Safe and Dynamic Drechtsteden

Re-balance the natural processes and human interventions through integrated flood risk management

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Delta interventions
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Appendix: Literature review
Project Background
The water is rising

Global warming leads to sea level rise, and affect the river discharge fluctuations. If the Rhine discharges increases, the discharge capacity of the Waal will have to be increased as well. Higher discharges combined with sea level rise have consequences for flood protection at ‘critical’ locations. The flood risk map on the right side shows that mainly the Rotterdam and Drechtsteden areas are both vulnerable and hazardous, due to the fact that floods may occur suddenly since the cities is located too close to the embankment, and this area is highly urbanized as the economic engine of the whole country (De Bruijn et al. 2009, p.15). Therefore, the flood risk management is a pressing issue right now, especially taking into account that these high density cities are also increasing in value along the time.

Delta cities are in danger

Nearly 9 million people live immediately behind the coast, in the low-lying plain areas of the Netherlands below sea level, protected by dikes and dunes along the main rivers and the lakes, while roughly 65% of GNP is generated here (Deltacommissie. 2008, p.21). This region is also the centre of the nation’s economy with heavy transport network as well as important locations for the goods and services industries. These are important reasons for maintaining such strict standards for flood protection. According to the results of the second safety audit of the primary flood defences (2006), the economic and social damage of a flooding in this densely populated and intensively utilized delta is unimaginable.
Flood risks and flood risk management

In this project, flood risk is defined as the expected yearly flood impact, and it can be mathematically calculated as the product of hazard, exposure and vulnerability (Hooijer et al., 2002). Generally speaking, flood hazard could be reduced by structural measures. The exposure and vulnerability can be limited by non-structural measures such as changing land use typology (Gouldby and Samuels, 2005). The term “flood risk management” is used here to emphasize that not only flood probabilities but also flood consequences that related to the socio-economic system can be managed (De Bruijn, 2005), as can be seen from the image below.

The current flood risk management of this region could be regarded as structural resistant strategy (De Bruijn, 2005), due to the fact that in the past hundreds of years people merely rely on structural measures to reduce the flood probability, such as dams, dikes, river training works and reservoirs. But little efforts were paid to mitigate the flood consequences until a decade ago.

However, the recent flooding in the Rhine River is a serious warning, which has aroused the current resistant strategy to be a very heated discussion recently. It is time to rethink the current flood risk management strategy. Indeed, it provided more safety, but also results in many problems, which will be elaborated in the following section.

RETHINKING THE CURRENT FLOOD RISK MANAGEMENT

*Drawn by the author, base on texts and diagrams from the books Dutch Water cities, Dutch Lowlands and Man-made lowland; and Maps from the website of EduGIS and watwaswaar.nl

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**Structural resistant strategy**

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**Natural levee (Local scale)**

**Dike and dam (Dike ring scale)**

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**Deltaworks (National scale)**

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**Sedimentation**

**Natural transition zone**

**Tidal influence**
Overall picture: Closed Haringvliet and the Drechtsteden region

The Drechtsteden area was selected, since this comprises several of the riskiest places in the Netherlands. It is located southeast of Rotterdam. It comprises three islands: IJsselmonde (dike ring 17, 1/2000), Hoekse Waard (dike ring 21, 1/2000) and Island of Dordrecht (dike ring 17, 1/4000) which are surrounded by large rivers. Land use in this area consists of agriculture, urban areas and industries (De Bruijn et al. 2009, p.33). It lies at the transition from the river area to the delta and as such is influenced by both of the flow of the rivers and the tidal working of the sea (Delta Programme. 2012, p.44). On one hand, the flood water brings sedimentation which enable large area of land reclamation. On another hand, along with the rapidly increasing population and urbanization, the floods has become into larger disasters. The region is a product of natural processes and human engineering in the past hundreds of years, as can be seen from the diagram on the left. When the development and technical levels were low in the past and retreat to higher ground is unthinkable due to that most of the country area is below sea level (Kundzewicz, 2003), people have to attack natural challenges by constructing embankments. After the 1953 flood disaster, the Deltaworks has closed all the estuaries of the southwest Delta with dams or storm-surge barriers except Nieuwe Waterweg.

As can be seen from the right side of the diagram, nowadays there is a big gap between natural processes and human interventions. Indeed, the construction of the Haringvliet dam has dispelled all threat from the sea and ensured a freshwater supply, but the long and short-term problems concerning water management, socio-economic status and landscape qualities have been uncovered gradually (Kundzewicz, 2000), such as the disappearance of the salt- and freshwater transitional area with its characteristic flora and fauna, the virtual disappearance of the tidal effects, which has resulted in banks caving in, and the urban vitality of Drechtsteden cities has been weakened due to the closure of Haringvliet mouth. Besides, as can be seen from the right side of the diagram, although currently the flood risk is quite small, potential probability and consequences of a flood are very high. Whenever there is an unpredictable disaster, the consequence is deadly; especially when we take into account this area is highly urbanized.

The problems could be therefore summarized as follow:

- “Lull before Storm”: Flood Hazard and Vulnerable;
- Loss of Dynamics (Land-Water, Life-Water);
- Loss of Urban Vitality.

Before the dam and sluices were constructed in the Haringvliet, the Drechtsteden area were part of a natural transitional area between the sea and the major rivers with large area of mud flats, sandbars and creeks. Twice a day, the sea could flow in and out freely. The tide and the changing discharge of freshwater from the rivers resulted in a continually changing and unique transitional area between saltwater and freshwater. It was also part of a large nature reserve together with the mouth of the Haringvliet, where the biggest pied avocet nesting ground could be founded, tens of thousands of wild geese would sit along the banks of the river, and the mudflats provided sufficient food for the birds. After the 1953 flood disaster, it was immediately decided to enhance flood safety by implementing Deltaworks. Both nature and the landscape have lost much of their original character and quality after the construction of the dam in the mouth of the Haringvliet.

Firstly, closing off the estuary has resulted in the natural saltwater-freshwater interface largely disappearing. The sluices are only open at low tide to drain surplus river water. The sluices’ barriers prevents migratory fish such as salmon, sea trout, allis shad and twaite shad from swimming up the Rhine to the spawning grounds. Although there are six fish sluices on the dam, which operate like locks to facilitate fish migration. Research has shown that fish hardly use these at all (Haringvlietsluizen op een Kier project organisation, 2010). Research by the Rhine Commission has shown that opening the Haringvliet is the only possible way of achieving free fish migration for salmon, which is one of the reasons why other European countries ask to re-open the Haringvliet dam as soon as possible.

