THE IMPACT OF SPATIAL ADAPTATION MEASURES ON FLOOD RESILIENCE

BACHELOR THESIS DELTA MANAGEMENT

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Preface

In front of you lies the bachelor thesis *"Impact of spatial adaptation measures on flood resilience".* This research searches for an impact assessment to assess the effects of spatial adaptation measures in relation to flood resilience. It has been written to fulfill the graduation requirements for the bachelor program Delta Management at the HZ University of Applied Sciences in Vlissingen.

The commissioner of this research is the research group Resilient Deltas of the Delta Academy of the same university. During the research, I sometimes got lost in the vast amounts of theory that this subject provides. Fortunately, both mr. Buijs and mr. Terpstra from the research group and my mentor from the HZ, ms. van der Reep, were always willing to answer my queries.

I would like to thank my supervisors for their guidance and support during the entire process. I also would like to thank the organizations that contributed to this thesis by making time for my interviews; Gemeente Reimerswaal, Provincie Zeeland, Waterschap Scheldestromen, and the VeiligheidsRegio Zeeland.

Thijs Hillebrand

Vlissingen, June 05, 2017

Abstract

This research is part of the international FRAMES project, a cooperation between the Netherlands, United Kingdom, Belgium, Germany, and Denmark to share knowledge and experiences with the Multi-Layer Safety approach. The shared data is used to build sustainable strategies and improve the capacity of authorities to cope with flooding. The aim of this research is to design an impact assessment for spatial adaptation measures in relation to flood resilience.

Spatial adaptation measures are not one-size-fits-all measures, recognizing that each area is different, with different spatial characteristics and different people. This fact underpins the notion that our environment is a complex adaptive social-ecological system. Resilience in social-ecological systems eliminates the assumption of fixed equilibria and assumes that systems continuously change. From this perspective, social-ecological resilience is not the capacity to bounce back to a previous state, but a systems capacity to deal with change.

The conceptualization of resilience has also been adapted into the field of flood risk management. Flood resilience includes four types of resilience; spatial resilience, structural resilience, social resilience, and flood risk resilience. The systems thinking approach learns that the focus should be on combining the four aspects of flood resilience.

An integral part of this research is to seek for a framework that can be used to assess spatial adaptation measures in relation to flood resilience. The definition of flood resilience shows strong similarities with the 4+1 model, which can be dismantled, adapted, and used as assessment framework. This leads to six aspects on which spatial adaptation measures are assessed; (1) water system, (2) land-use, (3) critical infrastructure, (4) economics, (5) social capital, and (6) ecology.

IMPACT ASSESSMENT

	Negative	Not	Positive
Water system			
Water quantity	○	○	○
Water quality	○	○	○
Land-use			
User value	○	○	○
Experienced value	○	○	○
Future value	○	○	○
Critical Infrastructure			
Vulnerability critical infrastr. and services	○	○	○
Vulnerability traffic and transport	○	○	○
Economics			
Business climate	○	○	○
Business Continuity Manag.	○	○	○
Social capital			
Social cohesion	○	○	○
Situational awareness	○	○	○
Ecology			
Biodiversity	○	○	○
Specie abundance	○	○	○

In accordance with professionals from various governing entities in the province of Zeeland, the aspects have been supplemented with indicators of flood resilience, which are presented in the "scorecard". Experts can assess the impact of the spatial adaptation measure for each of the latter aspects to desribe the impact on flood resilience.

This assessment framework is drafted using the showcase Yerseke, which is located in the FRAMES pilot area; the municipality of Reimerswaal. The three selected spatial adaptation measures are a wadi in the Marijkestraat, redevelopment of the Kerkhoekstraat, and constructing a ditch in the Molenpolderweg. All the measures positively contribute to flood resilience, but do not influence the critical infrastructure nor the economics in Yerseke.

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1. INTRODUCTION

In front of you lies the thesis named *"impact assessment for spatial measures in relation to flood resilience"*. The research is part of the international FRAMES-project, a cooperation between the Netherlands, United Kingdom, Belgium, Germany and Denmark to share knowledge and experiences with the Multi-Layer Safety (MLS). The MLS is a policy-tool that integrates flood prevention, adaptation via spatial planning, and emergency response measures in flood risk management. The FRAMES partners are working on pilots using a risk-based flood protection approach. Knowledge, data and experiences are shared within the partnership to build sustainable strategies and improve the capacity of authorities and society to cope with flooding; to improve the overall flood resilience.

