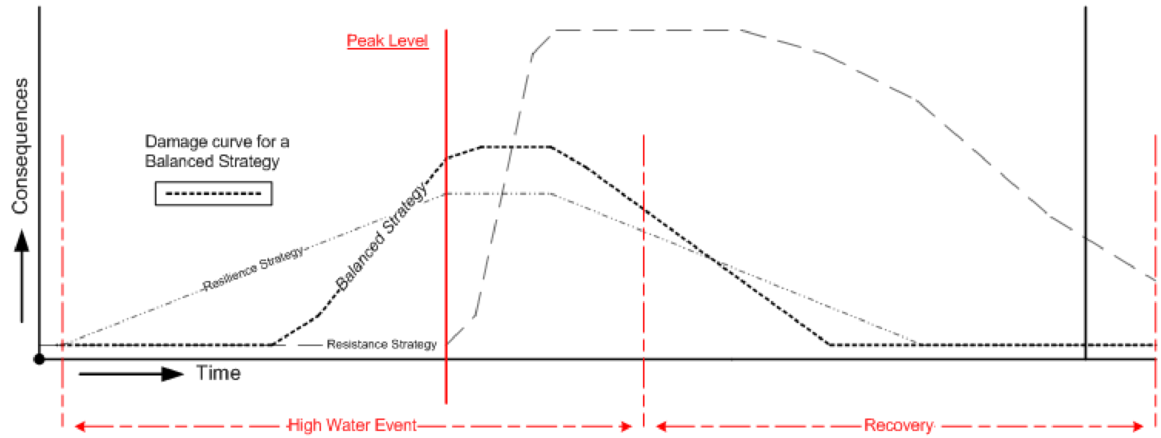


Figure 2.3: A comparison of the speed and extent of negative consequences and the recovery time after a flood event when using a balanced strategy

The major gain of this approach is that society is aware of and adjusted to the possible occurrence of flood events. Offering a full protection, which is technical almost impossible, is in this case not necessary. As shown before, heavy investments in defensive measures will eventually only lead to a higher economic loss potential, while investments in nonstructural measures potentially further reduce the risk.

In theory flood prone areas should search for a balanced strategy that combines both resistance and resilience measures, as this approach offers the best means to reduce vulnerability and to cope with the uncertainties of flood risk in general. According to Kundzewicz:

> 'As flood safety cannot be reached in most vulnerable areas with the help of structural means only, further flood risk reduction via non-structural measures is usually indispensable, and a site-specific mix of structural and non-structural measures seems to be a proper solution.' (Kundzewicz, 2002)

The actual balance between resistance and resilience should depend on the local environmental conditions and socio-economic characteristics. To make a flood risk management as effective as possible, the balance within a flood risk management strategy is either more on offering resistance through structural measures or on increasing resilience by investing more in nonstructural measures, depending on the local conditions (Green *et al.*, 2000). This role of the local contextual situation is elaborated in section 3.2.

3 Operationalization of resilience

3.1 Scoring Deltas on Resilience

3.1.1 *Resilience as a set of system attributes*

Earlier it was showed that relying on a resistance based strategy alone is not sufficient for effectively reducing flood risk (see also Kundzewicz, 2002). Godschalk (2002) says that 'A city without resilient physical systems will be extremely vulnerable to disasters.' From that perspective the attention of this thesis now shifts to resilience. Resilience is considered to be an important part in a flood risk management strategy, and essential to cope with the complex contexts and uncertainties that are inextricable with flood risk.

Since the resistance and resilience concepts are typically characteristics of ecosystems (Holling, 1973; 1996), human society has to be considered a system as well (de Bruijn, 2004). Human society can be described as a 'coupled' system of people and nature, termed a *socio-ecological system* (Blackmore and Plant, 2008). In this report is chosen to approach the human system as a complex *socio-physical system*, situated in a specific environmental and institutional context.
In both approaches resilience of the system is seen as the key to a sustainable situation. However, as Blackmore and Plant (2008) say: in spite of 30 years of scientific analysis and debate, no consensus on how to operationalize resilience has been reached.

In this thesis resilience is used more as an overarching term for a set of desirable system attributes, rather than a system attribute itself. In this chapter these resilience attributes are identified and put into a score card, based upon which deltas can be scored on their level of resilience. This is done to further test the theory used in this thesis to practice, and to develop a method for interpreting specific situations.

3.1.2 *Structural and nonstructural measures*

Flood risk reduction measures that are assigned for reducing flood *probability*, are generally denoted as structural measures, whereas measures taken for reducing *potential damage* are generally known as nonstructural measures (Few, 2003; Parker, 1999). The latter are characterized by an aspiration to accommodate water in our environment through e.g. better land use planning.
The application of flood risk mitigation measures is gradually shifting from structural to nonstructural actions, underlining a change in focus from resistance to resilience in flood risk management strategies (Vis *et al.*, 2003). In this sub-section the distinction between structural and nonstructural measures as given by, for example, Kundzewicz (2002) will

be applied for determining indicators of resilience. Therefore it is necessary to provide a clear description of both sets of measures.

In general, structural measures are described as technical, protective measures, applied to prevent an area from flooding (Smith, 2001). Structural measures can be found in every flood prone region in the world. They are a crucial, and until recently the only, part of a flood risk management strategy. In Kuala Lumpur, Malaysia, major concrete water diversion channels cross the city (Kranen, 2007), and the Netherlands and New Orleans are protected by dikes, levees and floodgates along the rivers and coastal zones. Other structural measures are sluices, dams, river channel modifications, storage reservoirs and barrages.
Structural measures are often applied based on a statistical flood hazard occurrence and offer robust, resistant lines of protection to extreme weather events. Structural measures have a rather intrusive, long term character, something that does not entirely fit with the contemporary general aspiration of sustainable development. These characteristics are one of the reasons that we witness the shift towards nonstructural measures nowadays. According to Kundzewicz:

> 'Following the most common interpretation of sustainable development, one should not choose flood protection policies that could be rated by future generations as inappropriate options of flood defense. This is how several large structural flood defenses are often viewed. Non-structural measures are in better agreement with the spirit of sustainable development, being more reversible, commonly acceptable, and environment-friendly.' (Kundzewicz, 2002)

Nonstructural measures typically refer to measures designed for reducing short and long term impacts of a flood (Few, 2003). They vary from warning systems, evacuation programs, public awareness campaigns, flood hazard exercises and insurance schemes on a macro-scale, to land use regulations, and adjustments and actions such as home elevation at the community or household (micro-) scale. Nonstructural measures mainly focus on the adaptation of the socio-physical environment to the present risk. Here, water is made part of daily life by interweaving it in the socio-physical environment. Nonstructural measures enhance awareness and preparedness of individuals, groups and society.

In this terminology of measures I would like to mention the distinction used by several authors between so-called hard- and soft-structural measures (Kundzewicz, 2002). The reason for this is that the latter, although they often have a technical, structural nature, take into account the potential inundation and seek to adapt physical environment to that possibility. From this point of view soft-structural measures can be put in line with the previously mentioned nonstructural measures. Realizing this is essential for the identification of resilience indicators in a socio-physical system.

3.1.3 *Identifying resilience*

In this sub-section several indicators are identified that are known as clear attributes of resilience. First the resilience principle and its components are further elaborated upon, after which the identified measures are listed and then clustered in several ways in order to obtain insight in the possible types of measures.

One can say that a society is less vulnerable to floods when they are prepared. The community is resilient if it has taken measures to minimize the negative effects of inundation. Preparedness can be both the *capacity of coping* with a flood during an inundation period, and post-flood *recovery capability* (van der Veen and Logtmeijer, 2005; Floodsite, 2006), the same characteristics that are attached to resilience (de Bruijn, 2005).

In general, coping capacity involves managing people, organizations, and resources, both in normal times as well as during crisis or adverse conditions. The strengthening of coping capacities builds resilience to withstand the effects of natural and human-induced hazards (UNISDR, 2009).

The resilience attributes *recovery capability* and *coping capacity* are further elaborated below, using reference to engineering resilience and ecology resilience as a basis.

Holling (1996) mentions the difference between *engineering resilience* and *ecology resilience*. According to engineering resilience (Pimm, 1991, referred to by Blackmore and Plant, 2008) ecosystems always exist close to a stable steady state. Resilience is then *the time a system needs to turn back to a new stage of stability* after disruption - recovery capability. According to ecology resilience, this new stable situation is generally not similar to the original state as development and evolution continue throughout the disruption period, although the most important characteristics will remain.

Ecology resilience emphasizes *absorption* and *adaptive capacity* as important characteristics to cope with disturbances, in other words: coping capacity is constituted of absorption and adaptive capacity (UNEP, 2002). I therefore consider these capacities as an important parts of socio-physical resilience. In preparation of the 3rd World Water Forum (WWF3), the water community backed up this point of view by stating that upgrading (inter)national capacities is crucial for sustainable development:

> '(… This critical water development process …) is a process that must be sustained and financed for the long term and undertaken in a holistic and integrated manner and therefore a new global strategy for capacity building needs to be developed.' (WWF3 Secretariat, 2002)

Absorption capacity

In literature absorption is seen as the capacity of the socio-physical environment to absorb the initial phase of disruption - in this case a high water event. We can distinguish two aspects that determine the absorption capacity of a socio-physical system: the physical environment and social characteristics.

Physical measures that enhance absorption capacity are, for example: green/infiltration areas, drainage and sewerage capacity, emergency flood storage areas, wetland protection and restoration, and additional 'room for water measures' (Commissie Luteijn, 2002; V&W, 2004; DEFRA, 2007; Oosterberg *et al.*, 2005).

Adaptive capacity

Adaptation is made up out of mid and long term actions throughout society, by individuals, groups and governments (Adger *et al.*, 2005). Adaptive capacity can also be seen as the capacity of actors in a system to influence and manage resilience (Blackmore and Plant, 2008), or as the capacity to learn from experience and the flexibility to be able to change when preferred (Godschalk, 2002). This report distinguishes 'social adaptive capacity' and 'physical adaptive capacity'.

An example of social adaptive capacity is the availability of possibilities to facilitate a fast recovery and reorganization of the socio-physical system after disturbance by flooding. Here, local power and *governance structure*, *organizational qualities*, and public and stake- and shareholders *involvement in decision-making* are seen as important aspects of adaptive capacity. These qualities are also necessary to implement regulations and legislature to mitigate flood risk (Godschalk, 2002). Examples are land use changes, building restrictions and monetary investments in safety measures (Raaijmakers et al. 2008).

Adaptive capacity is for a greater part determined by social factors. With social factors you can think of, for example, *social networks* that offer a buffer in case of emergency, *political (in)stability*, *living standards* or *demographic characteristics*. These characteristics are hard to influence as part of a flood risk management strategy, and are therefore seen as part of the context that determine the preferred measures within the strategy.

Adaptive capacity can be enhanced by physical measures as well. According to Deltares and NWP, adaptation in densely populated deltas may include infiltration areas, increasing retention capacity, or multifunctional land use, e.g. giving a water storage function to nature or recreational areas (NWP and Deltares 2009; Oosterberg *et al.*, 2005). These types of adaptive measure enhance absorption capacity as well, indicating that there is a certain overlap between the both. Other physical adaptive measures are, for example, building emergency shelters, flood proofing objects, and hardening or elevating infrastructure.

It has to be mentioned that many of the adaptive measures are reactive - triggered by past or current events (van Heerden *et al.*, 2006; Kranen, 2009; Adger *et al.*, 2005) - but more attention should be given to adaptation in the proactive or anticipatory sense (see also Godschalk, 2002; Burrell *et al.*, 2007).
A proactive attitude in especially land use planning and amongst policy makers offers many opportunities for incorporating flood risk mitigation measures into built environment, without the need for radical physical interventions. In this perspective a progressive society might prevail over a conservative one.

Information provision

Earlier it was argued that risk can be mitigated for the greater part by increasing public and political awareness (see also Burrell *et al.*, 2007). Teaching the city's social communities and institutions must be part of future mitigation programs (Godschalk, 2002). Measures and actions that increase awareness are for this reason seen as indicators for resilience.
Communication, *cooperation* and *public information* are key words here, as is underlined by Raaijmakers and his colleagues (Raaijmakers *et al.*, 2008). In their article they explain that awareness of the risk is an important aspect that determines preparedness, and thus, adaptation to that risk (see also Kraus and Slovic, 1988). Awareness increases when information and *education* about the hazard is more widely available (see also: Slovic and Weber, 2002; Renn, 1998; Godschalk, 2002).

Financial measures

Resilience can be increased through monetary measures as well. *Flood insurance* and/or damage *compensation funds* (e.g. FEMA, 2009; DIW, 2003; Schwarze and Wagner, 2002; Nussbaum, R., 2004) are effective measures to provide a financial buffer and to increase awareness amongst local inhabitants, and to offer fall back options in times of crisis.
Insurance can also be used as an incentive for sustainable development in floodplains. For example, in the USA the National Flood Insurance Program offers rate reduction for communities with floodplain management plans, based on a Community Rating System. FEMA provides a variety of incentives and physical assistance to communities to implement hazard-mitigation measures, often based on flood maps.

Creating a high level resilience comprises more than land use changes and physical adjustment. It is essential to invest in social and institutional capacity to anticipate, adjust to, and deal with the consequences of floods as well.
In figure 3.1 an overview is given of the identified indicators for resilience, categorized by the type of measure. These measures are derived from an extensive literature review using the above explained terminology. In addition, several interviews and discussions

with experts from the water management and land use planning professions are used as a frame of reference to ensure the completeness of the list of identified measures[2]. In the following sub-sections these resilience measures are clustered and used as input for a qualitative and quantitative analysis design that is tested for two case studies.

Nonstructural regulative
- Maintenance of defensive structures
- Flood risk maps / policy
    - Laws and legislation
    - Building codes
    - Land use regulations
    - Zoning / designation

Nonstructural financial
- Flood damage mitigation incentives
- Non-development incentives
- Relocation incentives / buy outs

Information and communication
- Flood forecasting system
- Flood warning system
- Flood risk assessment models
- Flood-related data-bases
- Public information / awareness
    - Media campaigns
    - Education
    - Neighborhood projects
- Cultural aspects / habits
    - Individual preparedness
    - Swimming lessons
    - Emergency stock (household)
- Emergency exercises
- Evacuation schemes

Adaptation measures
- Wet flood proofing
    - Interiors
    - Public functions
    - Public utilities
- Dry flood proofing
    - Industrial facilities
    - Commercial facilities
    - Secondary embankments
- Emergency shelters
- Structure elevation
- Floating structures
- Hardening critical infrastructure
    - Elevation
    - Wet flood proofing
    - Dry flood proofing

Absorption measures
- Drainage capacity
- Separate sewer system
- Urban infiltration areas
- Multiple land use areas
- Urban retention areas

Post-flood relief
- Flood insurance
- Damage compensation regulations
- Disaster aid organization
- Disaster aid instruments / material

Figure 3.1: Overview of the identified measures that will be used as indicators for resilience ordered by type of measure

3.1.4 *Clustering indicators*

Now the main measures and actions that enhance the resilience of the socio-physical system are collected and ordered, a score table can be created based upon which deltas can be scored on their level of resilience.
To keep the amount of information within workable limits it is preferred to create clusters of measures. I propose two ways of clustering the indicators. These are described below.

[2] The composed list contains generic resilience measures that can theoretically be applied in any given delta region. Additional measures like wetland protection and restoration are considered but not included as they apply only to specific delta environments.

The first set of clusters combines the measures that determine: (1) the effectiveness of Pre-flood mitigation and life-saving actions; (2) the economic and physical damage during Inundation, and; (3) the pace and effectiveness of Post-inundation socio-physical revitalization. The focus here lies on *chronology of the event* (Figure 3.2).

Using this set it is possible to determine whether the designed flood risk management strategy is strong on prevention, impact mitigation or recovery capability. This perspective can give an indication on which part of the chronologic flood event is covered best, and on where additional measures and actions may be needed in order to create a healthy balance.

It is important to realize that all applicable measures are more or less decisive for the damage and loss magnitude caused by a flood event, and for the recovery pace and effectiveness afterwards. For this reason, every distinction made in the chronology of event-related actions is debatable as they all apply on the event itself.