Secondly, the tidal difference has decreased from 2-3m to 20cm. The wash, which now hits the banks at approximately the same height every time causes the banks to cave in. The mudflats and salt marshes in areas outside the dykes that were created by tidal effects are gradually disappearing under water. Many birds have lost their nutrient-rich habitat, special plants have disappeared and reed borders have turned into fields of nettles (Haringvlietsluizen op een Kier project organisation, 2010). The disappearance of a large area of natural buffer zone has further weakened the resilience of the systems to cope with uncertainties.
As for the community and building scale, there are historically several types of dwellings: the dike town with ribbon development, the harbour town with canals and sluices, the water town built largely upon the land reclaimed from marsh or lake, and the dike and dam town with creeks and small harbours (Burke, 1956). The urban patterns have strong relationship with the water. The hydraulic system, polder patterns, harbours and urban functions were mixed together as a whole. Traditionally life was focused on and around the water with plenty of interesting path along the intertidal zone of land and water, while the small creeks interweave with the polder landscape and the water can be experienced everywhere.

However, the expansion of port-related industrial site and the followed heavy infrastructure along the river, the large area of land reclamation and dike rings, and the sprawl of urban areas and the vanishing of former water system has kept people away from the water (Bosch Slabbers Landscape Architects. 2012, p.54-61). As illustrated by the images below, the dike area has reverted to be a barrier between the water and the daily life. Along with the higher river discharge and the sea level rise, the continually dike reinforcement will make the mono-functional dike areas increasingly become a hard barrier instead of a seam in between of the open landscape, rural village and the cities shelter.

* Drawn by the author, based on historical maps from watwaswaar.nl
In addition to its function as dikes and dams, Deltaworks has enhanced the regional road connection, especially the directly connection between Rotterdam and Antwerp. However, along with the closure of the estuaries and the construction of national highway, the important role of small towns as trading centres and harbours has been weakened.

Take the Haringvliet-Hollandsch Diep-island of Dordrecht area as an example, in the 15-16th century it is the important gateway to the Dutch delta. But after Deltaworks, the Nieuwe Waterweg becomes the only water way to the North Sea, and the relationship with the South Wing is limited, both in functional and economic terms. As a result, this area has become the far side of Randstad that hardly attract any private investment in nature and recreation (Bosch Slabbers Landscape Architects. 2012, p.54-61). Besides, the urbanization process, vast rural areas and by-pass roads give this area an impression of periphery, and in return, the compact urban areas along Nieuwe Maas also have little relationship with the delta.

* Drawn by the author, based on historical maps and text from the book Dutch Lowlands.
Flood hazard and vulnerability

The Lull Before The Storm

Although currently the flood risk is quite small, potential consequences of a flood are very high. Whenever there is an unpredictable disaster, the consequence is deadly, especially when we take into account this area is highly urbanized. Future sea level rise and growing investments will increase flood risks. As the consequence of the sea level rise together with the increasing river discharge, the dikes will need to be heightened or reinforced in various places, and we shall have to explore more efficient methods for the long term.

The flood risks includes the potential failure of flood resistant structures and the likelihood of flooding elsewhere. Firstly, if an embankment fails, the unexpected high water level will suddenly occur in an area that was supposed to be protected. But for inhabitants, it is always unclear which risk they are facing. Within the “strong” protection of dike rings, urban sprawl quickly takes place on the former floodplain. But in fact, the quick economic development further increases its flood hazard and vulnerability. What is more, the disappeared buffer zone and the accelerated land subsidence also increase the flood probability. Besides, the flood threats may turn back to the upstream or low-lying areas and cause catastrophic floods there.

The traditional flood risk management focuses on preventing floods, until a decade ago little efforts were paid to mitigate the flood consequences (De Bruijn, 2005). While in fact, with the help of smart land-use or spatial strategies, we may not need to prevent floods everywhere. That is why integrative study on long-term strategies for flood risk management is needed. “A new strategy should not only focus on reaching a ‘safe’ situation by technical solutions.” (De Bruijn, 2005).
As explained before, the traditional flood risk management with many long and short-term problems related with the use of structural resistant measures are evident today (Kundzewicz, 2000). Besides, under the current closing regime of the Europoort barrier, a sea level rise of 1.30 meter would result in a closing frequency of 30 times every winter. This would lead to an unreliable shipping connection to the hinterland and a big blow to the port-related industry, which is very important to the Rijnmond-Drechtsteden region.

The objects that currently control water flows in the Rhine-Meuse estuary are either dam with gates (the Haringvliet dam), or movable barriers like the Maeslant Barrier. Recently, the recommendations of the Deltacommission is a so-called ‘Closeable Open Rhine Delta’. This is a vision of open river mouths and estuaries, only to be closed in case of an extreme storm at sea or a major storm in combination with high river discharges. Therefore, it could stays open for most of the time. It would be a barrier with high capacity for shipping passage, river discharge and ecological flows.

Research programme “Closeable Open Rhine Delta”. The programme is interwoven with research programmes at various Dutch universities and the Delta Committee.


In order to keep Haringvliet estuary open as long as possible,

What opportunities do the islands themselves provide to protect urban areas from flooding while gain benefit from the strategies?
The task is to devise strategies that will not only make the area safer, but will also improve the ecological quality and transform the area into an attractive place to live and work. In other words, the flood risk management strategies will not only work, but also have added value concerning natural environment, urban spatial dynamics and economic development.

More precisely:

- On the national scale, restore the natural dynamics by re-open Haringvliet for most of the time, but it could also be closed in case of a storm tide combine with a high river discharge;

- On the dike ring scale, transform the region into an attractive connector that connects the river to the delta, as well as put together the compact urban areas to the open rural areas, and bring the daily life back to the water. Through the enhanced accessibility, natural hydraulic system, shelters and facilities, it could also help to reduce flood hazard and its social vulnerability;

- On the local scale, make use of the existing facilities as well as the natural renewal rhythm of the city to make the communities more resilient and less vulnerable to future flood damages, both from functional and spatial perspectives.

- Notable mention is that, the strategies on the dike ring and local scales could also bring benefits to the regional and national scales in such a way that they help to enhance the dynamics and flexibility to the whole system, as well as allow keeping the mouth of the Haringvliet open to the sea as long as possible and bring prosperity to the entire river basin.
RESEARCH QUESTIONS

MAIN RESEARCH QUESTION:
How can the integrated flood risk management benefit the natural dynamics, spatial quality, and urban vitality in the context of sustainable development?