One of the pilot areas of the FRAMES project is the municipality of Reimerswaal in the province of Zeeland. Yerseke, a town in the pilot area is selected as case study for this research, because in the past years they had to deal with extensive precipitation that caused pluvial floods in the old town center. Recently, a package of measures has been designed and implemented to prevent this from happening in the future.

1.1 Background

The effects of climate change are diverse and strongly dependent on the location on earth (Lieske, 2015). In the Netherlands, climate change will cause more frequent high temperatures, dryer summers, rising sea level and more extreme weather events, like heatwaves, rain showers and hailstorms (Ministerie van Infrastructuur en Milieu, 2016). On December 12, 2015, the world agreed on a new climate act in Paris to mitigate and adapt to these consequences. The participating countries decided to limit the global temperature rise below 2 degrees Celsius. To achieve this goal a great deal of climate mitigation (prevention and reducing climate change effects) and climate adaptation (adapting to the changing climate consequences) is needed. Climate adaptation has already been part of the Dutch flood risk management for almost a decade.

In the European Flood Directive from 2007 (2007/60/EC) the European Union encourages its member states to integrate a risk-based approach in their flood prevention policy based on the potential consequences of floods combined with their probability. In the Netherlands, this resulted in the Multi-Layer Safety approach. This approach consists of 3 layers, i.e. (1) prevention, (2) damage reduction by spatial planning, and (3) preparing emergency response (Rijke, et al., 2014). In essence, the MLS approach integrates solutions for prevention and damage reduction with possibilities from emergency planning.

The MLS approach shifts the focus from conventional linear planning to a new way of parallel planning (Sophronides, Steenbrugge, Scholten, & Giaoutzi, 2016). This means that effective methods to strengthen flood protection include measures from all three layers, instead of conventional planning through which only one layer, in the Netherlands usually flood protection, is enforced. When using this old way of planning the chain is only as strong as its weakest link (Jongejan, Jonkman, & Vrijlating, 2012), thus if the first line of defense fails a catastrophe is inevitable. Obviously, utilizing the MLS approach in flood risk management implies engaging stakeholders from different domains in the planning process, leading to extra implications for budgeting, planning, and permitting. Engaging various domains in the planning process also leads to location-specific solutions to strengthen flood resilience in the area (Onur & Tezer, 2015).

Flood resilience is a contraction of flood risk management and the conceptualization of the definition of resilience. It encompasses more than flood proofing areas; it is about spatial resilience, structural resilience, social resilience, and flood risk resilience (Tourbier, 2012). The MLS-approach is, by opening the concept of spatial planning and flood risk management to other areas of study, a way to strengthen flood resiliency.

This study arises from the question whether the concept of flood resilience can provide a framework by which spatial adaptation measures can be assessed. Flood resilience is a widely-studied concept of which a lot of recent scientific information is available. The flood resilience approach demands a way of thinking that is called systems thinking. Systems thinking is derived from the notion that causes and effects are not linear. The mindset is to understand the function(s), elements and interrelations within a system which can have both, expected and unexpected responses when an event occurs (Meadows & Wright, 2008). An area (including both the physical and societal aspects) vulnerable to flooding, should be analyzed with a 'systems thinking' mindset; i.e. holistic approach.

1.2 Problem statement

Impacts of spatial planning measures have effects beyond the field of spatial planning and can also affect the economy, ecology and social organization (Koks, de Moel, Aerts, & Bouwer, 2014). It contributes in varying degrees to the flood resilience of the area; this may be a positive or negative contribution. Especially the second layer of the MLS approach (spatial adaptation) engages stakeholders from all domains into the planning process, leading to increased complexity.