Pre-flood
- Maintenance of defensive structures
- Flood risk maps / policy
    - Laws and legislation
    - Building codes
    - Land use regulations
    - Zoning / designation
- Flood mitigation incentives
- Non-developments incentives
- Relocation incentives / buy out
- Flood forecasting system
- Flood warning system
- Flood risk assessment models
- Flood-related data-bases
- Public information / awareness
    - Media campaigns
    - Education
    - Neighborhood projects
- Evacuation schemes
- Emergency exercises

Post-inundation
- Flood insurance
- Damage compensation regulations
- Disaster aid organization
- Disaster aid instruments / material

Inundation
- Cultural aspects / habits
    - Individual preparedness
    - Swimming lessons
    - Emergency stock (household)
- Drainage capacity
- Separate sewer system
- Urban infiltration areas
- Multiple land use areas
- Urban retention areas
- Wet flood proofing
    - Interiors
    - Public facilities
    - Public utilities
- Dry flood proofing
    - Industrial facilities
    - Commercial facilities
    - Secondary embankments
- Emergency shelters
- Structure elevation
- Floating structures
- Hardening critical infrastructure
    - Elevation
    - Wet flood proofing
    - Dry flood proofing

Figure 3.2: The indicators for resilience, clustered on place in the chronology of a flood event

The second possible set of clusters identifies several *disciplines* that can undertake actions to enhance resilience. Here the indicators are divided amongst (1) Water management, (2) Spatial planning, (3) Public / private developers, and (4) National security.

The perspective chosen here offers insight on where responsibilities lie for undertaking specific measures, and on which profession might undertake more concrete actions to enhance resilience (Figure 3.3). It is clear that coordination, communication and extensive cooperation is essential.

Logically, a combination of all thinkable measures would maximally reduce the vulnerability of society. Unfortunately such an ideal situation is not possible due to the institutional and environmental context, the socio-cultural and demographic characteristics of the object of research, and the characteristics of the hazard itself.

Spatial planning
- Flood risk maps / policy*
  - Laws and legislation
  - Building codes
  - Land use regulations
  - Zoning / designation
  - Secondary embankments
- Emergency shelters
- Non-developments incentives
- Relocation incentives / buy out
- Multiple land use areas*
- Urban retention areas*

Public / Private developers
- Wet flood proofing
  - Interiors
  - Public functions
  - Public utilities
- Dry flood proofing
  - Industrial facilities
  - Commercial facilities
- Structure elevation
- Floating structures
- Hardening critical infrastructure
  - Elevation
  - Wet flood proofing
  - Dry flood proofing

Water management
- Maintenance of defensive structures
- Drainage capacity
- Separate sewer system
- Urban infiltration areas
- Multiple land use areas**
- Urban retention areas**

National security
- Flood forecasting system*
- Flood warning system
- Flood risk assessment models* **
- Flood-related data-bases
- Public information / awareness*
  - Media campaigns
  - Education
  - Neighborhood projects
- Evacuation schemes
- Cultural aspects / habits
  - Individual preparedness
  - Swimming lessons
  - Emergency stock (household)
- Emergency exercises
- Flood mitigation incentives* **
- Flood insurance
- Damage compensation regulations
- Disaster aid organization
- Disaster aid instruments / material

* In cooperation with Water management ** In cooperation with spatial planning

Figure 3.3: The indicators for resilience, clustered by responsible disciplines

3.1.5 *Methods for further analysis*

For every single case each of the identified indicators is given a score by estimating the investments to be low, weak, marginal, good or strong, based on the information obtained during the case study. This classification implies that the weight is multiplied by one fifth if the investments are estimated to be low, two fifth if the investments are weak, and so on.
The eventual outcomes of the following analyses are highly influenced by this process of scoring. For this reason the scoring of the New Orleans case is done based on field observations and interviews during a two month internship and on an accurate descriptive analysis of scientific literature and working and policy documents in addition to that. For the case of the Netherlands seven experts from various relevant disciplines are asked for their opinion in addition to a literature study and policy documents analysis. Through this it is ensured that the scores approximately represent the real situation of both cases.

It is possible to use the identified and clustered indicators to analyze any given socio-physical delta system. This can be done in two ways.
The first is a *qualitative* analysis. For this an inventory needs to be made of all measures that are taken in a delta. By looking at the specific characteristics of a measure, and in what moment in the chronology of a flood event it is effective, it is possible to see what additional type of measure might be needed in a given situation. For this method the sum of weights per type of measures or place in the chronology counts up to one hundred percent, enabling clarification of the results and the visualization in a score card.
In figure 3.4 an example of this method for creating a score card with *chronology clusters* is shown.

Second, a *quantitative* analysis can be used to determine the effectiveness of certain measures by running a so-called sensitivity analysis.
To be able to obtain representative information, all indicators need to be given a specific *weight*. Although it is realized that allocating weights is always arbitrary (de Roo and Voogd, 2004), there should be some level of distinction between the several attributes.
In order to obtain an accurate view on the relative importance of the indicators it is decided to do two sets of runs with different weight sets, both based upon five different assumptions.
These assumptions are the following. (1) Information gathering and communication is the basis for effective flood risk management; (2) Law, legislation and spatial planning offer long term sustainability; (3) Focus should be on non-physical, resilience enhancing measures; (4) Public efforts are more important than private efforts, and; (5) Information provision and spatial planning are the fundaments of sustainable development.

The weight sets connected to these assumptions are named:

(1) *Information Provision and Education*;
(2) *Law, Legislation and Spatial Planning*;
(3) *Non-physical measures*;
(4) *Public efforts,* and;
(5) *Information Provision and Spatial Planning*.

In the first set of runs the distinction made in the valuation of measures is expressed in a weight allocation of one, two or three, with 'three' being the highest valued measures in the first set of runs. To find out more clear differences the second set of runs divides a total weight of ten among the various measures, with the least important type of measures given a weight of one, and the most important type of measure given a weight of five or six.
The resulting tables of the sensitivity analysis are displayed in Appendix A (A-2 to A-6).

3.1.6 *Schematic Reproduction of resilience in Deltas*

Both the qualitative and the quantitative methods for scoring case studies allow analyzing and determining the resilience of a socio-physical delta system. Based on the set of indicators one can tell to what extent measures are applied to e.g. reduce vulnerability of the community during inundation, or what discipline is responsible for taking a specific type of measure.
In Chapter four the outcomes of the analysis of the New Orleans (section 4.1) and the Netherlands (section 4.2) case studies are discussed.

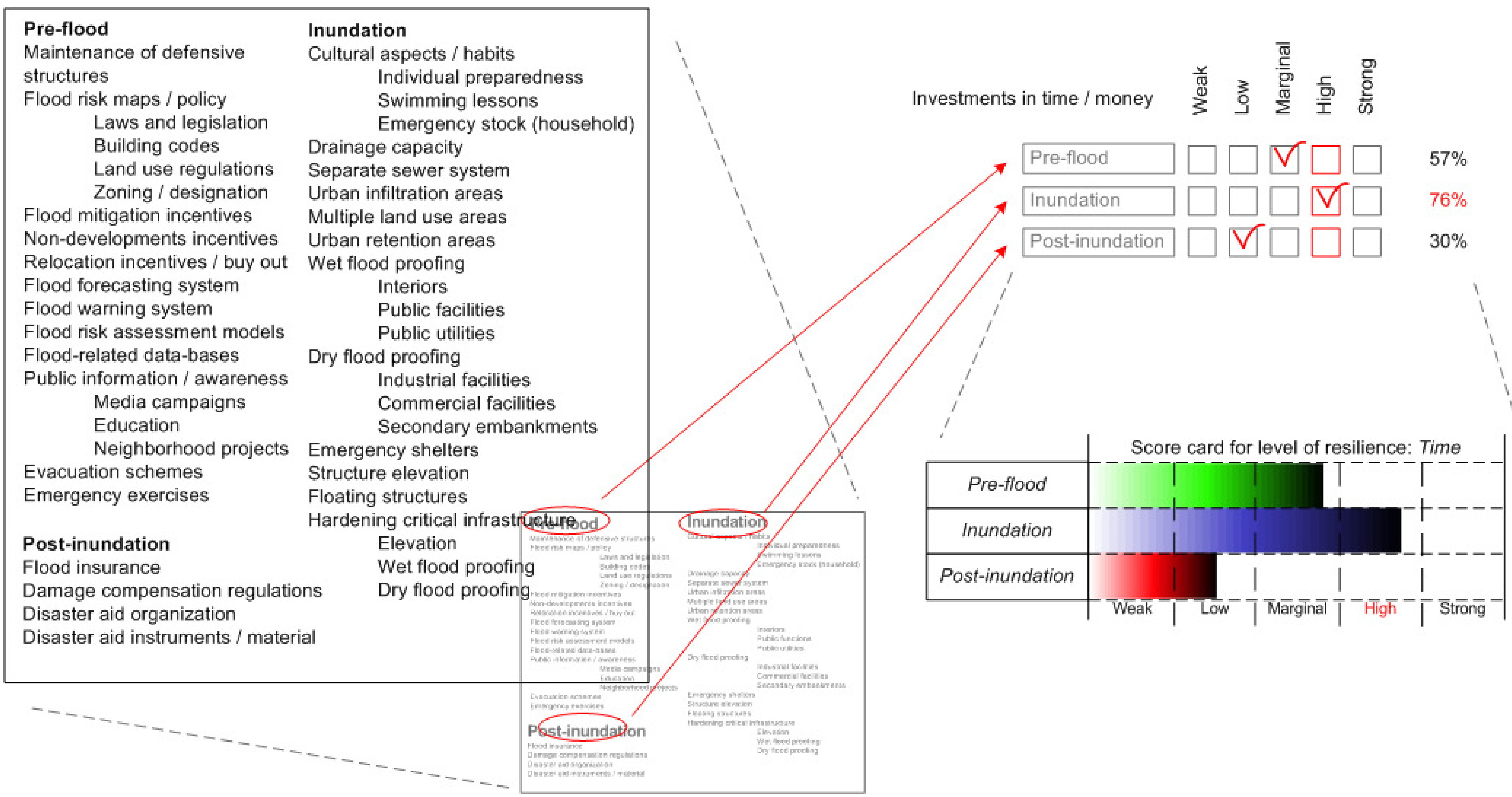
Although it is possible to assess a delta on resilience based upon previously defined clusters, no conclusions of significance can be attached to this type of analysis. I already argued that a flood risk management strategy ideally consists of both resistance and resilience capacities, meaning that the outcomes of the suggested method do not offer a complete flood risk management strategy; it can only help to indentify the existing balance between resistance and resilience in the present situation, and offer insight into which sort of measures might be necessary to change this balance in a preferred direction.

The preferred balance between resistance and resilience depends on many, often locally determined factors embedded within the context of the socio-physical system. The applicability and effectiveness of the chosen measures is highly dependent on this context:

> '*Measures should be evaluated in terms of feasibility, suitability, and environmental consequences at the locale*' (Burrell *et al.*, 2007).

The role of the context is discussed in the next section.

Figure 3.4: Method for creating a qualitative score card for resilience, based on the chronology of events



3.2 Context

Every socio-physical system is situated within its own unique institutional and environmental context. This context is to a large extent directive for spatial developments and the future outlay of built environment on every specific location.

> 'Sub-national spatial and social differentiation of vulnerability, and the way in which the impacts of national-scale processes are mediated by local conditions, should not be downplayed.' (Brooks *et al.*, 2005)

Many scientists and professional argue that the land use in flood prone lands should be compatible with the interdependent biological and physical components that make up an ecosystem. Land use is also shaped and steered by the institutional context, consisting of cultural aspects such as rules, norms, values and habits, as well as the political and social environment.

Although Burrell *et al* (2007) say that 'the contemporary approach is one of considering all feasible methods to yield an optimal cost-effective strategy for a specific flood situation, compatible with the policies, priorities and funds available to a governing agency.', still too often solutions to a flood threat are found solely in technical measures nowadays.

3.2.1 *The Environmental Context*

Historically, the natural environment induced human to settle down in a specific area, and directed local developments. The most triggering factors to establish a settlement were the presence of fertile lands or fishery areas, the availability of fresh water and lumber, or the possibilities for regional transportation and trade. Many of these favorable conditions could be found in delta areas where the confluence of river and maritime systems provided a naturally rich and diverse environment.
In present days the natural environment plays a different role in the development of inhabited areas. Nowadays, modern delta cities often accommodate such large populations and socio-physical capital in the form of houses, office buildings, infrastructure and other provisions so crucial for modern society that flood risk outweighs the original, relatively small scale environmental advantages like agriculture and lumbering.
Still, delta environments are of great importance to modern society, as they offer good opportunities for inland and international navigation, commercial fisheries and recreational activities. These 'new' advantages make modern cities once again dependant to their location, and lead to acceptation of the risk trade-off. This shift in appreciation of

the natural values also influenced development patterns, as nowadays development is directed by politic and economic powers.

Considering flood risk management, natural environment can offer great opportunities. For example, in the Mississippi delta, south from New Orleans, vast areas of wetland forests protect the coastal zone from the impact of hurricane induced storm surges. Conservation and protection of the wetlands in Southern Louisiana is an important part of the flood risk management strategy in Louisiana (LCPRA, 2007; Lake Pontchartrain Basin Foundation, 2008).

The preferred flood risk management strategy is highly dependant on the type of flood risk that a community is exposed to. There are many different types of floods, varying from floods caused by high river discharges to marine floods and from melting water-induced floods to flash floods caused by upstream precipitation (Parker, 2000). Besides the type of flood risk, the elevation and slope, type of soil, and local climate are all determinant for the preferred strategy design.

3.2.2 *The Institutional Context*

Each country in the world has its own specific institutional organization by which daily activities and developments are planned, guided and regulated. This institutional context mainly determines the effectiveness of spatial development plans that are important for managing flood risk in flood prone areas.
The importance of the institutional context is underlined by many authors. The role of institutions in hazard vulnerability is clearly formulated by Brooks *et al.*:

> 'Multidimensional institutional contexts determine attitudes to hazards and, ultimately, the severity of their impacts' (Brooks *et al.*, 2005)

Although many authors define institutions as 'systems of rules and decision-making procedures and programs' and make a clear distinction with organizations, I choose to combine both under the flag of the institutional context. In other words, this thesis considers the institutional context to be (1) the socio-cultural environment of the subject of research and (2) the setting of organizations, communities and politics that shape and steer it (see also Adger, 2000). It is important to realize that the internal policy and culture, and thus the behavior of organizations is a clear outcome of the institutional context of a society as a whole (Hall and Taylor, 1996).
Reason for combining the socio-cultural and the organizational aspects is that both are considered important influential factors in the process of flood risk management strategy development. Godschalk also recognizes this importance of organizations and communities:

> ‘Communities are the social and institutional components of the city. They include the formal and informal, stable and ad hoc human associations that operate in an urban area: neighbourhoods, agencies, organizations, enterprises, task forces, and the like.’ (Godschalk, 2002)

In the used definition, the institutional context encompasses all habits, norms and values, structures, power relations and ruling discourses that influence decision-making, spatial development and resource allocation.
I realize that such a definition is too broad to be used explicitly; although, it is suitable for defining the aspects of the institutional context that affect applicability and effectiveness of flood risk management strategies on a specific location.

An example of the strong role of the institutional context can be found in the communication of information. General awareness of the risk situation is an important aspect of risk mitigation. Most of the time awareness arises first amongst scientists who measure, calculate and observe in order to obtain knowledge. The next step is to make politicians, decision-makers and, through them, the public aware of the drawn conclusions.
To enable the successful forwarding of essential information, politicians need to be willing to listen and they need to accept the message in all its essence as it is brought to them. In the end, political institutions have the power to frame the perceptions of the public.
In a society where short term political stakes are considered to be more important than long term visions and progressive decision-making, there is a chance that the risk message will not be accepted instantly or to its full extent. Accepting the risk-message potentially imposes major consequences on, for example, development patterns and might require difficult decision-making about uncertain conditions far in the future. Such a situation can stress implementation of an effective strategy as market, industry, politics and private parties are simply not prepared to invest in expensive measures to adjust their property to the ‘threatening’ situation. In fact they prefer to ignore that their property is actually at risk, what gives them the argument that they don’t need to adapt. It is this state of deliberate ignorance that has been a drag on sustainable development in many deltas in the world.

Green *et al.* argue that: ‘Since decisions are made and implemented by institutions, institutional design is critical to the success of a flood hazard management policy’ (Green *et al.*, 2000). Burrell *et al.* (2007) say that ‘a flood management strategy requires forethought and commitment’, underlining the importance of a prescient attitude of politicians and the institutional context in general.
A proactive attitude in especially land use planning and amongst policy makers offers many opportunities for incorporating flood risk mitigation measures into built environment without the need for radical physical interventions. In this perspective a

progressive society might prevail over a conservative one. Even a dictatorship might be more effective in implementing such a strategy than a democratic society where decisions are mainly aimed at the four year political lifecycle.
Although far-sighted policies might prevail on the long term, politicians often choose for short term benefits in the form of votes. But prudent planning on the part of governments requires the early formulation of strategies for adaptation, to be effective on the long run (Burrell *et al.*, 2007).