SUB RESEARCH QUESTIONS:
Learn from the past
- What are the core principles and beliefs behind such theories as “Integrated flood risk management” and “More resilient system”?- How did the Rijnmond-Drechtsteden region function historically as an ecological system?
- What are the negatively impacts of existing flood risk management strategies on the natural processes and why?
- What measures can be taken to restore the delta back its original dynamic ecosystem, as well as to bring the drecht cities back to “the gateway to the delta”?
- How to deal with the salt water intrusion at the Haringvliet’s estuary?
- What will be the impacts on wildlife and other natural resources of the Southwest Delta and the river basin?
- How to cope with the unexpected water level rise rate and depth along the Haringvliet- Hollandsch Diep-Biesbosch?
- Which chances and challenges can be addressed from the point of view of the (potential) spatial and functional quality of the region?

Learn from the future
- What are the flood hazard and vulnerability of this region in the long term with a time horizon of 50-100 years?
- What opportunities do the islands themselves provide to protect urban areas from flooding, as well as to be more resilient to an ever-changing environment?
- How does the community and the region benefit from each other by applying different strategy alternatives?
- What is the effect of different measures on the variety of scales?
**SUB QUESTIONS:**

- Learn from the past
- Learn from the future

**MAIN METHODS**

**Step 1: REVIEW**
- Layer approach;
- Literature, toolkit & project review.

**Step 2: SITE ANALYSIS**
- Flood risks;
- Identity.

**Step 3: DESIGN WITH RESEARCH**
- Strategic alternatives;
- Comparative study;
- In-depth analysis.

**Step 4: VISUALIZATION (& TESTIFY)**

**OUTPUT**

- “Toolbox”
- Guidelines
- Strategic alternatives
RELEVANCE

SOCIETAL
Half of the world population lives in delta regions that are under increasing threats, all of which is under further pressure from global warming. When we compare the spatial character of the landscape in the year 1830 with the current situation, many changes have taken place, especially the change of the way how life is related with the landscape and especially with the water. Indeed we need flood resistant measures to protect the urban sites. However, long and short-term problems related with the use of structural resistant measures are evident today (Kundzewicz, 2000). There is now an opportunity to re-evaluate the important role of integrated flood risk management in creating a new harmonious relationship between natural processes and human interventions. The Drechtsteden area was selected, since it comprises several of the riskiest places in the Netherlands, and it is lies at the transition from open delta landscape to the compact urban areas. With grand challenges and great possibilities, major changes need to take place as to how society and the natural environment interact.

SCIENTIFIC
Many researches have been done into the flood control system of the Rhine-Meuse Delta, as well as the economic and spatial strategies for the Randstad region. Most of them focus on the civil engineering or the metropolitan strategy, little connection has been made between flood risk management, the natural environment and the urban development. But through the historical analysis, we can see that the urban development of the delta cities have been greatly influenced by the water infrastructure. Especially after 1953, when people started to build the regional flood control system.

This research and design project will contribute to the current philosophies of “integrated flood risk management strategy” (Findings from FLOODsite, MARE project, IPDD principles, LIFE project, Multilayered safety policy, Kennis voor Klimaat), which aiming to reduce both of the flood probability and its consequences, and make the system more resilient in an uncertain future. Currently, little has been show as how does such kind of strategy will influence the ecological, social and spatial qualities on different scales, and how to develop a balanced combination of various aspects for planning and design in urbanized delta areas, such as water management, urban development, economic development, natural environment, and recreation. This project will provide the opportunity to explore the strategy within the Drechtsteden region and lead to physical design principles that will help to elaborate and explain what “turn the flood risk management into benefit” actually means. The project will also show that the strategy, methodology and principles can be also applied to other deltas around the world.
Project Implementation
This thesis project will encompass several disciplines throughout the process of research and design: Civil engineering, Ecology, Landscape Architecture, Spatial Planning and Strategy, and Urban design.

The project will put considerable focus on involving flood risk management into restoring natural dynamics and enhancing spatial quality, it is therefore very important to understand the characters and effects of engineering structures, as well as the dynamic natural system and societal system. Besides, the project also involved landscape architecture, spatial planning and urban design, because of that it is important to realize how decisions at one scale will affect both of larger and smaller scales, especially taking into consideration the fact that integrated flood risk management requires coordination between national, regional, municipal and community scales, and it will also benefit to the variety of scales (Jha et al. 2011, p.494).
**LITERATURE REVIEW**

**Why: Learn from the past**
- How did the Rijnmond-Drechtsteden region function historically as an ecological system?
- What are the negatively impacts of existing flood risk management strategies on the natural processes and why?
- What measures can be taken to restore the delta back its original dynamic ecosystem, as well as to bring the drecht cities back to “the gateway to the delta”?
- What are the core principles and beliefs behind such theories as “Integrated flood risk management” and “More resilient system“?

**What/ How**
- Reviewing the existing theories and projects to understand the concept and principles of integrated flood risk management;
- Summarizing the existing measures and theories into a “flood risk management toolbox”

Generally, these theories advocate the same philosophy: the structural flood resistant measures and non-structural mitigation measures should work as a whole, in order to regulate the flood patterns in such a way that the vulnerable flood-prone area is protected by structural measures, as well as smart land-use planning, integrated landscape structure, public education, and so on. Based on relative theories and projects (FLOODsite, MARE project, IPDD principles, LIFE project, Multilayered safety policy, Kennis voor Klimaat), these measures will be summarized into a toolbox with four categories, including load reduction (hard/soft), flood protection and damage reduction.
SITE ANALYSIS

Why: Re-open Haringvliet (occasionally close) and learn from the future
- How did the Rijnmond-Drechtsteden region function historically as an ecological system?
- What will be the impacts on wildlife and other natural resources of the Southwest Delta and the river basin if re-open the Haringvliet mouth?
- How to deal with the salt water intrusion at the Haringvliet’s estuary?
- How to cope with the unexpected water level rise rate and depth along the Haringvliet- Hollandsch Diep-Biesbosch?
- What are the flood hazard and vulnerability of this region in the long term with a time horizon of 50-100 years?