Although it is assumed that the MLS approach generally contributes to the overall flood resilience of an area (Sophronides, Steenbrugge, Scholten, & Giaoutzi, 2016), a knowledge gap exists between the concept of flood resilience and the decision-making process in which measures from the MLS approach are chosen and implemented. The knowledge gap leaves space for doubt and debate concerning the extent of flood resilience, after all, in which extent of time and space is the impact of spatial adaptation measured? Which models and indicators can be used to measure flood resilience?

Paramount in this research is defining the indicators of floods resilience; how these indicators function as benchmark of resilience in a dynamic system. The case study Yerseke is used to define and validate the indicator. Using this case study leads to an emphasis on indicators of flood resilience in relation to pluvial floods.

The aforementioned, fundamental aspects of this research are merged in one integral research question which reads as follows;

"How can the impact of spatial adaptation measures be assessed in order to gain insight into their contribution to flood resilience?"

Subsequent research questions are used to answer the research question;

- What is the relation between flood resilience and spatial adaptation and which spatial measures are implemented in Yerseke to enhance flood resilience?
- Which spatial impact assessment method is compatible with the flood resilience approach?
    - What is the relation between impact assessments and the flood resilience approach?
    - Which legal instruments provide a framework for the impact assessment of flood resilience?
- What are the indicators of flood resilience?
    - What affects flood resilience?
    - How can the indicators be valued?
- How do the measures of the municipality of Reimerswaal to prevent pluvial flooding in Yerseke score in the proposed impact assessment?

This research is divided into four sub-questions, concerning the resilience approach combined with spatial adaptation, the impact assessment, and indicators of flood resilience. The first two sub-questions form the theoretical foundation of this research, the latter is obviously also established on a theoretical basis but requires both qualitative and quantitative field research. All three sub-questions have been split into two or three sub-sub-questions. These sub-sub-questions reflect the progress in the research and divide the sub-questions into manageable pieces. The sub-sub-questions are formulated in a way that they are seeking for the relation between relevant subjects and form the bricks of the assessment framework.

1.3 Scope

Flood resilience, spatial adaptation and impact assessments are three broad subjects which can individually offer numerous thesis possibilities. Thus, it is important to set a clear scope with limitations before starting the research.

This research will use flooding in Yerseke in the municipality of Reimerswaal as a case study. In June 2016 parts of the town of Yerseke suffered waterlogging due to heavy rainfall (19 mm/hour). In parts of the historic city center the water level was 40 – 50 cm high on the streets and the water poured underneath the front doors into the houses (PZC, 2016). In accordance with other governmental organizations a set of measures has been selected and is being implemented. The three measures which are being analyzed for this research are;

1. The wadi in the Marijkelaan
2. Redevelopment Kerkhoekstraat
3. Constructing a ditch

Figure 1 Location of spatial adaptation measures in Yerseke (GoogleMaps, 2017)

The location of these measures is presented in figure 1.

The case study of Yerseke provides the limitations for this research, regarding space, time, social organization, and governance. The spatial limitations are set in affected the city center of Yerseke (about 100 households suffered from the waterlogging). During the rain event the excess water was drained to an acceptable level within days, this timespan provides the research with limitations concerning time.

Important to note is that the Multi-Layered Safety approach is a Dutch response to the European Flood Directive from 2007. This directive urges EU Member states to integrate a risk-based approach in their flood prevention policy based on the potential consequences of floods combined with their probability. This means that other members of the FRAMES partnership possibly developed distinctive approaches to integrate flood prevention into their national policy. However, the MLS approach is the starting point for this research, since the case study in located in the Netherlands.

Costs of implementation and maintenance of the measures will also not be taken into account in the impact assessment. The aim of the impact assessment is to test the impact on flood resilience, costs of the measures are not a part of this. According to this same logic also public health has not been included in the impact assessment.

Recommendations leading from this research will be aimed at the work field of spatial planning, since the FRAMES-project is aimed at creating flood resilient areas by implementing spatial measures.

1.4 Readers guide

Chapter 2 provides a theoretical framework for this research. In this theoretical framework, relevant theories that lay the foundation of this research is explained. Relevant research into this topic is also included.

Chapter 3 describes the methodology used in this research. The used methodology explains the research design, data collection, literature research, data description and data analysis.

Chapter 4 presents the results of this research. The results are explained using the sub research questions. Conclusively the discussion puts the results in the right context.