Flood risk management asks for far going integration of plans, communication and cooperations across sectors and scales. Therefore it is always important to consider the local institutional context before formulating a preferred strategy. The creation of a resilient community largely depends on the institutional characteristics and behavior, as Godschalk argues:

> A resilient city has a strong central government, as well as vital private sector and non-governmental institutions. (Godschalk, 2002)

3.2.3 *Socio-economic characteristics*

Disasters are fundamentally social phenomena; the ability to cope with negative impacts is likely to be greater among advantaged groups than among disadvantaged groups, within and between regions (Blaikie *et al.*, 1994; Adger, 2000).
The social-economic situation of an individual or community is determinant for their flood susceptibility and vulnerability. It is commonly known that, for example, poor people suffer more and longer than wealthy people when a disaster strikes, because of their lack of ability to cope with and recover from such an event.

Besides *finances* there are many other social or economic factors thinkable that influence vulnerability. Some examples of determinant social factors are *social networks* that offer a buffer in case of emergency, *political stability*, *living standards* or *demographic characteristics* such as ethnic background or the number of elderly in a population. Also *public good*, *fairness* and *equity* are fundamental to flood management (Burrell *et al.*, 2007; Simpson and Human, 2008; Cutter, 2003).
Understanding these phenomena is important, and efforts and investments to improve them are believed to be very effective in reducing the total vulnerability of a society. There is a strong need to integrate hazard mitigation with economic development and social justice (see also Godschalk, 2002).

Socio-economic equity is an important aspect of flood risk management. Unfortunately, the principle of fairness is difficult to implement, particularly when the affected parties can not see a clear advantage, or when short-term consequences are valued higher than future gains. Another disadvantage of socio-economic investments is that the benefits for flood risk mitigation are not tangible enough to measure. (Plate, referred to by Burrell *et al*., 2007).

As we see, many socio-economic characteristics are hard to influence as part of a flood risk management strategy, and are therefore seen as a part of the context that determines the preferred measures within the strategy.

4 Case Studies

Two case studies are done in respect of this research. The first is New Orleans, situated in the State of Louisiana, USA. This case is typified by historical fluvial floods from the Mississippi River, and more recently by Hurricane induced floods form the Gulf of Mexico. The flood protection system consists of an extended levee system of concrete and earthen stretches called the Hurricane Storm Damage Risk Reduction System (HSDRRS), a large wetlands and mangrove area downstream that serves as an important high water level buffer, and local flood mitigation measures like flood proofing and structure elevation. Recently a ‘multiple lines of defense’ strategy is adopted here (Curole, 2006). Typical for the New Orleans case is the usage of flood risk maps of FEMA and the connected flood insurance system.
The second case is that of the Netherlands. This country can be seen as the largest river delta in Northwestern Europe. The Rhine, Meuse, Scheldt and Ems Rivers enter the North Sea in Dutch territory. The low lying country is famous for its polders, pumping-stations, dikes, dunes, sluices and of course the Delta Works. The Rhine and Muse Rivers represent the most present flood risk, although floods due to high sea levels or drought (bursting dikes) have occurred in the past as well.

In this chapter the analysis methods described in section 3.1.5 are applied to the New Orleans and the Netherlands case studies. For the qualitative analysis two clusters are chosen: the *chronology* cluster and the *type of measure* cluster. This analysis is done in section 4.1.1.

Section 4.1.2 shows the results of the quantitative method and analyzes the information found. In section 4.1.3 the conclusions of the New Orleans case study report and the result of the qualitative and quantitative analysis are merged together into a final discussion.

In section 4.2.1 the Netherlands case study is analyzed, using both the qualitative and the quantitative methods. As main source of information input the report ‘De veerkracht van een ontwikkelde delta’ (Kranen, 2008, in Dutch) is used, combined with an analysis of scientific literature and policy documents.
The results of the analysis of the Netherlands case are discussed in section 4.2.2, after which a final overview of the case studies is given in section 4.3.

4.1 New Orleans

In the additional case study report 'New New Orleans' an extensive and detailed analysis is made of the socio-physical system in the Mississippi delta, metropolitan New Orleans. A selection of the results is displayed in Appendix C. The information collected through field observations, contents analysis and interviews with professionals is transferred into a score table for the case New Orleans. The music notes in the table represent the scores of New Orleans on the investments made in each single measure (see figure 4.1).

First, the obtained information is used as input in a qualitative score card method as proposed in section 3.1. This is done using a code set (A, B or C) for the type of measures, and applying it to the *chronology* cluster (see section 3.1.4).
Second, a sensitivity analysis is done based on five different assumptions and using two different methods to distribute the weights. This allows a quantitative comparing of scores between the different weight sets used and the assumptions made.

The results are all placed within the local context, after which this section derives some recommendations on possible future decisions. The section is concluded by describing the possible role of spatial planning for the New Orleans case.

4.1.1 *Creating a qualitative score card for New Orleans*

Based on the information collected a table of indicators for resilience is generated. The indicators are clustered by chronology - pre-flood, inundation, and post-inundation - and coded by type (Figure 4.1).
Code A represents measures that enhance *social adaptive capacity*, code B measures aim at *physical adaptive capacity*, and code C are measures that increase the *absorption capacity* of the case study area (see also Appendix A-1).

By multiplying the number of indicators by the value allocated to the estimated investments made (1/5 to 5/5) it is possible to add a score to each of the clusters. In addition, a percentage can be calculated for both each code indicating the estimated investments made in a specific type of measure.

From the resulting table (Figure 4.1 and appendix A-1) it can be concluded that, considering the chronology of a flood event, in the case of New Orleans investments in resilience measures that are effective in time of inundation are lagging behind (50%), while the investments in measures that prepare society to a flood event can be valued just marginal. The low score for *inundation* mainly concentrates on three aspects: individual preparation, internal water storage and drainage capacity, and the protection of critical infrastructure. A possible explanation for this is that despite of historical experiences decision makers seem to rely on the defense works that protect the city from flooding. Investments that aim at flood occurrence, thus, lag behind.

The *post-inundation* efforts score really well in this case. This result can be mainly subscribed to the efforts undertaken by FEMA and LRA, who strongly invested in the recovery process and post-flood relief after Katrina struck. Although investments are high at his point, it has to be mentioned that the lack of vertical and horizontal coordination, e.g. in the flow of money to lower authorities and small scale projects and inter-organizational cooperation, puts a drag on the recovery and rebuilding process.

Pre-flood	Weak	Low	Marginal	High	Strong		
19 indicators; max. score = 19 (100%)	1/5	2/5	3/5	4/5	1	Code	
Maintenance of defensive structures			♫			B	
Flood risk maps / policy			♫			A	
Laws and legislation				♫		A	
Building codes			♫			B	
Land use regulations			♫			A	
Zoning / designation			♫			A	
Flood mitigation incentives		♫				A	
Non-developments incentives			♫			A	
Relocation incentives / buy out			♫			A	
Flood forecasting system					♫	B	
Flood warning system				♫		B	
Flood risk assessment models				♫		B	
Flood-related data-bases				♫		B	
Public information / awareness			♫			A	
Media campaigns		♫				A	
Education			♫			A	
Neighborhood projects			♫			A	
Evacuation schemes					♫	A	
Emergency exercises			♫			A	
Total =	0	0,8	6,6	3,2	2	12,6	66,32 %

Inundation	W	L	M	H	S		
23 indicators; max. score = 23 (100%)	1/5	2/5	3/5	4/5	1	Code	
Cultural aspects / habits		♫				A	
Individual preparedness			♫			A	
Swimming lessons	♫					A	
Emergency stock (household)		♫				A	
Drainage capacity		♫				C	
Separate sewer system	♫					C	
Urban infiltration areas	♫					C	
Multiple land use areas		♫				C	
Urban retention areas	♫					C	
Wet flood proofing				♫		B	
Interiors				♫		B	
Public functions			♫			B	
Dry flood proofing				♫		B	
Industrial facilities				♫		B	
Commercial facilities				♫		B	
Secondary embankments			♫			B	
Emergency shelters				♫		B	
Structure elevation			♫			B	
Floating structures	♫					B	
Hardening critical infrastructure		♫				B	
Elevation		♫				B	
Wet flood proofing			♫			B	
Dry flood proofing		♫				B	
Total =	1	2,8	3	4,8	0	11,6	50,43 %

Post inundation	W	L	M	H	S		
4 indicators; max. score = 4 (100%)	1/5	2/5	3/5	4/5	1	Code	
Flood insurance			♫			A	
Damage compensation regulations				♫		A	
Disaster aid organization					♫	A	
Disaster aid instruments / material				♫		A	
Total =	0	0	0,6	1,6	1	3,2	80,00 %

Figure 4.1:
Results table for the New Orleans case study, displaying the indicative score for all identified resilience based measures, clustered by chronology of a flood event and coded by type.
Code A represents *social adaptive capacity*, B is *physical adaptive capacity*, and C is *absorption capacity*.
Striking results are accentuated in this table

Some additional information can be derived if the maximum score *per type* is calculated, and compared to the actual score based on the collected information. If the numbers are viewed from this angle the results are striking. As you can see in figure 4.2, it is clear that especially absorption enhancing measures score very low.

	Pre-flood	Inundation	Post inundation	*Max total*	Score	%
Total A	8	1 3/5	3 1/5	21	12,8	61,0
Total B	4 3/5	8 3/5	0/5	20	13,2	66,0
Total C	0/5	1 2/5	0/5	5	1,4	28,0

Figure 4.2: Comparing scores of resilience based measures, clustered by social adaptive capacity (A), physical adaptive capacity (B), and absorption capacity (C)

To make the results displayed above more clearly visible they can be transferred into a score card following the method described earlier (see section 3.1.6 and figure 3.4), resulting in figure 4.3. Now it is clearly visible there is a lot to gain considering resilience in the New Orleans case with scores of 66, 50, and 80 percent of the theoretical resilience maximum.

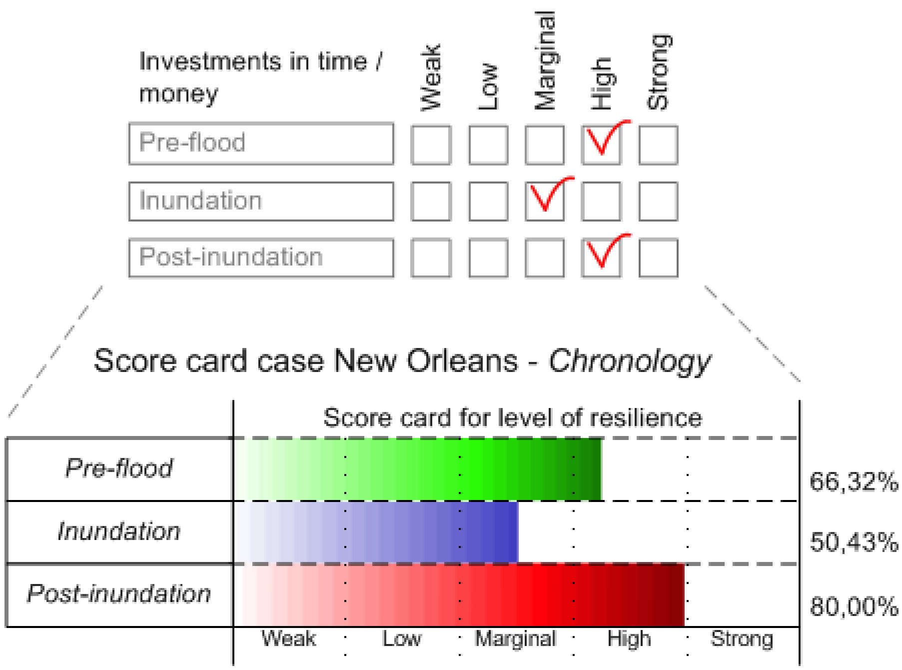


Figure 4.3: Score card for the New Orleans case, displaying the level of investments in resilience based measures at different moments in a flood event chronology

4.1.2 *Quantitative analysis of the indicators*

To obtain more quantitative information a sensitivity analysis has been carried out as well. It is decided to do two calculations, each based on the same five assumptions (see section 3.1.5). The first calculation is done using the original weights distribution of 1 to 3, with three assumed to be the most important kind of measure. Because the difference between the several types of measures is rather marginal using this weights distribution it is difficult to draw a strong conclusion from the results (Figure 4.4).
To be able to more clearly identify the influence and importance of specific measures it is decided to use a different weights distribution for the second calculation. In this distribution, called 'weights-10', the total of weights distributed among the types of measures counts up to ten, allowing making a clearer distinction between more and less important measures according to the assumption made.

An overview of these results is given in appendix A-2 to A-6. It is clear that using the *original distribution* there is almost no difference in scores when the weight sets of the assumptions are compared (Figure 4.4). Only when information provision and spatial planning are assumed to be highly valuable, the results drop below average.

	Orginal distribution - 1 to 3		
Assumption weight set	**Pre-flood**	**Innundation**	**Post innundation**
Information provision and Education	28,4	13,2	6,4
Law, Legislation and Spatial Planning	25,2	22,4	7,4
Non-physical measures	30	19,2	6,4
Public efforts	29	29,2	6,8
Information Provision and Spatial Planning	29,2	12,4	4,6
Average	28,36	19,28	6,32

Figure 4.4: Sensitivity analysis - summarizing table of the calculation results using the original weights distribution of 1 to 3

If we look more closely at the results from the 'weights-10' calculation it is obvious that, when the gap between the important and less important measures increases, more scores drop below average (Figure 4.5). Hence again it seems that measures that focus on communication, information provision, and spatial planning score low in New Orleans. On the contrary, the results of pre-flood measures increase considerably when using the 'weights-10' distribution.
From this sensitivity analysis it can be concluded that especially the application of spatial planning to reduce the vulnerability of New Orleans is underrated and not applied to its full potential. In addition, information on flood risk and flood risk management is abundant in New Orleans, as we can conclude from the high scores on pre-flood

measures. The main is, however, is that the communication between organizations and authorities as well as towards the public is less accurate and effective than desired.

	Extreme distribution - 10		
Assumption weight set	**Pre-flood**	**Innundation**	**Post innundation**
Information provision and Education	49,6 ↑	14,8	9,6
Law, Legislation and Spatial Planning	30,6 ↓	14 ↓	7,4 ↓
Non-physical measures	54 ↑	34,4	12,8
Public efforts	37,4	49,2 ↑	12
Information Provision and Spatial Planning	50 ↑	14	7,4
Average	44,32	25,28	9,84

Figure 4.5: Sensitivity analysis - summarizing table of the calculation results using the weights-10 distribution method

4.1.3 *Discussion of the New Orleans case study*

Combining the results from section 4.1.1 and 4.1.2 with the final discussion of the case study report 'New New Orleans' additional to this thesis, some main conclusions can be drawn.

New Orleans historically relied mainly on structural, engineering measures to mitigate flood risk. This approach has failed repeatedly in the past. Still, after the disastrous events in 2005 when Katrina stroke New Orleans, the first reaction of the State and Federal governments was to raise an even higher defense wall to keep the water out in the future. This reaction is logical if considered from a cost and time perspective, and keeping in mind that most reactions to crises are rather strong and technical. But, if a sustainable future situation for New Orleans is desired, a more strategic approach is needed to solve the issues at hand.

In the post-Katrina recovery and rebuilding period little attention has been paid to measures that increase the resilience of the New Orleans community, institutions, and the physical environment. A missed chance as Katrina actually offered decision-makers a blank sheet, an ultimate opportunity to implement a radical new policy that aims for long term sustainability and that takes into account the harsh environmental context in which the city is situated.

Shown in the results above, measures that count on an eventual flood in the future are implemented just marginally and scattered across the metropolitan area, reducing their effectiveness. Little signals are there that promise a radical change in direction within a short time span.

Reason for this are the difficulties connected to the implementation of a strategy that offers no clear short term benefits, but only long term and vague positive outcomes. The local culture of 'political planning' combined with the specific role of money and power in the decision-making process stress the implementation of a new radically different development policy.