What/ How
- Field study, mapping, 3x3x3 layers approach, and modeling;

Analysis the characteristics and development process by layers approach;
Rethinking the existing flood risk measures and its spatial and ecological impacts by models, field study and drawings;
Investigate the flood hazard and vulnerability based on existing researches and field study.
COMPARATIVE ANALYSIS

Why: Assessment of existing strategic alternatives
- What opportunities do the islands themselves provide to protect urban areas from flooding, as well as to be more resilient to an ever-changing environment?

- Which chances and challenges can be addressed from the point of view of the (potential) spatial and functional quality of the region?

What & How
- Comparative study of Scheldt estuary and Drechtsteden region

Scheldt estuary shares the similar situation with Drechtsteden region. It is close to the world port-Antwerpen, and the urban areas are facing flood hazardous and vulnerability as well, such as Vlissingen. Currently several different flood risk management strategies for the region are in discussion, as shown on the right side. The strategies and evaluation results could present a clue to the Drechtsteden region.

Learn from Scheldt estuary strategies to figure out how to combine resistant and resilient measures into the islands;
By learning from the results and impacts of different strategies, we could reinforce the natural and spatial quality of Drechtsteden region from different aspects. For example, if we apply the storm surge barrier option, more attention need to be paid to reinforce the natural quality and economic growth.

*Source: Long-term strategies for flood risk management- Scenario definition and strategic alternative design
**METHODOLOGY**

**Potential Case Studies**

Palisade Bay: Urban waterfront

“Room for the river” program

Hamburger Elbinsel: Dike landscape

**IN-DEPTH ANALYSIS ON SPECIFIC LOCATION**

**Why: Theory into practice**
- How does the community and the region benefit from each other by applying different strategy alternatives?
- What is the effect of different measures on the variety of scales?

**What & How**
- Case studies, Mapping, Modeling.

The strip along the Oude Maas (between N217 and the river) has been chosen for the physical design solutions, in order to elaborate and explain what “turn the flood risk management into benefit” actually means, and it also shows how to use the flood risk management toolbox to the specific locations;

The case studies will help to further understand how to imply different measures into reality and what will be the possible impacts on the larger and smaller scales;

The experience and feedback obtained from this project could also be used to other deltas.
**Context & Relevance**

- **Thesis plan**
  Defining context, objects, process & final products
  Document with text and images

**Research with design**

- **Literature review paper**
  Research into theories, methods, & approaches,
  Products: Document with text and images.

- **Analysis of the Rijnmond-Drechtsteden**
  Using 3x3x3 layer approach and models,
  Maps, Diagrams and Conclusions.

- **Design guidelines**
  Restoration of delta landscape and relationship between urban areas and rural areas,
  Overall map.

- **Toolbox for reducing flood probability and flood consequence**
  Research into current theories, strategies and projects. The result will be summarized as a toolbox with four categories based on the principles of integrated flood risk management, including load reduction (hard/soft), flood protection and damage reduction.
- **Analysis of the Drechtsteden region**
Maps and diagrams that investigate the flood hazard and vulnerability, socio-economic structure, landscape pattern, infrastructure network, etc.
Maps, Diagrams and Conclusions

- **Regional strategic alternatives (Scale = 1:5,000)**
Different strategies for the Drechtsteden region are explored to reduce the flood risks, and to stimulate the functional and spatial possibilities of the sites,
Overall plans, diagrams, sections / elevations, perspectives.

- **Site-specific analysis of the strip along Oude Maas**
In-depth analysis on the spatial quality, social status, green structure, etc.
Models, Diagrams, Maps, Sections and Conclusions.

- **Key interventions (Scale = 1:500-1:2,000)**
Master plan: maps, diagrams, models, sections / elevations, perspectives
TIME SCHEDULE

P1: Literature Review; Thesis Plan
P2: Comparative Study
P3: Case Studies
P4: In-depth Analysis
P5: Field Study, Design principles, Regional strategic alternatives, Key interventions, Report

SAFE & DYNAMIC DRECHTSTEDEN
Review
More resilient! “Turn the flood risk management into benefit.”

--MARE Toolbox

Due to the intentions to keep the Haringvliet estuary open for most of the time, strategies related to regional and local differentiations are needed to be developed in such a way that the future flood risk management could be transformed into benefit for sustainable development. Therefore the Dutch policy makers suggest making water systems more resilient for the long-term scenarios with a time horizon of 50-100 years.

As can be seen from the diagram there are mainly four types of measures related to resistant and resilient strategies (* The diagrams are drawn by the author based on the former analysis and the findings from FLOODsite and Deltaras): At the National or regional scale, there are structural load reduction and non-structural load reduction measures, such as dam, storm surge barriers, and floodplain management; At dike ring scale, there is structural flood protection, mainly focus on the primary dike ring system; At the community and building scale, there are diverse non-structural mitigation measures, such as spatial planning, evacuation plan, and relocation.

But one should bear in mind that all the measures are not separated from each other, “they should consist of combinations of structural and non-structural measures (De Bruijm et al. 2009, p.76).” With the help of more resilient flood risk management on different scales, “Instead of a foe - that should be tamed and conquered - water is becoming more and more a friend for the planners and water managers. There is growing awareness among them that water and flood protection measures create opportunities for spatial development, such as nature, recreation and housing.” (Sokolewicza et al., 2011, p.143).

Rethinking: Human intervention & Natural process

Load reduction (structural)
- Regional scale: Reduce the hydraulic loads, including water levels and waves by engineering structures.

Load reduction (non-structural)
- Regional scale: Reduce the hydraulic loads by working together with the nature.

Flood protection
- Dike ring scale: Unbreachable flood defences

Consequence reduction
- Local scale: Reduce the extent of the flooding and its depth. Reduce the vulnerability.

Traditional flood adaptation:
- Retreat

Traditional flood control:
- Resistant strategy
  - Structural measures

Other possibility:
- Resilient strategy
  - + Non-structural measures

<table>
<thead>
<tr>
<th>H1N2</th>
<th>Load reduction (structural)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2N2</td>
<td>Load reduction (non-structural)</td>
</tr>
<tr>
<td>H1N1</td>
<td>Flood protection</td>
</tr>
<tr>
<td>H2N1</td>
<td>Consequence reduction</td>
</tr>
</tbody>
</table>

Probability Reduction
- 12-16th century
- 17-19th century
- 20th century
- 21st century
Integrated Flood risk management

- Regional flood control

**Load reduction**
1) Structural Flood-Control Measures;
2) Non-Structural Flood Mitigation Measures *

**Flood protection**
Structural Flood-Control Measures

**Damage reduction**
Non-Structural Flood Mitigation Measures

**Regional**
Dikering
Local

Local flood risk management

WATER-RELATED INFRASTRUCTURE

SAFE & DYNAMIC DRECHTSTEDEN
Toolbox

**AD**

**Load Reduction (structural measures)**
- Concrete dam
- Earth dam
- Fixed dam
- Fixed dam (with sluices)
- Fixed dam (with shipping capacity)
- Storm surge barrier
- River training works (canalisation or normalisation)
- Reservoirs

Reduce wave height, volume or impact
Natural, functional, spatial impacts.