In chapter 5 the conclusion of this research is discussed, which is followed by recommendations for application of the impact assessment, further research, and recommendations leading from the impact assessment of Yerseke.

2. THEORETICAL FRAMEWORK

This chapter discusses relevant theories in the field of research of this topic. Spatial adaptation measures form the starting point of this research and are therefore discussed first. Secondly, the resilience theory is elaborated to provide the reader with a clear understanding of this topic. Thirdly, the conceptualization of resilience in the 4+1 model is discussed. Fourthly, legal forms of impact assessments are discussed to gain insight into how these impact assessments are used. Consequently, the theories are wrapped-up in a conceptual framework.

2.1 Spatial adaptation

Spatial adaptation measures are physical responses to flood events, with the intention of lowering the flood risk. To thoroughly understand the flood risk in any given area it is of crucial importance to understand the probability, exposure, and vulnerability of flooding in the area. Risk-based flood management has become increasingly important since the European Union urges its member states to integrate a risk-based approach in their flood prevention policy (European Flood Directive from 2007 (2007/60/EC)), which is based on the potential consequences of the flood combined with the probability. In the Netherlands, this approach resulted in the Multi-Layer Safety approach, an approach consisting of 3 layers, i.e. (1) prevention, (2) damage reduction by spatial planning, and (3) preparing emergency response (Rijke, et al., 2014). See figure 2.

Even though the elaboration of the MLS approach in the National Water Plan 2016-2021 focusses on the primary water system, the approach is applicable to other situations where flooding is a realistic risk (Kolen & Kok, 2011).

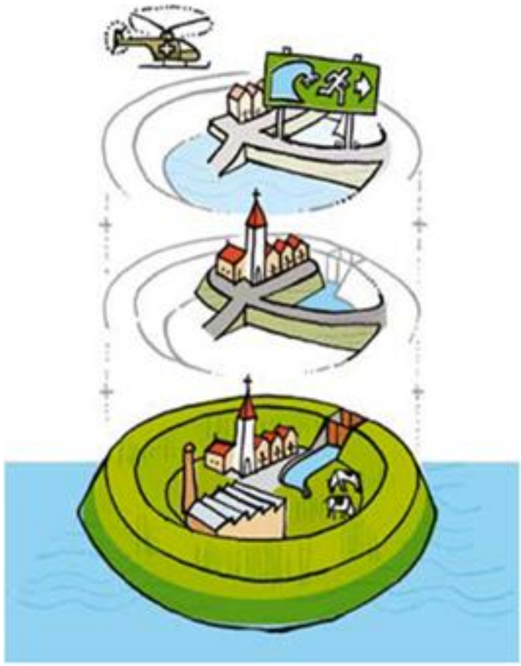


Figure 2 Schematic representation of MLS (Kolen & Kok, 2011)

2.1.1 Archetype spatial adaptation measures

Spatial adaptation measures depend on the source of the waterlogging; protection against marine or pluvial floods. Therefore, two approaches of spatial measures are discussed. Firstly, spatial adaptation according to the MLS approach, aimed at spatial adaptation for marine and fluvial floods. Secondly, spatial adaptation according to the three-step strategy aimed at pluvial floods.

Spatial adaptation according to the MLS approach

Layer two of the MLS approach involves damage reduction by spatial planning. Hereby the focus is on sustainable land-use planning whereby proposed measures are designed to keep critical infrastructure available and the damages to a minimum. Examples of measures deriving from the second layer of MLS are according to (Zethof, Maaskant, Stone, Kolen, & Hoogendoorn, 2012);

- Lifting ground level
- Dry proof building
- Wet proof building

Spatial adaptation according to the three-step strategy
Spatial adaptation measures can strongly diverge, depending on local characteristics. The Commission *Water Management In The 21st Century* described a strategy to deal with water problems in the Netherlands, to implement a three-stage strategy in which water is being retained, stored, and drained (WB21, 2000). In the Commission's opinion retaining and storing water can contribute to the water supply in times of drought, and positively contributes to nature development and agriculture.