This situation poses the risk that the awareness of the public and decision-makers will fade away as time passes by and the defense structures grow. The physical environment is getting more and more excluded from the socio-physical environment, a trend that is potentially harmful according to several professionals involved in governance, planning and architecture in the region. Such threatening ignorance may result in the socio-physical development of flood prone areas, and in a situation in which the community, its built environment, and its institutions once again do not calculate in the possibility of flooding. Eventually such a situation will remain until a new disaster triggers a policy shift.

The following recommendations for the New Orleans case result from this research.

(1) The development of Southern Louisiana is not internally coordinated. All parishes use their own spatial plans, leading to a scattered, often unsustainable development pattern. It is recommended to design a *strategic spatial plan* for the South Louisiana region that takes into account the physical environment and long term climatologic changes;
(2) To ensure sustainable development of the area, the plan needs to contain a specific section that formulates how to incorporate a *flood risk management strategy* in the future development of metropolitan New Orleans;
(3) All *existing plans* need to be merged and adapted to fit the regional strategic development plan;
(4) To generate *general agreement and commitment* to the chosen policy it is recommended to define the existing problems and possible solutions in cooperation with representatives from all levels of government (Federal, State and Parish), public communities and organizations, and professions involved in spatial development (Spatial planners, water managers, architects, and environmental organizations);
(5) For reducing the vulnerability of New Orleans, the region should aim at measures that enhance *resilience* of the region, and focus on increasing flood risk *awareness* of the public, politics and decision-makers, and across all sectors;
(6) To ensure the main functions of New Orleans to operate, even at time of inundation, first priority should be hardening the *critical infrastructure*. Flood proofing or elevating road, rail, water and energy networks is critical for the

continuation of the city's main functions, and e.g. for evacuation and emergency supply;

(7) It is important that there is a constant control and evaluation of the chosen policy in order to be able to anticipate to changing circumstances without loosing sight of the ultimate goals. It is recommended to appoint a *coordinative organization* or authority in the region that has the political power and financial means to initiate and steer the process, preferably Louisiana State;

(8) The *data and information* that is abundant in the region and available at many public and private organizations should be collected, organized and stored at one location. This will improve the possibilities to communicate essential information towards the public and decision-makers, and use it as a basis for decisions on future developments;

(9) New Orleans is more and more cut of from its natural environment. The Mississippi River and the outfall canals are enclosed by high concrete walls, closing these water bodies off for the inhabitants. It is strongly recommended to *bring water back into the city*, instead of closing it out.

4.2 The Netherlands

As a basis for the analysis of the Netherlands case a literature research and contents analysis is done. Combined with the conclusions of the report '*de veerkracht van een ontwikkelde delta'* (Kranen, 2008, in Dutch) a comparable score table as for the New Orleans case is created (see figure 4.6). Since I realize the allocating of scores, although based on previous research, is rather subjective it is decided to ask the opinion of several experts[3] in the fields of spatial planning, water management and adaptation strategies. Their scores are used as a frame of reference to ensure the scores applied are representative for the Netherlands.
The windmills in the table indicate the score of the Netherlands per type of resilience indicator (Figure 4.6).

Comparable to the New Orleans case, the obtained information is first used as input in a qualitative score card method (see section 3.1). This is done using the code set for types of measures, and applying it to the *chronology* cluster (see section 3.1.4).
Second, a double sensitivity analysis is done based on the five assumptions, allowing a quantitative comparing of scores between the different weight sets used and the assumptions made.

[3] The experts consulted are: Margo van den Brink (University of Groningen), Karin de Bruijn (Deltares), Terry van Dijk (University of Groningen), Bas Jonkman (University of Delft), Frans Klijn (Deltares), and Johan Woltjer (University of Groningen)

Just like in the New Orleans case, the results are all placed within the local context. Finally this section derives some conclusive recommendations on possible future decisions. The section is concluded by describing the possible role of spatial planning for the Netherlands case.

4.2.1 *Creating a qualitative score card for the Netherlands*

Based on literature research and the information collected during a previous analysis of the Netherlands a table of indicators is generated. The indicators are again clustered by chronology and coded by type (Appendix B-1).

By multiplying the number of indicators by the value allocated to the estimated investments made (1/5 to 5/5) it is possible to add a score to each of the clusters. In addition, a percentage can be calculated for both sets of clusters indicating the estimated investments made in a specific type of measure.

From the resulting table (Figure 4.6) it can be concluded that, considering the chronology of a flood event, in the case of the Netherlands investments in resilience measures that are effective in time of inundation score strikingly low (40%). Analyzing this result it can be concluded the Netherlands do not anticipate on incidental flooding of protected areas, as it seems that little of built environment is flood proofed, and critical infrastructure is minimally protected against flood.
The low scores on measures that actually calculate in incidental flooding can be explained by the historical development of the country. The Dutch have a long and rich history of water management and are as a consequence regarded as one of the leading countries in flood protection technology. Many of the water works in the Netherlands are state of the art, and the water system functions as one entity. This good quality of works imposes that the public and decision-makers fully rely on it. The possibility that things go wrong is generally put aside, or treated as an acceptable risk. This leads to a situation in which apparently only small pieces of the famous low lying Netherlands are actually prepared to flood.
The pre-flood measures, on the contrary, are relatively in order. Especially the flood forecasting and flood warning efforts score high in the Netherlands. Strangely enough it seems that the knowledge and techniques are present, but that this works contradictory when it comes to flood preparedness. The staying out of big disasters - the last real disaster took place in 1953 - only encourages decision-makers to continue on the same route.

Pre-flood	Weak	Low	Marginal	High	Strong		
19 indicators; max. score = 19 (100%)	1/5	2/5	3/5	4/5	1	Code	
Maintenance of defensive structures					x	B	
Flood risk maps / policy			x			A	
Laws and legislation				x		A	
Building codes		x				B	
Land use regulations			x			A	
Zoning / designation			x			A	
Flood mitigation incentives		x				A	
Non-developments incentives		x				A	
Relocation incentives / buy out		x				A	
Flood forecasting system				x		B	
Flood warning system				x		B	
Flood risk assessment models				x		B	
Flood-related data-bases				x		B	
Public information / awareness			x			A	
Media campaigns				x		A	
Education		x				A	
Neighborhood projects	x					A	
Evacuation schemes		x				A	
Emergency exercises			x			A	
Total =	0,2	2,4	3	4,8	1	11,4	60,00 %

Inundation	W	L	M	H	S		
23 indicators; max. score = 23 (100%)	1/5	2/5	3/5	4/5	1	Code	
Cultural aspects / habits			x			A	
Individual preparedness	x					A	
Swimming lessons				x		A	
Emergency stock (household)	x					A	
Drainage capacity				x		C	
Separate sewer system				x		C	
Urban infiltration areas			x			C	
Multiple land use areas			x			C	
Urban retention areas		x				C	
Wet flood proofing	x					B	
Interiors	x					B	
Public functions	x					B	
Dry flood proofing		x				B	
Industrial facilities		x				B	
Commercial facilities	x					B	
Secondary embankments			x			B	
Emergency shelters	x					B	
Structure elevation		x				B	
Floating structures		x				B	
Hardening critical infrastructure	x					B	
Elevation		x				B	
Wet flood proofing	x					B	
Dry flood proofing	x					B	
Total =	2	2,4	2,4	2,4	0	9,2	40,00 %

Post inundation	W	L	M	H	S		
4 indicators; max. score = 4 (100%)	1/5	2/5	3/5	4/5	1	Code	
Flood insurance	x					A	
Damage compensation regulations			x			A	
Disaster aid organization				x		A	
Disaster aid instruments / material			x			A	
Total =	0,2	0	1,2	0,8	0	2,2	55,00 %

Figure 4.6: Results table for the Netherlands case study, displaying the indicative score for all identified resilience based measures, clustered by chronology of a flood event and coded by type. Code A represents *social adaptive capacity*, B is *physical adaptive capacity*, and C is *absorption capacity*. Striking results are accentuated in this table

The previous case study analysis proved that additional information can be derived if the maximum score *per type* is calculated and compared to the actual score based on the collected information. Doing the same for the Netherlands shows that the results are not that remarkable. If you look at figure 4.7, it is clear that there is no big difference between the different types of measures, although it is interesting to see that all score rather low, considering 100% is the best achievable result.

	Pre-flood	Inundation	Post inundation	*Max total*	Score	%
Total A	7	1 4/5	2 1/5	21	11,0	52,4
Total B	4 3/5	4 1/5	0/5	20	8,8	44,0
Total C	0/5	3 1/5	0/5	5	3,2	64,0

Figure 4.7: Comparing scores of resilience based measures, clustered by social adaptive capacity (A), physical adaptive capacity (B), and absorption capacity (C)

To make the results displayed above more clearly visible they are transferred into a score card, resulting in figure 4.8. It is clearly visible that, comparable to the New Orleans case, the Dutch investments in resilience based measures are marginal, as is displayed by the scores of 52, 54 and 64 percent of the possible measures that can be taken. This indicates that there are little incentives in the Netherlands to prepare built environment, the community and its institutions for floods.

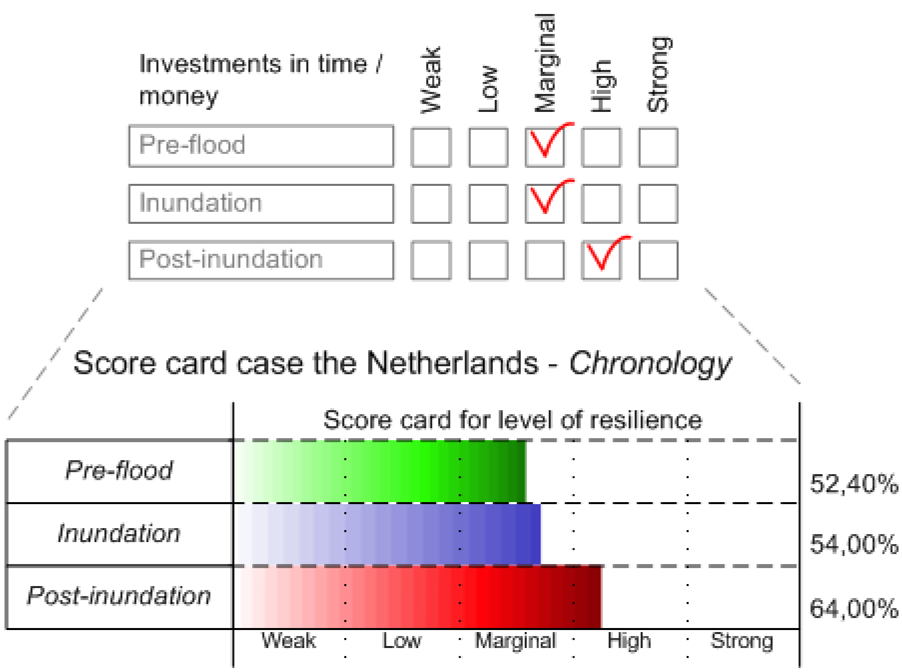


Figure 4.8: Score card for the Netherlands case, displaying the level of investments in resilience based measures at different moments in a flood event chronology

4.2.2 *Quantitative analysis of the indicators*

To obtain more quantitative information a sensitivity analysis has been carried out as well. Two calculations are done, each based on the same five assumptions that were used earlier (see section 3.1.5). The first calculation uses the original weights distribution of 1 to 3; the second calculation uses the 'weights-10' distribution to be able to make a more clear distinction between the several measures.

An overview of the results is given in appendix B-2 to B-6. Again, using the original distribution offers no striking results when the weight sets of the different assumptions are compared (Figure 4.9). There are signs that information provision and spatial planning are below average, but to draw secure conclusions a second calculation in which the weights are distributed more extremely is needed.

	Orginal distribution - 1 to 3		
Assumption weight set	**Pre-flood**	**Innundation**	**Post innundation**
Information provision and Education	25,6	11	4,4
Law, Legislation and Spatial Planning	22,2	18,2	4,6
Non-physical measures	26,8	16,4	4,4
Public efforts	26	21,6	5
Information Provision and Spatial Planning	26,6	10,8	3
Average	25,44	15,6	4,28

Figure 4.9: Sensitivity analysis - summarizing table of the calculation results using the original weights distribution of 1 to 3

The results of the 'weights-10' calculation are displayed below (Figure 4.10). Comparing them to the results of the original weights distributions learns that when the assumed important measures are accentuated, the public efforts and non-physical measures in the Netherlands appear to be scoring quite well compared to the average in the concerned time period.
Yet again it is obvious that the scores drop at the weight sets that prioritize spatial planning. It seems that, despite the well-developed spatial planning practice in the Netherlands, the available information on flood risk is minimally transferred into concrete spatial policy.

Similar to the New Orleans case, it can be concluded that especially the application of spatial planning to reduce the vulnerability of society is underrated and not applied to its full potential. Even though the needed knowledge is widely available, it seems to be difficult to translate this into concrete rules and regulations that steer spatial development.

	Extreme distribution - 10		
Assumption weight set	**Pre-flood**	**Innundation**	**Post innundation**
Information provision and Education	44,8 ↑	12,8	6,6
Law, Legislation and Spatial Planning	27 ↓	14 ↓	4,6 ↓
Non-physical measures	47,6 ↑	30,8	8,8 ↑
Public efforts	33,2	36,4 ↑	9 ↑
Information Provision and Spatial Planning	45,4 ↑	14	4,6
Average	35,6	21,6	6,72

Figure 4.10: Sensitivity analysis - summarizing table of the calculation results using the weights-10 distribution method

4.2.3 *Discussion of the Netherlands case study*

The results shown above give a good impression of the contemporary situation in the Netherlands. As is generally agreed upon, the Dutch are experts on water management and have proved to be successful in protecting their lands against flooding. Where in this case the structural lines of defense are strong, the areas protected are extremely vulnerable. A reason for this is, according to the results of the analysis, that especially the spatial planning practice falls short on its responsibilities.

This conclusion is in line with some of the final remarks made in a previous paper (Kranen, 2008, in Dutch), indicating that the method proposed in this thesis may indeed be a valuable tool for analyzing deltas on resilience. Summarizing the paper from 2008 recommended that:

1. The risk of protected areas should be re-calculated based upon object-specific characteristics. Critical infrastructure and vulnerable groups of people should get higher priority;
2. The present level of resistance is broadly sufficient according to the present protection norms. But the contextual situation is changing rapidly as socio-economic value behind the dikes is growing and pressure at the front door is increasing due to climate change and soil subsidence;
3. Especially in such low lying areas built environment should be adapted to the present flood risk. Buildings, infrastructure, the inhabitants and the institutions should be prepared for an incidental flood at least to some degree;
4. Spatial planning plays a key role in this process. Adaptation of existing buildings and infrastructure is expensive and time-consuming, but new developments can be adapted more easier. By designing new rules and regulations for spatial development, and by offering flood insurance decision-makers can anticipate to changing circumstances.

Combining these remarks with the results from sections 4.2.1 and 4.2.2, some main conclusions can be drawn.

Large areas of the Netherlands seem to fully rely on structural, resistance offering measures to mitigate flood risk. This approach has proved to be effective, but also failed once in the past and many times in other deltas around the world as well.
The Netherlands are well protected but as a result minimally prepared for an eventual flood event. This imposes a major risk. In case things go wrong, it will take a very long time to recover, and the extent of damage and the number of casualties are potentially very high. Adaptation of the protected areas is highly necessary if the desire is to be safe in the future and to develop sustainable on the long term. In this respect, the recent adoption of the National Programme on Climate Adaptation and Spatial Planning (VROM, 2007) in the Netherlands is a strong turn in the positive direction. On the other hand the National Water Plan, adopted in December 2009 (V&W, 2009), amplifies the need the maintain and improve the level of resistance, a direction that is not preferred according to this study.
The knowledge is available and spatial planning in the Netherlands seems suitable to guide a gradually adaptation of the socio-physical system to the changing physical and climatic conditions.

Unlike the New Orleans case the present situation in the Netherlands the flood risk awareness at the national government is ever present and water-related issues are always high on the agenda. Unfortunately the local political situation - in my personal opinion a bureaucratic democracy that seldom generates strong and daring policy decisions - puts a drag on sustainable development. It can be feared that such a situation results in ongoing unsustainable developments and an increasing risk.

The following recommendations for the Netherlands case result from this research.