**BD**

**Load Reduction (non-structural measures)**
- Balance island
- Sand engion
- Floodplain management (Room for the river)
- Shellfish reef
- Buffer zone: Wetland, Marshflat
- Reforestation
- Rehabilitation
- Retention polders (with controlled inlets and outlets)
- Adapted agricultural practice

Reduce wave height, volume or impact
Need enough space.

**AC**

**Flood Protection (structural measures)**
- Super dike/ Delta dike
- House dike
- Dam/ Sluice
- Elevated road/railway
- Unbreachable dike
- Flood defence stairs
- Quay wall
- Temporary defences
- Fortification
- Park dike
- Grass dike
- Rich revetment

Robust flood defences
Multi-functional

**BC**

**Consequence Reduction (non-structural measures)**
- Compartmentalization
- Unbreachable dike
- Former military defense line
- Intersection (eg. the Dief dike and A2)
- Small-scale retention
- Creek
- Pump
- Temporary defences
- Dune/ Natural levee
- Spatial planning
- Relocation
- Sealing of openings
- Elevated ground
- Surrounding defences
- Insusceptible construction
- Early warning
- Evacuation plan & Shelters
- Insurance
Different measures should work together and depend on the differentiation of flood risks and local situation (Meerlaagsveiligheid, 2011).

Toolbox: How to use?

Identity

Site Analysis

Flood risks

Guidelines
Site Analysis
Differentiation of spatial character

IJsselmonde

- Extensively urbanized
- Rely on the primary dike ring

- The secondary dikes may partly be used, but they play a minor role for spatial coherence;

- The buildings, road infrastructure, industry, and urban landscape dominant the spatial structure;

- The port-related industry along the river push people away from the water.
Dike and dam village, mound village.
Original cultural landscape.

The secondary dikes are combined with the local road system. **Dike compartments dominate the spatial structure**, eg. ribbon development;

**Canals and creeks** enable people experience the water everywhere.
Differentiation of spatial character

Island Dordrecht

Port-related industry

Historical town

Polder landscape

Natural reserve

Half-Half
Conclusion: Compact urban area & Open rural area

With regional road N217 as the edge of the city and the cultural landscape

From the analysis, we can see that, the polder parcel, urban pattern, and building typology of IJsselmond and the city of Dordrecht are different from those of Hoeksche Waard.

The spatial structure of IJsselmond and Dordrecht island is dominated by heavy infrastructure and human settlements. By contrast, due to the history of urbanization and water management, the spatial character of Hoeksche Waard and the south part of Dordrecht island is dominated by the open landscape. The secondary dikes and creeks still play a key role in the spatial structure, and they have a strong relationship with the urban pattern. Compare with IJsselmonde, the villages of Hoeksch Waard are highly rely on the regional and local road, especially N217, which connects the small villages with the urban areas, as well as connects the open polder landscape with the urban landscape.
Differentiation of Flood risks

- **Outer dike areas task**

**Residential area:** Dordrecht town centre and Rotterdam dock areas;

**Agriculture:** Along the Oude Maas and the island of Tiengemeten;

**Industry:** Northeast side of IJsselmonde; Part of Dordrecht seaport.
Maximum discharge capacity of the river Rhine will increase from 15,000 m³/s to 18,000 m³/s.
Differentiation of Flood risks

- Dike strengthening task

Need to upgrade to unbreachable dikes.

Embankment sections that do not meet the standard - Average 40 cm height deficit (2100, W+ scenario)

Further research is needed

- Too close to the river
- High casualty rate and damage

- Unexpected water rise rate and depth
- High casualty rate and damage

- Low vulnerability
- Water storage task

*Flood risks map. Drawn by the author, base on maps and texts from Deltaportal website (www.deltaportal.nl); Reports of Deltaprogramma 2012 Probleemanalyse Rijnmond-Drechtsteden, Deltaprogramma 2013 Probleemanalyse Rijnmond-Drechtsteden, Mapping casualty risks in the Netherlands
### Conclusion: Flood hazard and vulnerability

<table>
<thead>
<tr>
<th>Flood hazard (Occupied area)</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep and fast</td>
<td>National/Regional measures: Reduce opportunity, exposure and vulnerability.</td>
</tr>
<tr>
<td>Deep and slow</td>
<td>National/Regional measures, Reduce exposure and vulnerability.</td>
</tr>
<tr>
<td>Middle deep</td>
<td>Local measures: Limitation of exposure</td>
</tr>
<tr>
<td>Shallow</td>
<td>Normal protection</td>
</tr>
</tbody>
</table>

**Flood hazard**
- outer dike area (occupied)
- deep (>2m), fast
- deep (>2m), slow
- middle deep (0.5-2m)
- shallow
- occupation

**Flood vulnerability**
- Breach scenarios with highest flood vulnerability. (Casualty and Damage)
Guidelines

IJsselmonde:
Primary dike ring.

Island Dordrecht:
Dike ring & weak points.

Hoeksche Waard:
Dike compartments.

Compact urban area: Structural measures dominated
- Regional scale / Primary dike ring scale: Reduce flood probability, exposure and vulnerability.

Open rural area: Non-structural measures dominated
- Using dike compartments to reduce flood exposure and vulnerability, and to enhance the water storage capacity;
- Improve natural and recreational function.