<u>Measures to retain water</u>
Retaining water is the first step. Measures to retain water close to the place it touches the surface include;

- Green roofs
- Adding public green

<u>Measures to store water</u>
If the measures to retain water are saturated, the water should be stored to be used in dry periods. Examples of measures to store water are;

- Wadi
- Open water (ditches or ponds)
- Water square
- Lowering the roads

<u>Measures to drain water</u>
Draining water is the last option if the storage and retain measures are not sufficient. Examples of measures to drain water are;

- Detached sewage system
- Redesigning sewer system

Spatial adaptation measures are not one-size-fits-all measures and should be adapted to different area's; recognizing that each area is different, with different spatial characteristics and different people. In the Delta Decision Spatial Adaptation this is recognized. Therefore, the central theme of the Delta Congress 2016 was *Connecting the challenges, together on course!* One of the outcomes of this day was that civilians need to be involved in designing the spatial adaptation plans (Nationaal Delta Congres, 2016). This implies that the societal aspects of spatial adaptation are acknowledged and flood resilience is enhanced.

2.2 The resilience approach

The broad concept of resilience is derived from the Latin word *Resilio*, as in jumping back to the previous state. Since the 1970's this concept has been used in many work fields, like psychology and economy. In 1973 C.S. Holling adapted this concept in his seminal work *Resilience and stability of ecological systems*. According to Holling (1973) an ecological system has two kinds of behavior; (1) stability, which represents a system's ability to recover from a disturbance and achieve a new stable state, and (2) resilience, which is a measure of a systems ability to absorb changes and maintain the same structure and function.

In his later work Holling (1996) defined two types of resilience; engineering resilience and ecological resilience. In later works, the concept of socio-ecological resilience was added;

1. *Engineering resilience* is the type of resilience Holling referred to in 1973. This system returns to its status quo after a disturbance. How quickly a system returns to this status its pre-existing state measures its linear resilience.
2. *Ecological resilience* dismisses the idea that a system has one equilibrium-state and acknowledges that nonlinear systems can have numerous equilibrium-states. The system's capacity to absorb the magnitude of the disturbance, while maintaining its core structure and functions determines the system's resilience.
3. *Socio-ecological resilience* has the underlying theory that social and ecological systems are interlinked and interact (Wilkinson, 2012). The idea is that the boundaries of a system co-evolve with the system. These flexible boundaries are inherent with a systems capacity to adapt to a new equilibrium, by changing its structure and its function. A social-ecological system has multiple equilibria and is a complex adaptive system.

Figure 3 shows a graphical representation of the three types of resilience.

Figure 3 Types of resilience (Tempels, 2016)

Even though the engineering resilience and ecological resilience are fundamentally different, they both recognize the existence of one or more equilibria in a system, whether this is a fixed equilibrium (engineering resilience) to which a system can bounce back, or a system with multiple equilibria to bounce forwards to. Social-ecological resilience eliminates the assumption of fixed equilibria and assumes that systems continuously change. From this perspective resilience is not the capacity to bounce back to a previous state, but a systems capacity to deal with change.

In essence, resilience describes a system's capacity to absorb and deal with shocks. From a spatial planning perspective, this implies that flexibility should be incorporated into spatial plans to deal with disruptions, like a flood event.

2.3 The 4+1 model

When looking at an urban or rural area the conclusion can be drawn that the areas are social-ecological systems, because numerous subsystems are present and interact dynamically. Ecological, social, economic and political subsystems all function together as a highly complex social-ecological system, but also function as independent systems. The HZ Research Group Resilient Deltas conceptualized resilience in the 4+1 model. This 4+1 model emerges from the notion that four subsystems, social capital, use of space, economy and critical infrastructure are distinctive of one contextual subsystem; governance (figure 3) (Fundter, et al., 2015). Important to mention is that figure 4 is an oversimplification of the 4+1 model, and solely shows the subsystems. The graphical representation does not present the interrelations between the functions within the aspects.