(1) Due to changing conditions the actual risk in the Netherlands is ever increasing, while the protection norms are fixed. It is recommended to re-assess the used protection norms, considering the value of the areas protected. Hereby take into account the characteristics of social groups, specific buildings and important functions to determine the preferred level of protection;
(2) The all-time functioning of critical infrastructure should be guaranteed to limit the extent of consequences when an incidental flood occurs, and to increase recovery pace. The usage of secondary embankments and flood proofing measures are ways to achieve this;
(3) Flood risk management needs to be stronger connected to spatial planning. The creation and usage of flood maps is an important step in this process. If based on

the first mentioned, and calculating in future developments and possible climate changes to assess the risk, flood maps may become a valuable part of spatial plans;

(4) Although the national government uses large-scale media campaigns to inform the public, the general opinion amongst the consulted experts is that information provision is far from optimal in the Netherlands (see appendix D). It is recommended to improve the information flow to the public, as well as the communication between science and decision-makers. Especially education, neighborhood projects and the combined usage of flood maps and spatial plans can increase communication;

(5) Despite it is generally known that two thirds of the country will flood if there were no dikes in the Netherlands, there is no well-functioning flood insurance system. Insurance will not only offer post-flood relief but will also increase general awareness of the unique situation of the country. Flood maps can be used as a basis to assess the costs of insurance. The USA method can be used as an example;

(6) Because built environment can not be adapted in one day, a gradual process of transformation should be initiated. It is recommended to re-consider building codes and land use designation based on the newly created flood maps. Ensure all new and future developments take place in the light of the present flood risk;

(7) The national democracy does not allow the adoption of a radical new and costly development policy. Therefore I call for the appointment of an ambassador at the political level to carry out the importance of reconsidering of development patterns in the Netherlands[4].

Many of the above mentioned recommendations and suggestions can not be adopted without detailed analysis of the possible implications of implementation. It is realized that the conclusions for the Dutch case study are formulated in general terms and that further research is needed This thesis does not aim to elaborated on suggested measures in such detail.

4.3 Discussion of the Case Studies

All proposed methods and tables, as well as the used scores, weights and clusters are based upon the author's findings during the case study researches, and his personal reasoning about how to apply this collected information.
The results derived from the different methods can be used as an indicator for judging the level of investments made in measures that are identified to enhance resilience.

Based on the case studies on New Orleans and the Netherlands I conclude that in both situations the available information on flood risk is abundant. Flood risk assessment

[4] During the execution of this research a Delta Commissioner is appointed in the Netherlands

methods and models as well as warning systems are highly developed. Information on flood risk and water management is widely available for the public in New Orleans, but scattered amongst various authorities and institutions. This increases the chance on re-inventing the wheel and might cause inefficiency in research practices. Unlike the New Orleans situation, information is collected and maintained by just a couple of institutions and authorities in the Netherlands; it is only less available for the public. The usage and application of information differs between the two cases. In the USA information is used as an input for the creation of flood maps that function as the basis for flood insurance considerations and spatial planning issues. The Netherlands appear to be not that advanced in the practical application of the available information and only seem to use it sporadic in practice.

The abundance of information, knowledge and technology in the Netherlands seems to evoke a sort of arrogance that reminds of the attitude of 'the makeable society' from the sixties and seventies, when it was considered possible to fully control the natural environment and socio-economic development patterns. The Dutch are proud of their water management practice and the system works properly. The recent absence of serious flood events is often used as an argument to found the statement that the flood risk management strategy applied works. Ongoing socio-physical development of protected lands and climate changes imply an ongoing increase of the risk. On the contrary, the protection norms and defense structures in the Netherlands are static and not growing with the risk. This leads to the conclusion that there is more need for flexibility in such complex and constantly changing circumstances.

In an area where floods occurred more often in the past, like in New Orleans, you see that society is gradually adapting to that phenomenon. Although on a scattered scale, houses are elevated, public buildings are flood proofed, critical infrastructure is protected, and people are mentally more prepared to a flood than in the Netherlands. Even with these additional protection measures the consequences of a flood disaster were devastating in New Orleans, and the time needed to recover exceeded all expectations. A reason for this was the inefficient application of mitigation measures. Spatial planning in the USA is not as strictly organized as in the Netherlands. If strategically planned, measures like flood proofing structures, protection of critical infrastructure, elevating houses, and non-development policies can be much more effective than they are now in New Orleans.

Compared to the USA, here lies the strength of the Netherlands. Caused by the scarcity of space spatial planning in the Netherlands is strategic and hierarchical organized. It seems that if the choice is made at national level, in the Netherlands adaptations in rules and regulations to change development patterns can be enforced more efficiently than in the USA.

In both cases the message of the changing climate and the consequences for the local situation is understood well. But for different reasons a strong and decisive reaction failed to occur in both the cases. The construction of the new defense line around New Orleans

(the so-called HSDRRS) is a direct reaction on the public unrest caused by the Katrina disaster, and decisions not to rebuild on threatened lands are being postponed or cancelled because of elective vote related stakes.
In the Netherlands the process of acceptation of the adaptation message goes slow caused by the four year political life cycle of the national democracy. Although it can not be proved scientifically, it seems that politicians that are fighting to keep their place in the parliament are reticent to plea for radical changes that cost lots of money at the short term, and only generate benefits if an unforeseen event occurs in an uncertain future. This counts even more when they are backed up by a present system that is functioning well so far.

From the analyses of the cases it can be concluded that both in New Orleans and in the Netherlands there are much more measures that can be taken to reduce the vulnerability of society. It is obvious that the level of resistance in both cases reaches the maximum and that the highest benefits can be gained by increasing the resilience of the built environment, the population, and the local institutions in the near future.

As a final remark on the case studies I would like to argument that both can learn a lot from each other. It is obvious that in the Netherlands flood risk management is organized regionally through the water boards and centrally through the national government. An advantage of such an organization is that measures, if taken, are planned strategically and implemented in a whole region at the same time. In New Orleans, on the other hand, more responsibility is put on the individual. Here, the flood insurance system generates a higher individual preparedness (and awareness) than in the Netherlands. A combination of both approaches seems interesting to elaborate on in subsequent flood risk management theory studies.
The Netherlands can and do share their knowledge on and experience in water management with the USA, while the Americans can teach the Dutch how to generate accurate flood maps. The information collection and maintenance needed for these map is better organized in the Netherlands, an aspect that is in need of improvement in the New Orleans case. On the other hand the Dutch can use the experience of FEMA for designing a flood insurance system based on flood maps and object specific characteristics.
Considering New Orleans, it would be recommendable to design a strategic regional development plan for the whole South of Louisiana to make flood risk mitigation efforts more effective and to integrate water into built environment. Here the Americans can learn from the Dutch as they do this for a long time already. Disaster aid organization is something that the USA is more experienced in, as well as in structure elevation and flood proofing methods.

The many interviews and discussions I had with experts from various disciplines that somehow deal with flood risk management enlightened my view on the complexity of the issues at hand. If I had to choose what to do differently in conducting a case study research I would spend much less time behind my desk, and more in the offices of these people. There is so much to learn only by sharing thoughts and visions.
I feel strengthened by the idea that there are many professionals out there that somehow share the same vision on how things should change to make deltas les vulnerable and more sustainable. From that point of view I see this report as a small support to those who are carrying out this message.

5 Conclusion

The goal of this thesis is to assess flood vulnerability in delta regions and to elaborate on the resilience concept in flood risk management theory. In this thesis resilience is analyzed and made workable by using a composed list of indicators that is based on a newly designed risk formula. The indicators are used to assess the risk situation of delta regions and to make recommendations on possible improvements. The proposed methods for delta analysis are tested in two case studies, that of the Netherlands and New Orleans. The results show that both assessed case studies can significantly reduce their vulnerability by adopting a balanced flood risk management strategy.

As a result of socio-physical development, land subsidence, increasing rainfall and a rising sea level the flood risk in deltas is increasing. With these constantly changing conditions it should be considered not to rely solely on structural solutions anymore, but to strive for new strategies to protect deltaic communities against floods.
The literature and taken interviews show that international flood risk management is surrounded by uncertainty, unpredictability and uncontrollability. Events in the past prove that relying on technical, static defense structures that are based on norms derived from statistical models seems to be a risk itself.
The essence of *resilience* in international flood risk management is generally recognized in scientific literature, although this importance is not reflected in practice yet. This thesis and various other studies show that the more resilient, the less vulnerable a community is.

From the literature I concluded that in order to determine resilience in the context of flood risk it is necessary to analyze *vulnerability* in all its aspects and through that identify the factors that constitute the actual risk. To achieve this objective it proved to be absolutely necessary to make some radical adjustments to the commonly used risk formula. This thesis shows that the original formula ‘probability times consequences’ is too limited to fully comprise the risk. It is therefore *replaced by a formula* that contains hazard characteristics and vulnerability aspects, and that considers object specific characteristics.
This formula reveals the total complexity of flood risk. It seems that risk is composed not only of probability and consequences, but, moreover, of a complex whole of socio-physical aspects, exposure, capacities, resistance and resilience levels, and an constantly changing and unpredictable context.
A main advantage of the newly composed risk formula is that not only the hazard itself is calculated in, but also the consequences during the aftermath. This thesis shows that rebuilding and recovery time are important factors that determine the level of risk. Furthermore it shows the importance of considering the features exposed when assessing the risk and it stresses the essential role of capacities. The risk formula applied in this thesis makes flood risk more workable and better assessable.

The explicit choice for resilience in this study is based upon the thought that the traditional resistance strategy does not calculate in possible failure and is not flexible enough to suit the dynamic delta conditions. Besides, the limits to the level of resistance defense structure can offer will be reached eventually. It is generally believed amongst scientists that improvement of the level of resilience will most likely offer big opportunities for deltas.

This thesis identified a generic collection of resilience measures that can be implemented to complement already existing resistance measures (Figure 5.1). These measures are used as indicators to assess delta regions on vulnerability.

The application of the identified measures as indicators for resilience formed the basis for the proposed delta assessment methods. By clustering the indicators by type, responsible discipline, or place in the chronology of a flood event it is possible to design a *qualitative analysis method*. This method is tested on two cases, namely the Netherlands and New Orleans. The results show that *clustering* and classification of resilience measures offers valuable information. The method enables to assess a delta on vulnerability, and to make recommendations on measures that can be taken to enhance resilience.

To ensure the legitimacy of the research a sensitivity analysis of the used indicators is carried out. A *quantitative analysis method* is designed to identify those types of measures that are needed in a specific situation. First five assumptions were formulated based on which different weight sets were allocated to the indicators. For both cases a run with all five assumptions was done. A second set of runs using more extreme weight sets filtered out the most essential indicators.

The results show that carrying out a quantitative analysis is highly valuable as it points out the most important indicators. Application of this analysis showed that in both cases there is a strong need for improvement of information provision and coordinated spatial planning.

- Maintenance of defensive structures
- Flood risk maps / policy
    - Laws and legislation
    - Building codes
    - Land use regulations
    - Zoning / designation
- Flood mitigation incentives
- Non-developments incentives
- Relocation incentives / buy out
- Flood forecasting system
- Flood warning system
- Flood risk assessment models
- Flood-related data-bases
- Public information / awareness
    - Media campaigns
    - Education
    - Neighborhood projects
- Evacuation schemes
- Emergency exercises
- Cultural aspects / habits
    - Individual preparedness
    - Swimming lessons
    - Emergency stock (household)
- Drainage capacity
- Separate sewer system
- Urban infiltration areas
- Multiple land use areas
- Urban retention areas
- Wet flood proofing
    - Interiors
    - Public facilities
    - Public utilities
- Dry flood proofing
    - Industrial facilities
    - Commercial facilities
    - Secondary embankments
- Emergency shelters
- Structure elevation
- Floating structures
- Hardening critical infrastructure
    - Elevation
    - Wet flood proofing
    - Dry flood proofing
- Flood insurance
- Damage compensation regulations
- Disaster aid organization
- Disaster aid instruments / material

Figure 5.1: List of the identified resilience measures used in this thesis

Successful implementation of a flood risk management strategy depends on an accurate analysis of the local socio-physical situation and on the serious consideration of the *environmental* and *institutional context*. To fit a flood risk management strategy to the local conditions decision-makers can invest in resistance and/or resilience measures.
As it turns out in this research, a flood risk management strategy that consists of both resistance and resilience aspects offers the best opportunities to achieve long term sustainability because it is both robust and flexible at the same time. Therefore this thesis proposes to formulate a so-called *balanced strategy* (Figure 5.2) for delta regions by which decision-makers consciously invest in measures that fit the unique local conditions. By focusing on a specific type of resilience measures, like information provision or flood proofing efforts, nuances can be put in the flood risk management strategy in accordance to the specific needs of a locality.
The results of the case studies show that application of a balanced strategy would indeed reduce vulnerability in both cases, and that further research on this proposition is valuable.

The research shows that an important requirement to successfully implement a balanced flood risk management strategy is the application of strategic *spatial planning*. By repeatedly performing risk assessments, and creating, updating and using flood maps, spatial developments can be steered, adapted, or limited in accordance with the local flood risk.
The gradual transformation of built environment into a flood proof community takes decennia, but starts at ensuring that new developments are sustainable. Many of the proposed measures to upgrade a region's resilience can be implemented through well considered spatial planning (see also Godschalk, 2002). Good examples are risk zoning regulations that limit the intensity of development and compartmentalization; an area as a whole is considered more resilient if the less valuable parts are flooded prior to the more valuable parts, which are being safeguarded longest (Vis *et al.*, 2003).
Although many authors stress the importance and possible opportunities of spatial planning in handling the flood risk assignment, its actual role is still very limited in both the analyzed cases. These results subscribe NWP and Deltares (2009) who say that the awareness that deltas are potentially risky areas is growing, but that there are hardly examples of formal risk based spatial planning in practice.
An explanation for this phenomenon can be that in many regions the present high safety standards sustain the impression that the dike-rings are safe areas to live in, with the effect that there are no strong incentives to continue minimizing vulnerability to flooding by appropriate land use planning

The importance of adopting a hybrid strategy of combined resistance and resilience based measures is confirmed, however, constant monitoring, evaluation and adaptation to changing circumstances is needed to make it successful. This is why it is called a management strategy; it is not a one-time fix but an *ongoing process* of implementing measures. For this, a strong legislative foundation is essential. If executed well, a resilience based strategy may turn risk into opportunity as resilience is not fixed in a certain development.

To ensure effective management there is a need for flexible, vital and committed social communities and institutions that are able to anticipate to changing conditions, enabling the possibility to make strong decisions and enforce new policy in the light of the present and future flood risk. In order to make a flood risk management strategy successful not only built environment, but also the social environment needs to be adapted to the present flood risk.

Adapting the institutions that shape built environment is a first step in the evolutional process that makes society gradually more resilient. Improvement of the social and physical adaptive capacities will generate flexibility and the ability to adapt to changing circumstances.

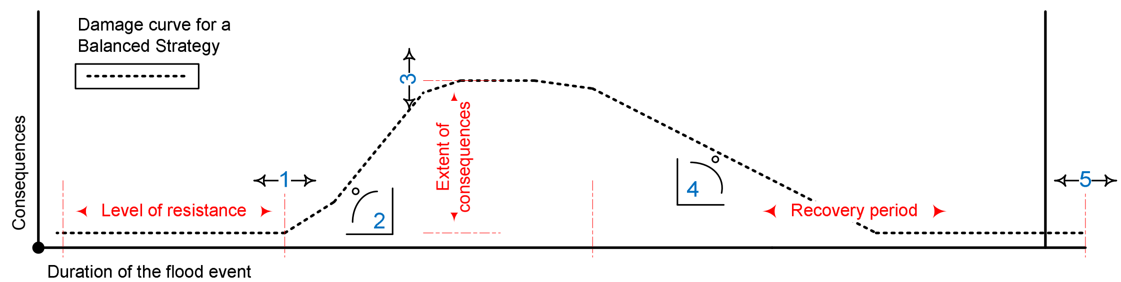


Figure 5.2: Visualization of a Balanced Strategy. The arrows indicate the effect of moving the balance between resistance and resilience

1. The higher the level of resistance the longer it takes before high water affects society
2. The pace of damage increase is determined by the level of physical and social preparedness. With very high resistance levels damage increase may be high as well because of the sudden and unexpected character of the flood
3. The extent of damage reduces with higher levels of resilience e.g. by flood proofing buildings and infrastructure
4. In resilient communities the consequences decrease gradually as water withdraws
5. Some resilience measures reduce the period a society needs to recover from disruption

From the case study analyses I can conclude that in the Netherlands flood risk management mainly focused on offering resistance, while recently a tendency towards a more integral, adaptive based strategy can be seen.

In New Orleans the historical levee protection system has been upgraded several times in the past. Although rather randomly applied, efforts of internal flood mitigation that are scaled under resilience measures in this thesis are gaining more attention in the last decennia. Mainly flood proofing and structure elevation are examples of this.