In-between Area:
- Regional road N217 as the seam to connect both sides;
- Involve Delta landscape into urban areas.
Design with Research
strategic alternatives A:

**Storm surge barrier**

Regional:
Flood probability reduction.

strategic alternatives B:

**Risk approach**

Dike ring/ Local:
Flood protection,
Flood consequence reduction.
Comparative Study: the Schelde estuary

Base on the two strategic alternatives, further comparative study and case studies will be made to show the possible outcomes of the two strategies, in order to better make use of the flood risk management toolbox. As for the comparative study, Scheldt estuary was chosen because of that it shares lots of similar situation with Drechtsteden region. On one hand, it is close to the world port- Antwerpen, and the villages also facing the problem of losing the urban vitality. On another hand, the urban areas are facing flood hazardous and vulnerability as well, such as Vlissingen. Currently several different flood risk management strategies for the region are in discussion, as shown on the right side. The strategies and evaluation results could present a clue to the Drechtsteden region. There are three strategic alternatives:

1. Storm surge barrier:
This alternative incorporates a storm surge barrier near Vlissingen to prevent high water levels in the Westerschelde. This alternative is a resistance alternative.

2. Risk approach without spatial planning:
Embarkments along each subarea are raised and land use developments are considered to occur autonomously.

3. Risk approach with spatial planning:
Flood protection levels are used to guide spatial developments. Spatial developments do not occur autonomously, but they are planned in such a way that vulnerability is reduced.

The results indicates that the more resistant strategic alternatives score well on people aspects (casualty and damage reduction), while the more resilient strategic alternatives score better on the planet, profit and sensitivity for uncertainty aspects.

If the socio-economic growth is high, then a more resistant strategy such as the strom surge barriers seems then sensible. But more attention need to be taken for natural aspect. The Spatial planning strategic alternative scores reasonably well in all scenarios. However, it scores relatively low on the people aspects. Scores could be improved by better flood event management (shelters, warning and evacuation) and by compensation or support for those people who are negatively affected.
## Comparative Study

Assessment of different strategic alternatives:


<table>
<thead>
<tr>
<th>Indicator**</th>
<th>Scenario</th>
<th>Do Nothing</th>
<th>Current policy</th>
<th>Storm surge</th>
<th>Risk approach</th>
<th>Risk approach</th>
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</thead>
<tbody>
<tr>
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<td></td>
<td></td>
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<td>No Spatial planning</td>
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<td>Flexibility</td>
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<td>1 (-2-0)</td>
<td>1.2 (-0-3)</td>
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</tr>
</tbody>
</table>

![Storm surge barrier](image1)

![Risk approach without Spatial planning](image2)

![Risk approach & Spatial planning](image3)
Comparative Study: Feedback on Toolbox

If the socio-economic growth is high:

- Socio-economy: +
- Climate change: +

If there is less economic growth and climate changes less:

- Socio-economy: +
- Climate change: +

Storm surge barrier

- Nature: - - -
- Economy: - - 
- Safety: + + +

Risk approach

- Nature: + + +
- Economy: +
- Safety: -

In-depth analysis

A: Visualize & Testify
B: Visualize & Testify

Comparative Study: Feedback on Toolbox
Strategic alternative A: Storm surge barrier

Toolbox

Structural measures:
- Storm surge barrier
- Park dike

Non-structural measures:
- Floodplain management
- Room for the water
- Shellfish reef
- Buffer zone: Wetland, Marshflat
- Retention polders
- Adapted agricultural practice
- Compartmen-talisation
- Small-scale retention
- Elevated ground
- Relocation
- Insusceptible construction

+ Resilience  ▲ Nature  ▲ Economy
Strategic alternative A: In-Depth Analysis
Strategic alternative A: “Regulate the Flood Pattern”
Strategic alternative A: “Regulate the Flood Pattern”

- Wetland/surge barrier
- Deltapoort
- Main regional road
- Shipping route
- Port
- Harbour
- More room for the water
- Adapted agricultural practice
- Energy farm
- Business/industry
- Dwelling
Strategic alternative A: “Regulate the Flood Pattern”

New urban waterfront
Strategic alternative A: “Regulate the Flood Pattern”

More room for the water
- shipping route
Strategic alternative A: “Regulate the Flood Pattern”

More room for the water
- back to harbour villages
Strategic alternative A: “Regulate the Flood Pattern”

More room for the water
- Tidal energy
Strategic alternative A: “Regulate the Flood Pattern”

More room for the water
- islands
Strategic alternative B: Risk approach & Spatial planning

Toolbox

**Structural measures:**
- Super dike/ Delta dike
- House dike
- Flood defence stairs
- Elevated road/railway
- Unbreachable dike
- Quay wall
- Temporary defence
- Park dike
- Grass dike

**Non-structural measures:**
- Rehabilitation
- Shellfish reef
- Retention polders
- Relocation
- Dike compartments
- Retention
- Pump
- Insusceptible construction
- Relocation
- Elevated ground
- Surrounding defences

+ Resilience → Safety → Evacuation plan & Shelters → Insurance
Strategic alternative B: In-Depth Analysis

Dike reinforcement

Unbreachable dikes are needed since these embankment sections result in the highest casualty numbers.

Other embankment sections that do not meet the standard in 2100 (Average 40 cm height deficit), in the scenario’s Warm en Stoom (W+ scenario)
Strategic alternative B: “Dike Landscape”
Strategic alternative B: in-Depth Analysis

Existing green-blue structure
Strategic alternative B: “Dike Landscape”
Strategic alternative B: “Dike Landscape”
Strategic alternative B: “Dike Landscape”

Multi-functional Evacuation plan

Vital facilities

Normal days: recreational facilities
Emergency event: shelters
Next step...

TO BE CONTINUED...

NaiLi Zhao, (2013) Safe and Dynamic Drechtsteden: Re-balance the natural processes and human interventions through integrated flood risk management


THEORY ESSAY ABSTRACT

Key words - lowland, flood risk management, delta cities, structural resistant measure, non-structural mitigation measure, resilience

Water as Foe, Water as Friend
Reviewing Long-term strategies for flood risk management of lowland river systems

Course AR3U022, Theory of Urbanism

Abstract – For the past hundreds of years, flood risk management has mainly focused on reduction of flood probability with the help of structural resistant measures. While recently policy makers propose to increase the resilience of systems, since scientists expect resilient systems to better cope with the flood consequences in the face of urbanization, growing populations and long-term climate change trends (Waterstaat, 1999, Gouldby and Samuels, 2005, Deltas, 2010, Hooijer et al., 2002).

In this review paper this advantage of more resilient flood risk management was verified based on the current theories and projects. The objective was to explore comprehensive strategies for flood risk management which not only better reduce the flood probability but also mitigate the flood consequences in the long run.