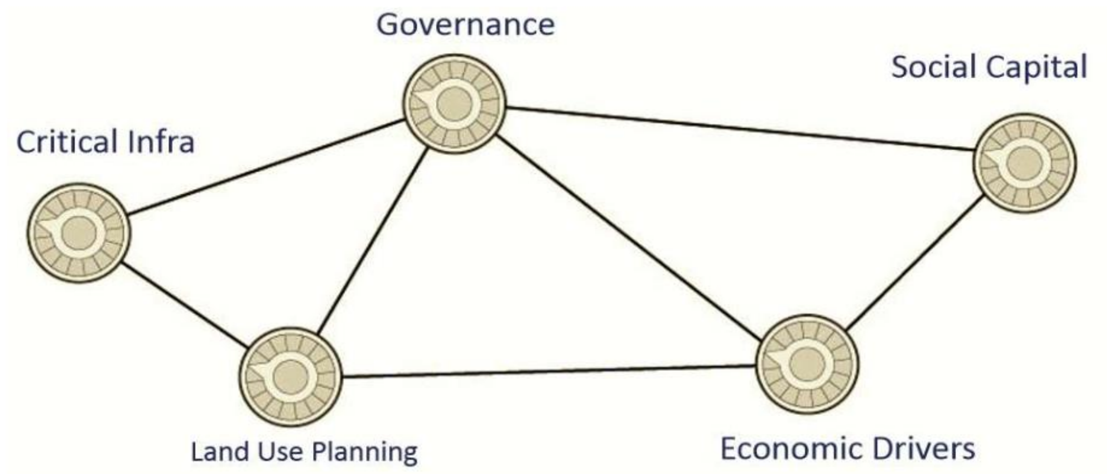


Figure 1 Simplified visualization of the 4+1 model (Fundter, et al, 2015)

Within the 4+1 model, social capital shows the relation between the strength of social networks within a society and its capacity to be resilient and self-reliant. The structure of the social networks and the character of the interrelations affect how a society deals with change and how it adapts to other situations. The strength of the social relations determines the capacity of a community to cooperate and to build towards collective well-being (Fundter, et al., 2015).

The second aspect of the 4+1 model is land use planning, which concerns the relation between people usage of their landscape. The landscape can be assessed by using the layer approach (RPD, 2000). This approach distinguishes 3 layers, i.e. occupation, network, and substrate, in the landscape to determine the social and environmental shifts and to simplify assessment of the landscape (see figure 5).

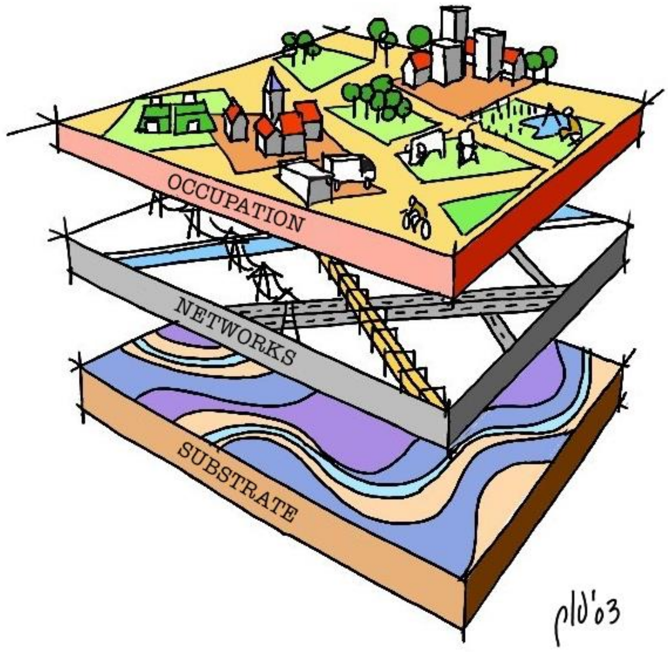


Figure 2 The three distinctive layers (RPD, 2000)

Economic resilience involves keeping the areas economic status as close to its potential as possible and absorb shocks to keep the economic damages at a minimum level (OECD, 2016). Important indicators of economic resilience are economic diversification, income equality and sustainable long-term perspective.

The continuity of critical infrastructure determines to a large extent the magnitude of the impact (flood). These vast complex networks are the fulcrum of the crisis because they determine whether the crisis gets worse or better. Critical infrastructure also determines the scale of the impact because it can lift the crisis to a higher scale (from local to regional) (Fundter, et al., 2015).