The specific case of New Orleans showed that a key aspect in achieving a more resilient community is *information provision and education*. Risk awareness creates self-preparedness and offers a good argument for implementing certain radical measures that are beneficial to all on the long run.

As an outcome of this research I would like to take the message to policy- and decision-makers that there are major opportunities for delta regions when switching the focus in flood risk management towards a more hybrid, or balanced, flood risk management strategy, especially in the light of climate change.

This thesis proposes several methods that can help determining possible resilience based measures complement to the existing defense works. It is shown that both in the Netherlands as in New Orleans such a balanced strategy would significantly reduce vulnerability. This strengthens the suspicion that a balanced strategy can be successfully implemented in any delta region, if tailor made to the local conditions and context.

The risk and vulnerability assessment methods proposed in this thesis are useful, although it is recommended to remain cautious in applying them in practice. There are many external factors hidden in the complexity of delta regions that can significantly influence the validity of the results.

In line with the previous mentioned further empirical research is needed to refine flood risk management theory and methodology. It is recommended to adopt the risk formula suggested in this thesis - Risk = *f* (Hazard * Exposure * Vulnerability) - in subsequent studies in order to obtain a more accurate insight in the actual risk.

Additional research is needed on how to transform the applied resilience indicators and the obtained results of risk assessments and vulnerability analyses into concrete practical action.

All developments that take place influence the vulnerability of society and contribute to the flood risk. Therefore it is time to close the gap between water management and spatial planning. In unfavorable environments like that of New Orleans all developments should take place in the light of the present risk if sustainability is desired. Further research is needed on how to increase effectiveness of sustainable development policy in respect to flood risk.

As a final remark I like to emphasize it would be of great value to study more cases worldwide. This will help international flood risk management to determine the possible implementation methods of specific measures. Comparison of delta regions is needed to gain better insight in the essential role that the local context plays in flood risk management.

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Appendix A - Score tables case New Orleans

A-1: Codes used: *Absorption* and *Adaptive Capacity*

Assumption: *Resilience* is determined by adaptive and absorption capacity
Coding applied:

A = Social adaptive capacity; **B** = Physical adaptive capacity; **C** = Absorption capacity

Pre-flood	Weak	Low	Marginal	High	Strong		
19 indicators; max. score = 19 (100%)	1/5	2/5	3/5	4/5	1	Code	
Maintenance of defensive structures			♫			B	
Flood risk maps / policy			♫			A	
Laws and legislation				♫		A	
Building codes			♫			B	
Land use regulations			♫			A	
Zoning / designation			♫			A	
Flood mitigation incentives		♫				A	
Non-developments incentives			♫			A	
Relocation incentives / buy out			♫			A	
Flood forecasting system					♫	B	
Flood warning system				♫		B	
Flood risk assessment models				♫		B	
Flood-related data-bases				♫		B	
Public information / awareness			♫			A	
Media campaigns		♫				A	
Education			♫			A	
Neighborhood projects			♫			A	
Evacuation schemes					♫	A	
Emergency exercises			♫			A	
Total =	0	0,8	6,6	3,2	2	12,6	66,32 %

Inundation	W	L	M	H	S		
23 indicators; max. score = 23 (100%)	1/5	2/5	3/5	4/5	1	Code	
Cultural aspects / habits		♫				A	
Individual preparedness			♫			A	
Swimming lessons	♫					A	
Emergency stock (household)		♫				A	
Drainage capacity		♫				C	
Separate sewer system	♫					C	
Urban infiltration areas	♫					C	
Multiple land use areas		♫				C	
Urban retention areas	♫					C	
Wet flood proofing				♫		B	
Interiors				♫		B	
Public functions			♫			B	
Dry flood proofing				♫		B	
Industrial facilities				♫		B	
Commercial facilities				♫		B	
Secondary embankments			♫			B	
Emergency shelters				♫		B	
Structure elevation			♫			B	
Floating structures	♫					B	
Hardening critical infrastructure		♫				B	
Elevation		♫				B	
Wet flood proofing			♫			B	
Dry flood proofing		♫				B	
Total =	1	2,8	3	4,8	0	11,6	50,43 %

Post inundation	W	L	M	H	S		
4 indicators; max. score = 4 (100%)	1/5	2/5	3/5	4/5	1	Code	
Flood insurance			♫			A	
Damage compensation regulations				♫		A	
Disaster aid organization					♫	A	
Disaster aid instruments / material				♫		A	
Total =	0	0	0,6	1,6	1	3,2	80,00 %

A-2: Weight set used: *Information provision* and *Education*

Assumption: **Information** provision and education is the basis for effective flood risk management
Weight sets applied:

Weights = **1 to 3**:
3 = Information gathering and communication
2 = Direct Resulting policy, schemes and actions
1 = Indirect resulting measures

Weight = **10**
6 = Information gathering and communication
3 = Direct Resulting policy, schemes and actions
1 = Indirect resulting measures

Pre-flood	**Weak**	**Low**	**Marginal**	**High**	**Strong**	**Weight**		**Weight**	
19 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Maintenance of defensive structures			♫			1	0,6	1	0,6
Flood risk maps / policy			♫			3	1,8	6	3,6
Laws and legislation				♫		2	1,6	3	2,4
Building codes			♫			2	1,2	3	1,8
Land use regulations			♫			2	1,2	3	1,8
Zoning / designation			♫			2	1,2	3	1,8
Flood mitigation incentives		♫				1	0,4	1	0,4
Non-developments incentives			♫			1	0,6	1	0,6
Relocation incentives / buy out			♫			1	0,6	1	0,6
Flood forecasting system					♫	3	3,0	6	6,0
Flood warning system				♫		2	1,6	3	2,4
Flood risk assessment models				♫		3	2,4	6	4,8
Flood-related data-bases				♫		3	2,4	6	4,8
Public information / awareness			♫			3	1,8	6	3,6
Media campaigns		♫				3	1,2	6	2,4
Education			♫			3	1,8	6	3,6
Neighborhood projects			♫			3	1,8	6	3,6
Evacuation schemes					♫	2	2,0	3	3,0
Emergency exercises			♫			2	1,2	3	1,8
Total =	0	1,6	13,2	8	5		**28,4**		**49,6**

Inundation	**W**	**L**	**M**	**H**	**S**	**Weight**		**Weight**	
23 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Cultural aspects / habits		♫				2	0,8	3	1,2
Individual preparedness			♫			2	1,2	3	1,8
Swimming lessons	♫					2	0,4	3	0,6
Emergency stock (household)		♫				2	0,8	3	1,2
Drainage capacity		♫				1	0,4	1	0,4
Separate sewer system	♫					1	0,2	1	0,2
Urban infiltration areas	♫					1	0,2	1	0,2
Multiple land use areas		♫				1	0,4	1	0,4
Urban retention areas	♫					1	0,2	1	0,2
Wet flood proofing				♫		1	0,8	1	0,8
Interiors				♫		1	0,8	1	0,8
Public functions			♫			1	0,6	1	0,6
Dry flood proofing				♫		1	0,8	1	0,8
Industrial facilities				♫		1	0,8	1	0,8
Commercial facilities				♫		1	0,8	1	0,8
Secondary embankments			♫			1	0,6	1	0,6
Emergency shelters				♫		1	0,8	1	0,8
Structure elevation			♫			1	0,6	1	0,6
Floating structures	♫					1	0,2	1	0,2
Hardening critical infrastructure		♫				1	0,4	1	0,4
Elevation		♫				1	0,4	1	0,4
Wet flood proofing			♫			1	0,6	1	0,6
Dry flood proofing		♫				1	0,4	1	0,4
Total =	1,2	3,6	3,6	4,8	0		**13,2**		**14,8**

Post inundation	**W**	**L**	**M**	**H**	**S**	**Weight**		**Weight**	
4 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Flood insurance			♫			2	1,2	3	1,8
Damage compensation regulations				♫		2	1,6	3	2,4
Disaster aid organization					♫	2	2,0	3	3,0
Disaster aid instruments / material				♫		2	1,6	3	2,4
Total =	0	0	1,2	3,2	2		**6,4**		**9,6**

A-3: Weight set used: *Law, Legislation* and *Spatial planning*

Assumption: **Law, legislation** and **spatial planning** offer long term sustainability
Weight sets applied:

Weights = **1 to 3**:
4 = Law and legislation
3 = Spatial Planning
2 = Engineering
1 = Other

Weight = **10**
4 = Law and legislation
4 = Spatial Planning
1 = Engineering
1 = Other

Pre-flood		Weak	Low	Marginal	High	Strong	Weight		Weight	
19 indicators		1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Maintenance of defensive structures				♫			3	1,8	4	2,4
Flood risk maps / policy				♫			1	0,6	1	0,6
	Laws and legislation				♫		4	3,2	4	3,2
	Building codes			♫			4	2,4	4	2,4
	Land use regulations			♫			3	1,8	4	2,4
	Zoning / designation			♫			3	1,8	4	2,4
Flood mitigation incentives			♫				2	0,8	1	0,4
Non-developments incentives				♫			3	1,8	4	2,4
Relocation incentives / buy out				♫			3	1,8	4	2,4
Flood forecasting system						♫	1	1,0	1	1,0
Flood warning system					♫		1	0,8	1	0,8
Flood risk assessment models					♫		1	0,8	1	0,8
Flood-related data-bases					♫		1	0,8	1	0,8
Public information / awareness				♫			1	0,6	1	0,6
	Media campaigns		♫				1	0,4	1	0,4
	Education			♫			1	0,6	1	0,6
	Neighborhood projects			♫			1	0,6	1	0,6
Evacuation schemes						♫	3	3,0	4	4,0
Emergency exercises				♫			1	0,6	4	2,4
	Total =	0	1,2	14,4	5,6	4		**25,2**		**30,6**

Inundation		W	L	M	H	S	Weight		Weight	
23 indicators		1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Cultural aspects / habits			♫				1	0,4	1	0,4
	Individual preparedness			♫			1	0,6	1	0,6
	Swimming lessons	♫					1	0,2	1	0,2
	Emergency stock (household)		♫				1	0,4	1	0,4
Drainage capacity			♫				2	0,8	1	0,4
Separate sewer system		♫					2	0,4	1	0,2
Urban infiltration areas		♫					3	0,6	4	0,8
Multiple land use areas			♫				3	1,2	4	1,6
Urban retention areas		♫					3	0,6	4	0,8
Wet flood proofing					♫		2	1,6	1	0,8
	Interiors				♫		2	1,6	1	0,8
	Public functions			♫			2	1,2	1	0,6
Dry flood proofing					♫		2	1,6	1	0,8
	Industrial facilities				♫		2	1,6	1	0,8
	Commercial facilities				♫		2	1,6	1	0,8
	Secondary embankments			♫			2	1,2	1	0,6
Emergency shelters					♫		2	1,6	1	0,8
Structure elevation				♫			2	1,2	1	0,6
Floating structures		♫					2	0,4	1	0,2
Hardening critical infrastructure			♫				2	0,8	1	0,4
	Elevation		♫				2	0,8	1	0,4
	Wet flood proofing			♫			2	1,2	1	0,6
	Dry flood proofing		♫				2	0,8	1	0,4
	Total =	2,2	5,2	5,4	9,6	0		**22,4**		**14,0**

Post inundation		W	L	M	H	S	Weight		Weight	
4 indicators		1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Flood insurance				♫			4	2,4	4	2,4
Damage compensation regulations					♫		4	3,2	4	3,2
Disaster aid organization						♫	1	1,0	1	1,0
Disaster aid instruments / material					♫		1	0,8	1	0,8
	Total =	0	0	2,4	4	1		**7,4**		**7,4**

A-4: Weight set used: *Non-physical measures*

Assumption: Focus should be on **non-physical**, **resilience** enhancing measures
Weight sets applied:

Weights = **1 to 3**:
3 = Non-physical measures
2 = Physical measures aimed at resilience
1 = Physical measures aimed at resistance

Weight = **10**
5 = Non-physical measures
4 = Physical measures aimed at resilience
1 = Physical measures aimed at resistance

Pre-flood	**Weak**	**Low**	**Marginal**	**High**	**Strong**	**Weight**		**Weight**	
19 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Maintenance of defensive structures			♫			1	0,6	1	0,6
Flood risk maps / policy			♫			3	1,8	5	3,0
Laws and legislation				♫		2	1,6	4	3,2
Building codes			♫			2	1,2	4	2,4
Land use regulations			♫			2	1,2	4	2,4
Zoning / designation			♫			2	1,2	4	2,4
Flood mitigation incentives		♫				2	0,8	4	1,6
Non-developments incentives			♫			2	1,2	4	2,4
Relocation incentives / buy out			♫			2	1,2	4	2,4
Flood forecasting system					♫	3	3,0	5	5,0
Flood warning system				♫		2	1,6	4	3,2
Flood risk assessment models				♫		3	2,4	5	4,0
Flood-related data-bases				♫		3	2,4	5	4,0
Public information / awareness			♫			3	1,8	5	3,0
Media campaigns		♫				3	1,2	5	2,0
Education			♫			3	1,8	5	3,0
Neighborhood projects			♫			3	1,8	5	3,0
Evacuation schemes					♫	2	2,0	4	4,0
Emergency exercises			♫			2	1,2	4	2,4
Total =	0	2	15	8	5		**30,0**		**54,0**

Inundation	**W**	**L**	**M**	**H**	**S**	**Weight**		**Weight**	
23 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Cultural aspects / habits		♫				2	0,8	4	1,6
Individual preparedness			♫			2	1,2	4	2,4
Swimming lessons	♫					2	0,4	4	0,8
Emergency stock (household)		♫				2	0,8	4	1,6
Drainage capacity		♫				2	0,8	4	1,6
Separate sewer system	♫					2	0,4	4	0,8
Urban infiltration areas	♫					2	0,4	4	0,8
Multiple land use areas		♫				2	0,8	4	1,6
Urban retention areas	♫					2	0,4	4	0,8
Wet flood proofing				♫		2	1,6	4	3,2
Interiors				♫		2	1,6	4	3,2
Public functions			♫			2	1,2	4	2,4
Dry flood proofing				♫		1	0,8	1	0,8
Industrial facilities				♫		1	0,8	1	0,8
Commercial facilities				♫		1	0,8	1	0,8
Secondary embankments			♫			1	0,6	1	0,6
Emergency shelters				♫		2	1,6	4	3,2
Structure elevation			♫			2	1,2	4	2,4
Floating structures	♫					2	0,4	4	0,8
Hardening critical infrastructure		♫				2	0,8	4	1,6
Elevation		♫				2	0,8	4	1,6
Wet flood proofing			♫			2	0,6	4	0,6
Dry flood proofing		♫				1	0,4	1	0,4
Total =	2	5,2	5,4	7,2	0		**19,2**		**34,4**

Post inundation	**W**	**L**	**M**	**H**	**S**	**Weight**		**Weight**	
4 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Flood insurance			♫			2	1,2	4	2,4
Damage compensation regulations				♫		2	1,6	4	3,2
Disaster aid organization					♫	2	2,0	4	4,0
Disaster aid instruments / material				♫		2	1,6	4	3,2
Total =	0	0	1,2	3,2	2		**6,4**		**12,8**

A-5: Weight set used: *Public efforts*

Assumption: **Public efforts** are important
Weight sets applied:

Weights = **1 to 3**:
3 = Public direct life and cost saving
2 = Public indirect measures
1 = Private preparedness

Weight = **10**
5 = Public direct life and cost saving
4 = Public indirect measures
1 = Private preparedness

Pre-flood		Weak	Low	Marginal	High	Strong	Weight		Weight	
19 indicators		1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Maintenance of defensive structures				♫			3	1,8	5	3,0
Flood risk maps / policy				♫			2	1,2	4	2,4
	Laws and legislation				♫		2	1,6	4	3,2
	Building codes			♫			2	1,2	4	2,4
	Land use regulations			♫			2	1,2	4	2,4
	Zoning / designation			♫			2	1,2	4	2,4
Flood mitigation incentives			♫				3	1,2	5	2,0
Non-developments incentives				♫			3	1,8	5	3,0
Relocation incentives / buy out				♫			3	1,8	5	3,0
Flood forecasting system						♫	2	2,0	1	1,0
Flood warning system					♫		2	1,6	1	0,8
Flood risk assessment models					♫		2	1,6	1	0,8
Flood-related data-bases					♫		2	1,6	1	0,8
Public information / awareness				♫			2	1,2	1	0,6
	Media campaigns		♫				2	0,8	1	0,4
	Education			♫			2	1,2	1	0,6
	Neighborhood projects			♫			2	1,2	1	0,6
Evacuation schemes						♫	3	3,0	5	5,0
Emergency exercises				♫			3	1,8	5	3,0
	Total =	0	2	15,6	6,4	5		**29,0**		**37,4**