This literature review will look into the first section the traditional structural resistant measures and the non-structural mitigation measures in view of sustainable development. Then it will conclude the character of long-term strategies for flood risk management. The following section will further explain the key elements in the continuing cycle of flood risk management measures. Finally it will work as the theoretic framework of the graduation project.
urbanization, the floods has become into larger disasters. In this paper, flood risk is defined as the expected yearly flood impact, and it can be mathematically calculated as the product of hazard, exposure and vulnerability (Hooijer et al., 2002). Generally speaking, flood hazard could be reduced by structural measures. The exposure and vulnerability can be limited by non-structural measures such as changing land use typology (Gouldby and Samuels, 2005). The term “flood risk management” is used here to emphasize that not only flood probabilities but also flood consequences that related to the socio-economic system can be managed (De Bruijn, 2005).

The current flood risk management of the Rhine River could be regarded a resistant strategy (De Bruijn, 2005). Because of that in the past hundreds of years, the flood risk management has been merely focusing on reducing the flood probability by structural measures, such as dams, dikes, river training works and reservoirs. Especially when the development and technical levels were low in the past and retreat to higher ground is unthinkable due to that most of the country area is below sea level (Kundzewicz, 2003). Thus from the start of the civilization, people have started to attack natural challenges by constructing embankments. Later on, along with the construction of large and impressive engineering structures such as the Delta works, the vulnerability to flood hazards has increased because of the exploded urban development has taken place on the former floodplain (Rossi et al., 1994). As a consequence, long and short-term problems related with the use of structural resistant measures are evident today (Kundzewicz, 2000), which will be elaborated in the next chapter.

Maybe the recent flood disaster of 1953 and 1995 could be seen as a wake-up call. The climate change has accelerated sea-level rise with elevated tidal inundation, which result in higher hazard and vulnerability of delta cities. The traditional flood resistant strategy is based on "we know it could work", but there are so many complex and interacting variables that the future is full of uncertainties (Evans et al., 2004). In Deltares' report, there are mainly four types of delta scenarios combined different socio-economic status with climate change gradients (Deltares, 2011). This complexities and uncertainties require a changing perspective. Instead of traditionally only focusing on the river itself to reduce the flood probability, we need to consider the whole area threatened by floods to mitigate flood impact as well. Developing a long-term flood risk management vision (with the time horizon of 50-100 years) could therefore help to better motivate short and middle-term programs to prevent future regret (De Bruijn et al., 2008, De Bruijn, 2005, Lyle, 2001).

In this context this paper's main research questions are: What is the long-term flood risk management for lowland rivers? How to reduce the flood probability and its impacts?

Firstly, it will examine the advantages and disadvantages of the structural resistant measures. Then, it will look into the non-structural mitigation measures which start to receive more attention recently. After that, the first question will be answered based on different theories and projects. The following section will answer the second question with key elements in the continuing cycle of flood risk management.

2. Rethinking the current flood risk management strategy

As a lowland country, the commonly applied flood risk management strategy in the Netherlands is based on flood resistance, which aiming at raising and strengthening dikes. However, the recent flooding in the Rhine River is a serious warning, which has aroused the structural measures to be a very heated discussion recently. It has been puzzling our major that for how long does it still work for protecting us from floods.

2.1 Discussions on the structural measures

On one hand, the hydraulic structures have advantages of flood attenuation and downstream discharge control (Petry, 2002), such as concrete dam, storm surge barriers, and so on. Therefore they have been largely used in areas with rapid pace of industrialization and urban sprawl, such as Pearl River Delta and Melong Delta.

But on another hand, although the construction of structural measures may have higher cost benefit in the short term, it is usually being considered as "over-designed" or "over-scaled", due to the current strategy is based on "one design discharge for the entire area", but actually, the flood impacts of the Betuwe area are much higher than the Lobith area (De Bruijn, 2005). Generally, the disadvantages of the current structural measures can be listed as follows: Low cost benefit for the long term.

Firstly, large amounts of sediment have been deposited on the narrowed river basin which results in an increase of its level (De Bruijn, 2005). As a result, there is an endless need for heightening the height of the embankments. Secondly, we also need to take into account the enormous environmental costs. For example, the construction of Deltaworks influences the tidal condition of the whole region, which caused environmental problems such as the blue algae. As a result, the excess nutrients and pollutants directly affect the shellfish reefs in Eastern Scheldt and bring a big blow to the local economic development.

False sense of safety to public.

It includes the potential failure of flood resistant structures and the likelihood of flooding elsewhere. Firstly, if an embankment fails, the unexpected high water level will suddenly occur in an area that was supposed to be protected. But for inhabitants, it is always unclear which risk they are facing. Within the "strong" protection of dike rings, urban sprawl quickly takes place on the former floodplain. But in fact, the quick economic development further increases its flood hazard and vulnerability. What is more, the disappeared buffer zone and the accelerated land subsidence also increase the flood probability. Besides, the flood threats may turn back to the upstream or low-lying areas and cause catastrophic floods there.

Little attention paid to the reduction of flood impacts

The traditional flood risk management focuses on preventing floods, until a decade ago little efforts were paid to mitigate the flood consequences (De Bruijn, 2003). While in fact, with the help of smart land-use or spatial strategies, we may not need to prevent floods everywhere. That is why integrative study on long-term strategies for flood risk management is needed. "A new strategy should not only focus on reaching a 'safe' situation by technical solutions." (De Bruijn, 2005).

2.2. Non-structural measures that alleviate future flooding events

Therefore, recently we can see a shift from flood control to more holistic approaches for managing flood risk (De Bruijn, 2003) "instead of a foe - that should be tamed and conquered - water is becoming more and more a friend for the planners and water managers. There is growing awareness among them that water and flood protection measures create opportunities for spatial development, such as nature, recreation and housing." (Sokoliewicz et al., 2011, p.143).

In order to live and work with the water, the flood risk management has been divided into flood prevention, protection and mitigation according to the European commission. The FLOODsite (a major European research project on Methodologies for Integrated Flood Risk) also indicate that the management of flood risks involves a wide range of actions that consist of prevention, preparation, response and recovery.
The Flood Risk Directive (FRD) suggests the risk-based approach comprising prevention, protection, preparedness, emergency response and recovery. As can be seen in common, great effort is put on preventing and reducing flood consequences by involving more non-structural measures (Lumbros, 2007), rather than traditionally attempts to reduce the flood risks only through reducing the flood hazard such as the frequency of flooding. This changing perspective towards flood risk management is illustrated with figure 1.