Governance differs from the other subsystems because it is mainly concerned with context instead of content. Indicators of the subsystems governance are adaptive capacity, reconciliation between the government and civilians and polycentric governance.

2.4 Impact assessments

The impact assessment is a policy tool to measure the economic, social or environmental impact of a policy or an action. The results of the impact assessment will help policy makers and decision makers. However, an impact assessment can be executed in different ways. The following subparagraphs will discuss relevant impact assessment methodologies for spatial plans deriving from European or Dutch legislation. Analyzing impact assessment methodologies with a legal basis provides insight into how the proposed impact assessment in this research should be shaped to acquire practical value.

2.4.1 The Water Assessment, Environmental Impact Assessment and Strategic Impact Assessment compared

According to Dutch and European legislation spatial plans and projects need to be assessed in order to be implemented (receive a permit). The Environmental Impact Assessment (EIA) and the Strategic Impact Assessment (SIA) have a basis in European legislation, the Water Assessment (WA) is not required by the EU. This paragraph will briefly compare these legal planning instruments and conclude what can be learned from the assessments.

Water Assessment

Water Assessments are required for plans on all levels of scale for formal and informal plans in the Netherlands (art. 3.1.6 section 2 Spatial Planning Decree 2015). The WA assesses the water related impacts of a spatial plans by the criteria that have been defines by the water authority in accordance with the spatial planning authorities and are based on policy documents. The WA is executed by experts from the involved water authority(s). Finally, the WA results in a Water Recommendation written by the involved water authorities.

Environmental Impact Assessment

Unlike the WA, the EIA is extensively described in European and Dutch legislation (Environmental Management Act, 1994)(*Wet milieubeheer)* and is required by the EU. It is applicable for spatial and non-spatial decisions (decision is made before the construction can start; permit for projects) including activities listed in annex B and C of the Environmental Management Act, in Dutch the EAI is sometimes referred to as *project-m.e.r. (milieueffectrapportage)*. The EIA describes environmental impacts, including water impacts and involvement of independent experts is obligatory. Finally, the EIA results in decision with a statement written by the competent authority.

Strategic Environmental Assessment

The SEA is also required by the EU and has a legal basis in EU and Dutch legislation (Environmental Management Act, 2006) and is obligatory in formal plans including a listed activity and plans with impacts on natural habitats. In Dutch the SEA is often referred to as a *plan-m.e.r.*. The most important difference between the EIA and the SEA is that the SEA procedure has more links with planning procedures than the EIA.

Comparison

The WA, EIA and SEA are legal instruments required by EU and/or Dutch legislation to assess the impact of plans and projects on the natural environment (Van Dijk, 2008). Standards bandwidths by which is being measured are established in the law, this provides little space for considerations for tailored plans. The assessments only focus on environmental impacts and do not consider the other aspects which are necessary to build flood resilience, like social-economic circumstances or governance. Also, the scope of involved actors is too narrow to apply on flood resilience because only (independent) experts and authorities are involved. Only in the EIA dedicated public consultation is always part of the process.

However, the valuable lessons can be learned from the processes and procedures. When a WA is necessary the initiator and water manages agree and the assessment criteria and process to be followed in the initial phase of the project. By doing this the WA is an integrated part of the planning process and an actual part of the plan. In the reviewing (final) phase of the project the water paragraph is reviewed by a higher authority. From the procedure of the EIA and SEA a valuable lesson can be learned of how the guidelines for the Environmental Impact Statement are set by using input from the public, legal advisors and the EIA Commission. These actors are also involved with reviewing the plan in the developing phase.