Inundation		W	L	M	H	S	Weight		Weight	
23 indicators		1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Cultural aspects / habits			♫				1	0,4	1	0,4
	Individual preparedness			♫			1	0,6	1	0,6
	Swimming lessons	♫					1	0,2	1	0,2
	Emergency stock (household)		♫				1	0,4	1	0,4
Drainage capacity			♫				3	1,2	5	2,0
Separate sewer system		♫					2	0,4	4	0,8
Urban infiltration areas		♫					3	0,6	5	1,0
Multiple land use areas			♫				2	0,8	4	1,6
Urban retention areas		♫					3	0,6	5	1,0
Wet flood proofing					♫		3	2,4	5	4,0
	Interiors				♫		3	2,4	5	4,0
	Public functions			♫			3	1,8	5	3,0
Dry flood proofing					♫		3	2,4	5	4,0
	Industrial facilities				♫		3	2,4	5	4,0
	Commercial facilities				♫		3	2,4	5	4,0
	Secondary embankments			♫			3	1,8	5	3,0
Emergency shelters					♫		3	2,4	5	4,0
Structure elevation				♫			3	1,8	5	3,0
Floating structures		♫					3	0,6	5	1,0
Hardening critical infrastructure			♫				2	0,8	4	1,6
	Elevation		♫				2	0,8	4	1,6
	Wet flood proofing			♫			2	1,2	4	2,4
	Dry flood proofing		♫				2	0,8	4	1,6
	Total =	2,4	5,2	7,2	14,4	0		**29,2**		**49,2**

Post inundation		W	L	M	H	S	Weight		Weight	
4 indicators		1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Flood insurance				♫			1	0,6	1	0,6
Damage compensation regulations					♫		2	1,6	4	3,2
Disaster aid organization						♫	3	3,0	5	5,0
Disaster aid instruments / material					♫		2	1,6	4	3,2
	Total =	0	0	0,6	3,2	3		**6,8**		**12,0**

A-6: Weight set used: *Information* and *spatial planning*

Assumption: **Information provision and** spatial planning are the fundaments of sustainable development
Weight sets applied:

Weights = **1 to 3**:
3 = Information gathering and provision
2 = Spatial planning and legislation
1 = Other

Weight = **10**
5 = Public direct life and cost saving
4 = Spatial planning and legislation
1 = Other

Pre-flood	Weak	Low	Marginal	High	Strong	Weight		Weight	
19 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Maintenance of defensive structures			♫			1	0,6	1	0,6
Flood risk maps / policy			♫			3	1,8	5	3,0
Laws and legislation				♫		2	1,6	4	3,2
Building codes			♫			2	1,2	4	2,4
Land use regulations			♫			2	1,2	4	2,4
Zoning / designation			♫			2	1,2	4	2,4
Flood mitigation incentives		♫				2	0,8	4	1,6
Non-developments incentives			♫			2	1,2	4	2,4
Relocation incentives / buy out			♫			2	1,2	4	2,4
Flood forecasting system					♫	3	3,0	5	5,0
Flood warning system				♫		3	2,4	5	4,0
Flood risk assessment models				♫		3	2,4	5	4,0
Flood-related data-bases				♫		3	2,4	5	4,0
Public information / awareness			♫			3	1,8	5	3,0
Media campaigns		♫				3	1,2	5	2,0
Education			♫			3	1,8	5	3,0
Neighborhood projects			♫			3	1,8	5	3,0
Evacuation schemes					♫	1	1,0	1	1,0
Emergency exercises			♫			1	0,6	1	0,6
Total =	0	2	14,4	8,8	4		**29,2**		**50,0**

Inundation	W	L	M	H	S	Weight		Weight	
23 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Cultural aspects / habits		♫				1	0,4	1	0,4
Individual preparedness			♫			1	0,6	1	0,6
Swimming lessons	♫					1	0,2	1	0,2
Emergency stock (household)		♫				1	0,4	1	0,4
Drainage capacity		♫				1	0,4	1	0,4
Separate sewer system	♫					1	0,2	1	0,2
Urban infiltration areas	♫					2	0,4	4	0,8
Multiple land use areas		♫				2	0,8	4	1,6
Urban retention areas	♫					2	0,4	4	0,8
Wet flood proofing				♫		1	0,8	1	0,8
Interiors				♫		1	0,8	1	0,8
Public functions			♫			1	0,6	1	0,6
Dry flood proofing				♫		1	0,8	1	0,8
Industrial facilities				♫		1	0,8	1	0,8
Commercial facilities				♫		1	0,8	1	0,8
Secondary embankments			♫			1	0,6	1	0,6
Emergency shelters				♫		1	0,8	1	0,8
Structure elevation			♫			1	0,6	1	0,6
Floating structures	♫					1	0,2	1	0,2
Hardening critical infrastructure		♫				1	0,4	1	0,4
Elevation		♫				1	0,4	1	0,4
Wet flood proofing			♫			1	0,6	1	0,6
Dry flood proofing		♫				1	0,4	1	0,4
Total =	1,4	3,2	3	4,8	0		**12,4**		**14,0**

Post inundation	W	L	M	H	S	Weight		Weight	
4 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Flood insurance			♫			2	1,2	4	2,4
Damage compensation regulations				♫		2	1,6	4	3,2
Disaster aid organization					♫	1	1,0	1	1,0
Disaster aid instruments / material				♫		1	0,8	1	0,8
Total =	0	0	1,2	2,4	1		**4,6**		**7,4**

Appendix B - Score tables case the Netherlands

B-1: Codes used: *Absorption* and *Adaptive Capacity*

Assumption: *Resilience* is determined by adaptive and absorption capacity
Coding applied:

A = Social adaptive capacity; **B** = Physical adaptive capacity; **C** = Absorption capacity

Pre-flood	**Weak**	**Low**	**Marginal**	**High**	**Strong**		
19 indicators; max. score = 19 (100%)	1/5	2/5	3/5	4/5	1	**Code**	
Maintenance of defensive structures					x	B	
Flood risk maps / policy			x			A	
Laws and legislation				x		A	
Building codes		x				B	
Land use regulations			x			A	
Zoning / designation			x			A	
Flood mitigation incentives		x				A	
Non-developments incentives		x				A	
Relocation incentives / buy out		x				A	
Flood forecasting system				x		B	
Flood warning system				x		B	
Flood risk assessment models				x		B	
Flood-related data-bases				x		B	
Public information / awareness			x			A	
Media campaigns				x		A	
Education		x				A	
Neighborhood projects	x					A	
Evacuation schemes		x				A	
Emergency exercises			x			A	
Total =	0,2	2,4	3	4,8	1	**11,4**	**60,00 %**

Inundation	**W**	**L**	**M**	**H**	**S**		
23 indicators; max. score = 23 (100%)	1/5	2/5	3/5	4/5	1	**Code**	
Cultural aspects / habits			x			A	
Individual preparedness	x					A	
Swimming lessons				x		A	
Emergency stock (household)	x					A	
Drainage capacity				x		C	
Separate sewer system				x		C	
Urban infiltration areas			x			C	
Multiple land use areas			x			C	
Urban retention areas		x				C	
Wet flood proofing	x					B	
Interiors	x					B	
Public functions	x					B	
Dry flood proofing		x				B	
Industrial facilities		x				B	
Commercial facilities	x					B	
Secondary embankments			x			B	
Emergency shelters	x					B	
Structure elevation		x				B	
Floating structures		x				B	
Hardening critical infrastructure	x					B	
Elevation		x				B	
Wet flood proofing	x					B	
Dry flood proofing	x					B	
Total =	2	2,4	2,4	2,4	0	**9,2**	**40,00 %**

Post inundation	**W**	**L**	**M**	**H**	**S**		
4 indicators; max. score = 4 (100%)	1/5	2/5	3/5	4/5	1	**Code**	
Flood insurance	x					A	
Damage compensation regulations			x			A	
Disaster aid organization				x		A	
Disaster aid instruments / material			x			A	
Total =	0,2	0	1,2	0,8	0	**2,2**	**55,00 %**

B-2: Weight set used: *Information provision* and *Education*

Assumption: **Information** provision and education is the basis for effective flood risk management
Weight sets applied:

Weights = **1 to 3**:
3 = Information gathering and communication
2 = Direct Resulting policy, schemes and actions
1 = Indirect resulting measures

Weight = **10**
6 = Information gathering and communication
3 = Direct Resulting policy, schemes and actions
1 = Indirect resulting measures

Pre-flood	**Weak**	**Low**	**Marginal**	**High**	**Strong**	**Weight**		**Weight**	
19 indicators	**1/5**	**2/5**	**3/5**	**4/5**	**1**	**1 to 3**	**Score**	**10**	**Score**
Maintenance of defensive structures					X	1	1,0	1	1,0
Flood risk maps / policy			X			3	1,8	6	3,6
Laws and legislation				X		2	1,6	3	2,4
Building codes		X				2	0,8	3	1,2
Land use regulations			X			2	1,2	3	1,8
Zoning / designation			X			2	1,2	3	1,8
Flood mitigation incentives		X				1	0,4	1	0,4
Non-developments incentives		X				1	0,4	1	0,4
Relocation incentives / buy out		X				1	0,4	1	0,4
Flood forecasting system				X		3	2,4	6	4,8
Flood warning system				X		2	1,6	3	2,4
Flood risk assessment models				X		3	2,4	6	4,8
Flood-related data-bases				X		3	2,4	6	4,8
Public information / awareness			X			3	1,8	6	3,6
Media campaigns				X		3	2,4	6	4,8
Education		X				3	1,2	6	2,4
Neighborhood projects	X					3	0,6	6	1,2
Evacuation schemes		X				2	0,8	3	1,2
Emergency exercises			X			2	1,2	3	1,8
Total **1 to 3 / 10**	0,4 / 0,2	5,6 / 9,6	10,2 / 12,6	8,8 / 9,6	0 / 0		**25,6**		**44,8**

Inundation	**W**	**L**	**M**	**H**	**S**	**Weight**		**Weight**	
23 indicators	**1/5**	**2/5**	**3/5**	**4/5**	**1**	**1 to 3**	**Score**	**10**	**Score**
Cultural aspects / habits			X			2	1,2	3	1,8
Individual preparedness	X					2	0,4	3	0,6
Swimming lessons				X		2	1,6	3	2,4
Emergency stock (household)	X					2	0,4	3	0,6
Drainage capacity				X		1	0,8	1	0,8
Separate sewer system				X		1	0,8	1	0,8
Urban infiltration areas			X			1	0,6	1	0,6
Multiple land use areas			X			1	0,6	1	0,6
Urban retention areas		X				1	0,4	1	0,4
Wet flood proofing	X					1	0,2	1	0,2
Interiors	X					1	0,2	1	0,2
Public functions	X					1	0,2	1	0,2
Dry flood proofing		X				1	0,4	1	0,4
Industrial facilities		X				1	0,4	1	0,4
Commercial facilities	X					1	0,2	1	0,2
Secondary embankments			X			1	0,6	1	0,6
Emergency shelters	X					1	0,2	1	0,2
Structure elevation		X				1	0,4	1	0,4
Floating structures		X				1	0,4	1	0,4
Hardening critical infrastructure	X					1	0,2	1	0,2
Elevation		X				1	0,4	1	0,4
Wet flood proofing	X					1	0,2	1	0,2
Dry flood proofing	X					1	0,2	1	0,2
Total **1 to 3 / 10**	3,8 / 6,6	3,6 / 5,6	10,8 / 15	6,4 / 11,2	1 / 1		**11,0**		**12,8**

Post inundation	**W**	**L**	**M**	**H**	**S**	**Weight**		**Weight**	
4 indicators	**1/5**	**2/5**	**3/5**	**4/5**	**1**	**1 to 3**	**Score**	**10**	**Score**
Flood insurance	X					2	0,4	3	0,6
Damage compensation regulations			X			2	1,2	3	1,8
Disaster aid organization				X		2	1,6	3	2,4
Disaster aid instruments / material			X			2	1,2	3	1,8
Total **1 to 3 / 10**	0,2 / 0,2	0 / 0	1,2 / 2,4	4 / 7,2	0 / 0		**4,4**		**6,6**

B-3: Weight set used: *Law, Legislation* and *Spatial planning*

Assumption: **Law, legislation** and **spatial planning** offer long term sustainability
Weight sets applied:

Weights = **1 to 3**:
4 = Law and legislation
3 = Spatial Planning
2 = Engineering
1 = Other

Weight = **10**
4 = Law and legislation
4 = Spatial Planning
1 = Engineering
1 = Other

Pre-flood	Weak	Low	Marginal	High	Strong	Weight		Weight	
19 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Maintenance of defensive structures					X	3	3,0	4	4,0
Flood risk maps / policy			X			1	0,6	1	0,6
Laws and legislation				X		4	3,2	4	3,2
Building codes		X				4	1,6	4	1,6
Land use regulations			X			3	1,8	4	2,4
Zoning / designation			X			3	1,8	4	2,4
Flood mitigation incentives		X				2	0,8	1	0,4
Non-developments incentives		X				3	1,2	4	1,6
Relocation incentives / buy out		X				3	1,2	4	1,6
Flood forecasting system				X		1	0,8	1	0,8
Flood warning system				X		1	0,8	1	0,8
Flood risk assessment models				X		1	0,8	1	0,8
Flood-related data-bases				X		1	0,8	1	0,8
Public information / awareness			X			1	0,6	1	0,6
Media campaigns				X		1	0,8	1	0,8
Education		X				1	0,4	1	0,4
Neighborhood projects	X					1	0,2	1	0,2
Evacuation schemes		X				3	1,2	4	1,6
Emergency exercises			X			1	0,6	4	2,4
Total 1 to 3 / 10	0,4 / 0,2	5,6 / 9,6	10,2 / 12,6	8,8 / 9,6	0 / 0		22,2		27,0

Inundation	W	L	M	H	S	Weight		Weight	
23 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Cultural aspects / habits			X			1	0,6	1	0,6
Individual preparedness	X					1	0,2	1	0,2
Swimming lessons				X		1	0,8	1	0,8
Emergency stock (household)	X					1	0,2	1	0,2
Drainage capacity				X		2	1,6	1	0,8
Separate sewer system				X		2	1,6	1	0,8
Urban infiltration areas			X			3	1,8	4	2,4
Multiple land use areas			X			3	1,8	4	2,4
Urban retention areas		X				3	1,2	4	1,6
Wet flood proofing	X					2	0,4	1	0,2
Interiors	X					2	0,4	1	0,2
Public functions	X					2	0,4	1	0,2
Dry flood proofing		X				2	0,8	1	0,4
Industrial facilities		X				2	0,8	1	0,4
Commercial facilities	X					2	0,4	1	0,2
Secondary embankments			X			2	1,2	1	0,6
Emergency shelters	X					2	0,4	1	0,2
Structure elevation		X				2	0,8	1	0,4
Floating structures		X				2	0,8	1	0,4
Hardening critical infrastructure	X					2	0,4	1	0,2
Elevation		X				2	0,8	1	0,4
Wet flood proofing	X					2	0,4	1	0,2
Dry flood proofing	X					2	0,4	1	0,2
Total 1 to 3 / 10	3,8 / 6,6	3,6 / 5,6	10,8 / 15	6,4 / 11,2	1 / 1		18,2		14,0

Post inundation	W	L	M	H	S	Weight		Weight	
4 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Flood insurance	X					4	0,8	4	0,8
Damage compensation regulations			X			4	2,4	4	2,4
Disaster aid organization				X		1	0,8	1	0,8
Disaster aid instruments / material			X			1	0,6	1	0,6
Total 1 to 3 / 10	0,2 / 0,2	0 / 0	1,2 / 2,4	4 / 7,2	0 / 0		4,6		4,6

B-4: Weight set used: *Non-physical measures*

Assumption: Focus should be on **non-physical**, **resilience** enhancing measures
Weight sets applied:

Weights = **1 to 3**:
3 = Non-physical measures
2 = Physical measures aimed at resilience
1 = Physical measures aimed at resistance

Weight = **10**
5 = Non-physical measures
4 = Physical measures aimed at resilience
1 = Physical measures aimed at resistance