Figure 1 Change of perspective (Councils for the Environment and Infrastructure, 2010).

As a result, non-structural measures started to receive more attention in recent years (Rossi et al., 1994; De Brujin, 2005). Compare with structural measures, non-structural measures also imply physical interfacing, but they do not rely merely on the introduction of large engineering structures. Instead of that, they focus on lowering flood damages by regulating "the way of floodplain use, enhancing preparedness, educating and warning system, or by redistributing flood damages in time and space by insurance, flood relief and other financial instruments (Karin, 2009)."

3. Long term flood risk management: “More resilient!”

Although the non-structural approaches have gradually been taken seriously as an effective method, without developing structural measures, they would be less effective (Heidari, 2008). As for the long term scenarios with a time horizon of 50-100 years, the Dutch policy makers suggest making water systems more resilient (De Brujin, 2003). According to Karin’s definition, resilience is defined as the ability of the system to prevent floods, while resilience is defined as the ability of the system to recover from floods (De Brujin, 2003). The difference between these two can be listed as follow: In resistance strategies structural measures tend to dominate, like dikes and dams, whereas resilience strategies include more of a mix of both structural and non-structural measures (Karin, 2009). The more resilient system is expected to adapt to long-term changes and unexpected events. As explained before, "uncertainty", including slow or fast climate change and socio-economic changes in growth (Delft in, 2011), is exactly one of the biggest challenges for delta cities. Therefore, recently there are more and more researches and projects that try to engage more resilience strategic alternatives into the long-term scenarios.

The Multilayered safety policy (meerlaags veiligheid) is a good example to show how to involve resiliency into flood risk management. In this concept, the first layer is preventing floods with dikes, dunes and barriers (structural measures). The second layer is achieving a sustainable land use planning (non-structural measures). And the third layer (non-structural measures) is emergency preparation and response. The first layer is traditionally the core measure to resist floods. The second and third layers are more resilient, and they try to limit losses and victims of the possible floods. As shown in figure 2, these two layers have strong relationship with spatial strategies, new technology, land-use planning, public education and evacuation plan. To achieve results in the second and third layers, the cooperation between local people, water managers, spatial planners and disaster managers is very crucial (Hoss et al., 2011).

Another example is the project “living with floods: Green Rivers in the Lower Rhine River”, which is a research projects based on long-term development. The strategy involves structural measures such as river training work and dike relocation, as well as non-structural measures such as land-use planning and floodplain management (De Brujin, 2005). For example, a large area of polders are used for most of the time but during periods of extreme river discharge they can be transformed into emergency floodplain to reduce the flood impacts. And the rural area between big cities will be transformed into wetland that serves as recreational parks and the buffer zone; What is more, the dikes could offer new possibilities for housing, industrial site, business center, and so on. With the cooperation of resilience and resistance strategies, the multi-functional variant and recovery capacity of this region are improved.

The above two examples are based on the regional or city scale, maybe we have to admit that the initial investment of more resilient strategies are usually high whereas the gains will only be perceivable in the long term (Vis et al., 2003). But from the following pilot "Oranjepolder" we can find out that, on the smaller scale, such as the community or building scale, more resilient strategies could offer more opportunities for both of the short-term and the long-term development.

The "Oranjepolder" project is located at Maasdijk village, where a large part of it is dominated by greenhouse industry (Hoogheemraadschap van Delfland, 2011). In order to deal with the flood inundations of the polders, local farmers are working together with urban planner to manage the flood risks through three aspects: Improving the river basin condition (widening and deepening); building retention ponds by themselves to manage storm water runoff; Increasing the height of the dikes (main protection). The measures are shown below:

Figure 3 Strategies of flood protection and prevention (Delfland, 2011)

The whole process is profit from the cooperation of structural measures and non-structural measures. Specifically, local farmers will be informed by the municipality before the storm about the expected water levels. Then, they will immediately pump certain amount of water out of the retention ponds, in order to guarantee enough space for water storage in the coming storm. In this way, the
retention ponds are not only used as storing production water for the local greenhouse industry, but also work as temporary reservoirs to limit the flood impacts for the whole neighborhood. The project is based on community resilience in such a way that local residents can receive economic and environmental profits in the short term, and it also create more room for the water in the long run. Notably mention is that the project would not be successful without the participant of stakeholders in the entire process (Delfland, 2011).

4. Elements of Long-term flood risk management

To summarize, the following conclusions can be drawn from the present study.

4.1 Changing attitudes towards flood risks

Traditionally, attempts have focused on reducing the flood probability such as the frequency of flooding. Recently another factor of flood risks has been uncovered, which is the consequences of flooding (i.e. the flood vulnerability of the flood-prone area). We could lower down flood risks by controlling flood patterns in such a way that primarily the vulnerable areas are protected by giving room to the water elsewhere (Klijn 2009, p.79)."

4.2 Changing attitudes towards uncertainty

The future uncertainty makes people full of anxiety. In the past, we had to live on the natural levees. Later on, with advanced windmills and steam pumps we could start to struggle with nature to keep "dry feet". Nowadays, due to the changing attitude towards flood risks and the improvement of technology, we gradually try to work and live together with floods. In the future we have to continually deal with unpredictable climate change and socio-economic status. How to guarantee the sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs? The existing theories may indicate one possible answer: "If we can't reduce uncertainty, then we shall have to reduce the importance of it (Blanksy 2011, p.8)." As explained before, making the system more resilient is a better way to reduce the importance of future uncertainty in such a way that limiting the potential flood impacts and leaving enough room for future development and new technology.

4.3 More resilient strategy: a combination of structural and non-structural measures

The traditional flood risk management is dominated by structural measures and it might cost huge ecological damage, increasing maintenance investment and it might increase the potential flood risks elsewhere. Non-structural mitigation measures, in contrast, are more flexible and resilient in the long run. But one should not ignore that without developing structural measures, they would become less effective. Therefore, "All strategic alternatives should consist of combinations of structural and non-structural measures, and all alternatives should aim at both hazard control and vulnerability reduction – although their respective shares may deviate substantially (Klijn 2009, p.76)."

4.4 Turn the flood risk management measures into benefits

Taking into account more resilient strategies instead of continuously increasing the height of the dike, we could "make the flood risk management measures part of something that (we) are going to do anyway. (And) Turn the flood risk management measures into benefits (Blanksky 2011, p.2)" such as better connectivity, urban recreational parks, housing program, and...
References


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