Pre-flood	**Weak**	**Low**	**Marginal**	**High**	**Strong**	**Weight**		**Weight**	
19 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Maintenance of defensive structures					X	1	1,0	1	1,0
Flood risk maps / policy			X			3	1,8	5	3,0
Laws and legislation				X		2	1,6	4	3,2
Building codes		X				2	0,8	4	1,6
Land use regulations			X			2	1,2	4	2,4
Zoning / designation			X			2	1,2	4	2,4
Flood mitigation incentives		X				2	0,8	4	1,6
Non-developments incentives		X				2	0,8	4	1,6
Relocation incentives / buy out		X				2	0,8	4	1,6
Flood forecasting system				X		3	2,4	5	4,0
Flood warning system				X		2	1,6	4	3,2
Flood risk assessment models				X		3	2,4	5	4,0
Flood-related data-bases				X		3	2,4	5	4,0
Public information / awareness			X			3	1,8	5	3,0
Media campaigns				X		3	2,4	5	4,0
Education		X				3	1,2	5	2,0
Neighborhood projects	X					3	0,6	5	1,0
Evacuation schemes		X				2	0,8	4	1,6
Emergency exercises			X			2	1,2	4	2,4
Total **1 to 3 / 10**	0,4 / 0,2	5,6 / 9,6	10,2 / 12,6	8,8 / 9,6	0 / 0		**26,8**		**47,6**

Inundation	**W**	**L**	**M**	**H**	**S**	**Weight**		**Weight**	
23 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Cultural aspects / habits			X			2	1,2	4	2,4
Individual preparedness	X					2	0,4	4	0,8
Swimming lessons				X		2	1,6	4	3,2
Emergency stock (household)	X					2	0,4	4	0,8
Drainage capacity				X		2	1,6	4	3,2
Separate sewer system				X		2	1,6	4	3,2
Urban infiltration areas			X			2	1,2	4	2,4
Multiple land use areas			X			2	1,2	4	2,4
Urban retention areas		X				2	0,8	4	1,6
Wet flood proofing	X					2	0,4	4	0,8
Interiors	X					2	0,4	4	0,8
Public functions	X					2	0,4	4	0,8
Dry flood proofing		X				1	0,4	1	0,4
Industrial facilities		X				1	0,4	1	0,4
Commercial facilities	X					1	0,2	1	0,2
Secondary embankments			X			1	0,6	1	0,6
Emergency shelters	X					2	0,4	4	0,8
Structure elevation		X				2	0,8	4	1,6
Floating structures		X				2	0,8	4	1,6
Hardening critical infrastructure	X					2	0,4	4	0,8
Elevation		X				2	0,8	4	1,6
Wet flood proofing	X					2	0,2	4	0,2
Dry flood proofing	X					1	0,2	1	0,2
Total **1 to 3 / 10**	3,8 / 6,6	3,6 / 5,6	10,8 / 15	6,4 / 11,2	1 / 1		**16,4**		**30,8**

Post inundation	**W**	**L**	**M**	**H**	**S**	**Weight**		**Weight**	
4 indicators	1/5	2/5	3/5	4/5	1	**1 to 3**	**Score**	**10**	**Score**
Flood insurance	X					2	0,4	4	0,8
Damage compensation regulations			X			2	1,2	4	2,4
Disaster aid organization				X		2	1,6	4	3,2
Disaster aid instruments / material			X			2	1,2	4	2,4
Total **1 to 3 / 10**	0,2 / 0,2	0 / 0	1,2 / 2,4	4 / 7,2	0 / 0		**4,4**		**8,8**

B-5: Weight set used: *Public efforts*

Assumption: **Public efforts** are important
Weight sets applied:

Weights = **1 to 3**:
3 = Public direct life and cost saving
2 = Public indirect measures
1 = Private preparedness

Weight = **10**
5 = Public direct life and cost saving
4 = Public indirect measures
1 = Private preparedness

Pre-flood	Weak	Low	Marginal	High	Strong	Weight	Score	Weight	Score
19 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Maintenance of defensive structures					X	3	3,0	5	5,0
Flood risk maps / policy			X			2	1,2	4	2,4
Laws and legislation				X		2	1,6	4	3,2
Building codes		X				2	0,8	4	1,6
Land use regulations			X			2	1,2	4	2,4
Zoning / designation			X			2	1,2	4	2,4
Flood mitigation incentives		X				3	1,2	5	2,0
Non-developments incentives		X				3	1,2	5	2,0
Relocation incentives / buy out		X				3	1,2	5	2,0
Flood forecasting system				X		2	1,6	1	0,8
Flood warning system				X		2	1,6	1	0,8
Flood risk assessment models				X		2	1,6	1	0,8
Flood-related data-bases				X		2	1,6	1	0,8
Public information / awareness			X			2	1,2	1	0,6
Media campaigns				X		2	1,6	1	0,8
Education		X				2	0,8	1	0,4
Neighborhood projects	X					2	0,4	1	0,2
Evacuation schemes		X				3	1,2	5	2,0
Emergency exercises			X			3	1,8	5	3,0
Total **1 to 3 / 10**	0,4 / 0,2	5,6 / 9,6	10,2 / 12,6	8,8 / 9,6	0 / 0		**26,0**		**33,2**

Inundation	W	L	M	H	S	Weight	Score	Weight	Score
23 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Cultural aspects / habits			X			1	0,6	1	0,6
Individual preparedness	X					1	0,2	1	0,2
Swimming lessons				X		1	0,8	1	0,8
Emergency stock (household)	X					1	0,2	1	0,2
Drainage capacity				X		3	2,4	5	4,0
Separate sewer system				X		2	1,6	4	3,2
Urban infiltration areas			X			3	1,8	5	3,0
Multiple land use areas			X			2	1,2	4	2,4
Urban retention areas		X				3	1,2	5	2,0
Wet flood proofing	X					3	0,6	5	1,0
Interiors	X					3	0,6	5	1,0
Public functions	X					3	0,6	5	1,0
Dry flood proofing		X				3	1,2	5	2,0
Industrial facilities		X				3	1,2	5	2,0
Commercial facilities	X					3	0,6	5	1,0
Secondary embankments			X			3	1,8	5	3,0
Emergency shelters	X					3	0,6	5	1,0
Structure elevation		X				3	1,2	5	2,0
Floating structures		X				3	1,2	5	2,0
Hardening critical infrastructure	X					2	0,4	4	0,8
Elevation		X				2	0,8	4	1,6
Wet flood proofing	X					2	0,4	4	0,8
Dry flood proofing	X					2	0,4	4	0,8
Total **1 to 3 / 10**	3,8 / 6,6	3,6 / 5,6	10,8 / 15	6,4 / 11,2	1 / 1		**21,6**		**36,4**

Post inundation	W	L	M	H	S	Weight	Score	Weight	Score
4 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Flood insurance	X					1	0,2	1	0,2
Damage compensation regulations			X			2	1,2	4	2,4
Disaster aid organization				X		3	2,4	5	4,0
Disaster aid instruments / material			X			2	1,2	4	2,4
Total **1 to 3 / 10**	0,2 / 0,2	0 / 0	1,2 / 2,4	4 / 7,2	0 / 0		**5,0**		**9,0**

B-6: Weight set used: *Information* and *spatial planning*

Assumption: **Information provision and** spatial planning are the fundaments of sustainable development
Weight sets applied:

Weights = **1 to 3**:
3 = Information gathering and provision
2 = Spatial planning and legislation
1 = Other

Weight = **10**
5 = Public direct life and cost saving
4 = Spatial planning and legislation
1 = Other

Pre-flood	Weak	Low	Marginal	High	Strong	Weight		Weight	
19 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Maintenance of defensive structures					X	1	1,0	1	1,0
Flood risk maps / policy			X			3	1,8	5	3,0
Laws and legislation				X		2	1,6	4	3,2
Building codes		X				2	0,8	4	1,6
Land use regulations			X			2	1,2	4	2,4
Zoning / designation			X			2	1,2	4	2,4
Flood mitigation incentives		X				2	0,8	4	1,6
Non-developments incentives		X				2	0,8	4	1,6
Relocation incentives / buy out		X				2	0,8	4	1,6
Flood forecasting system				X		3	2,4	5	4,0
Flood warning system				X		3	2,4	5	4,0
Flood risk assessment models				X		3	2,4	5	4,0
Flood-related data-bases				X		3	2,4	5	4,0
Public information / awareness			X			3	1,8	5	3,0
Media campaigns				X		3	2,4	5	4,0
Education		X				3	1,2	5	2,0
Neighborhood projects	X					3	0,6	5	1,0
Evacuation schemes		X				1	0,4	1	0,4
Emergency exercises			X			1	0,6	1	0,6
Total 1 to 3 / 10	0,4 / 0,2	5,6 / 9,6	10,2 / 12,6	8,8 / 9,6	0 / 0		**26,6**		**45,4**

Inundation	W	L	M	H	S	Weight		Weight	
23 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Cultural aspects / habits			X			1	0,6	1	0,6
Individual preparedness	X					1	0,2	1	0,2
Swimming lessons				X		1	0,8	1	0,8
Emergency stock (household)	X					1	0,2	1	0,2
Drainage capacity				X		1	0,8	1	0,8
Separate sewer system				X		1	0,8	1	0,8
Urban infiltration areas			X			2	1,2	4	2,4
Multiple land use areas			X			2	1,2	4	2,4
Urban retention areas		X				2	0,8	4	1,6
Wet flood proofing	X					1	0,2	1	0,2
Interiors	X					1	0,2	1	0,2
Public functions	X					1	0,2	1	0,2
Dry flood proofing		X				1	0,4	1	0,4
Industrial facilities		X				1	0,4	1	0,4
Commercial facilities	X					1	0,2	1	0,2
Secondary embankments			X			1	0,6	1	0,6
Emergency shelters	X					1	0,2	1	0,2
Structure elevation		X				1	0,4	1	0,4
Floating structures		X				1	0,4	1	0,4
Hardening critical infrastructure	X					1	0,2	1	0,2
Elevation		X				1	0,4	1	0,4
Wet flood proofing	X					1	0,2	1	0,2
Dry flood proofing	X					1	0,2	1	0,2
Total 1 to 3 / 10	3,8 / 6,6	3,6 / 5,6	10,8 / 15	6,4 / 11,2	1 / 1		**10,8**		**14,0**

Post inundation	W	L	M	H	S	Weight		Weight	
4 indicators	1/5	2/5	3/5	4/5	1	1 to 3	Score	10	Score
Flood insurance	X					2	0,4	4	0,8
Damage compensation regulations			X			2	1,2	4	2,4
Disaster aid organization				X		1	0,8	1	0,8
Disaster aid instruments / material			X			1	0,6	1	0,6
Total 1 to 3 / 10	0,2 / 0,2	0 / 0	1,2 / 2,4	4 / 7,2	0 / 0		**3,0**		**4,6**

Appendix C - The Institutional Context of New Orleans

Organization	*Funding*	*Budget*	*Main Activities*
Federal Authorities and Organizations involved in recovery and flood protection			
Task Force Guardian (USACE)	100% Federal Funding		Restoration pre-Katrina HSDRRS, Roofing individual property and Emergency Power
Task Force Hope (USACE and HPO)	Funding based on cost-share principle	$ 15 billion	Re-enforcing HSDRRS too 100 year Protection level
FEMA	Project Based	$ 60 billion	Restoration of public structurres to pre-Katrina state, no rebuilding
FEMA - HGMP	Cap of $ 100.000 individually	$ 750 million	Funding of home elevation to the ABFE or BFE level - Additional to RHP (LRA) (**OCD-DRU HMGP**)
FEMA - NFIP	Flood Insurance		Flood Insurance based on elevation level of property
			Provision of emergency housing - Trailers
HUD			Public Housing, especially for poor people and elderly
State Authorities and Organizations involved in recovery and flood prtection			
Louisiana Recovery Authority (LRA)	Individual, up to $ 150.00	$ 1 billion	Loss compensation, flood proofing and elevation of private property (**Road Home Program**)
	To individual small businesses	$ 138 million	Support small businesses recovery (**Business Recovery Grant and Loan Program**)
	Training of workers	$ 38 million	Training to fill high-demand jobs in construction, healthc., transp., advanced manufact., oil and gas, and the cultural sector (**RWTP**)
	Allocation of funds to Parishes for long-term plans	$ 700 million	Lousiana Speaks spatial planning program (Long term community planning task force)
CPRAL			Design of Louisiana's Comprehensive Master Plan for a Sustainable Coast
Local and Regional Authorities and Organizations involved in Urban Planning and Water Management			
City of Orleans / Orleans Parish - SWB	Local funding from tax revenues		Drainage of Orleans Parish
City of Orleans - NORA	State funding?		Selling of acquired properties to adjacent lots for de-densification of flood prone areas (**Lot Ext Door Program**)
			Acquiring blighted properties, back sale and donation (**REALM, Blighted Property Acquisition Program**)
			Expropriation and redevelopment of vacant and abandoned properties. Also implementing Community Improvement Plans
NO Hazard Mitigation unit			Comunication with public, hazard mitigation in NOLA Masterplan
St. Bernard Parish - DSD			Drainage of St. Bernard Parish
Jefferson Parish - DSD			Drainage of Jefferson Parish
Orleans Levee District			Constructing, operating and maintaining the Mississippi River and Hurricane Protection Flood Control Systems
East Jefferson Levee District			Maintains and operates the flood protection levee system around the east bank portion of Jefferson Parish
Lake Borgne Basin Levee District			Maintains and operates the flood protection levee system around the east bank portion of St. Bernard Parish
Southeast Louisiana Flood Protection Authority East			Coordinating the flood and hurricane protection systems of St. Bernard parish, the east bank of Orleans and Jefferson Parish
Other Institutions and Organizations involved in Recovery, Planning and Water Management			
Bring New Orleans Back			
Unified New Orleans			
Flood Protection Alliance			
Infrastructure Committee			
Center for Planning Excellence (CPEX)			
Abbreviations			
ABFE	Advisory Base Flood Elevation		
BFE	Base Flood Elevation		
CPRAL	Coastal Protection and Restoration Authority Louisiana		
DSD	Drainage and Sanitation Department		
FEMA	Federal Emergensy Management Agency		
HMGP	Hazard Mitigation Grant Program		
HPO	Hurricane Protection Office		
HUD	US Department of Housing and Urban Development		
NFIP	National Flood Insurance Program		
NORA	New Orleans Redevelopment Authority		
OCD-DRU	Office of Community Development – Disaster Recovery Unit		
REALM	Real Estate Acquisition and Land-banking Mechanism		
RWTP	Recovery Work Force Training Program		
SWB	Sewerage and Water Board		
USACE	US Army Corps of Engineers		

Appendix D - Results of the experts consultancy on the Netherlands case study

	Weak	Low	Marginal	High	Strong
Maintenance of defensive structures			F	BJ	TMKX
Laws and legislation	M	F		BJX	TK
Building codes	M	BFK	JX		T
Land use regulations	M	BK	JFX		T
Zoning / designation		BJK	FMX		T
Flood mitigation incentives	MKX	BJ	F	T	
Non-developments incentives	K	BJF	X	TM	
Relocation incentives / buy out	K	BFX	JT	M	
Flood forecasting system				BJFK	TMX
Flood warning system		J		BTFKX	M
Flood risk assessment models		J		TFX	BM
Flood-related data-bases			J	BTFX	M
Media campaigns		K	BJX	TFM	
Education	M	JFK	BT	X	
Neighborhood projects	JTF	BKX	M		
Evacuation schemes		BJT	FMX	K	
Emergency exercises	M	BJT	F	KX	
Level of individual preparedness	BJTMX	F	K		
Swimming lessons	MK			BX	JTF
Emergency stock (household)	TMKX	BJF			
Drainage capacity			F	BJTMX	
Separate sewer system	M		TX	J	BF
Urban infiltration areas	K	TM	JFX	B	
Multiple land use areas	K	TF	JX	BM	
Urban retention areas	K	TMX	F	BJ	
Wet flood proofing interiors	JTMKX	BF			
Wet flood proofing public functions	TMKX	BJF			
Dry flood proofing Industrial facilities	MKX	BJ	TF		
Dry flood proofing Commercial facilities	MKX	BJF		T	
Usage of Secondary embankments			BTFKX	J	M
Emergency shelters	BJTFM	X	K		
Structure elevation	F	BJTK		X	
Floating structures		BJTFK	X		
Elevation of critical infrastructure	BJFM	TKX			
Wet flood proofing critical infrastructure	BJTMX	F			
Dry flood proofing critical infrastructure	JTMX	BF			
Availability of flood insurance	BJFMKX	T			
Damage compensation regulations		T	BFMX	J	
Disaster aid organization		T	BF	JMX	
Disaster aid instruments / material stock		BTF	J	MX	