2.4.1 EU Commission IA Guidelines

The EU Commissions are obliged to execute an impact assessment if a Commission Initiative will presumably have an economic, social or environmental impact. The revised EU guidelines (European Commission, 2009) for drafting an impact assessment state that the impact assessment always;

- Follows a standard format
- Is a self-standing document with no more than 30 pages
- Presents the work of the IA in a concise manner
- Uses non-technical language
- Presents detailed supporting material in technical annexes

The standard format of a EU impact assessment;

- Section 1: Procedural issues and results from consultation of interested parties
- Section 2: Policy context, problem definition, and subsidiarity
- Section 3: Objectives
- Section 4: Policy options
- Section 5: Analysis of impacts
- Section 6: Comparing the options
- Section 7: Monitoring and evaluation

2.4.2 Socio-Economic Impact Assessment

The Socio-Economic Impact Assessment is an analysis model used to systematically identify and evaluate the potential socio-economic and cultural impact of a proposed measure or policy (Mackenzie Valley Environmental Impact Review Board, 2007). If the IA reveals that the proposed measure imposes significant negative impacts on one or more of the elements, the decision makers can find ways to reduce the impact, adapt the plans and prevent these impacts from happening.

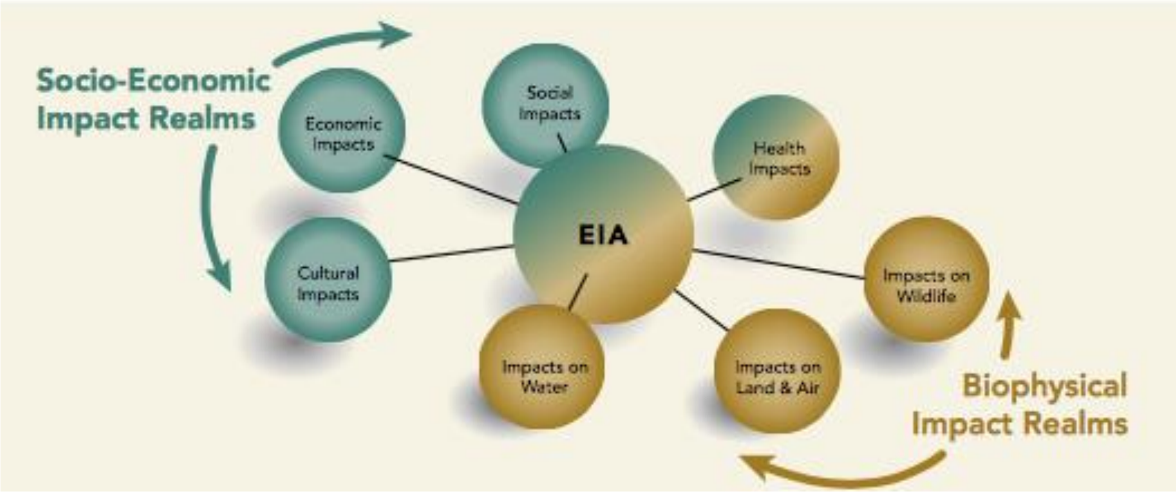


Figure 6 Aspects of an SEIM (Mackenzie Valley Environmental Impact Review Board, 2007)

The elements which are being assessed and valued in this SEIA are; *(See figure 6)*

- Health and wellbeing
- Sustainable wildlife harvesting
- Land access and use
- Protecting heritage and cultural resources
- Equitable business and employment opportunities
- Population sustainability
- Adequate services and infrastructure
- Adequate sustainable income and lifestyle

The process of executing an SEIA runs according to six distinctive steps;

1. *Scoping:* A preliminary analysis that identifies and prioritizes SEIA considerations and required information.
2. *Profiling baseline conditions:* Focus on the gathered data and define measureable indicators.
3. *Predicting impacts:* Predict impacts based on the gathered data and baseline conditions and identify tradeoffs between the beneficial and adverse impacts.
4. *Identifying mitigation:* Design strategies to reduce, avoid or manage the adverse impacts.
5. *Evaluating significance*: Evaluate if the proposed mitigation strategies will tackle the adverse impacts, otherwise the proposed measure may not be approved.
6. *Applying mitigation & monitoring:* Monitor if the mitigation strategies work effectively and if necessary adapt the mitigation measures.

2.5 Case study: Flood disaster resilience evaluation

In the past various attempts have been made to measure flood resilience. Here is a review of the case study Regional flood disaster resilience evaluation based on analytic network process: a case study of the Chaohu Lake Basin, Anrhui Province China (Sun, Cheng, & Mengqin, 2016).

This paper evaluates flood disaster resilience in the Chaohu Lake Basin in China. According to this research, flood disaster resilience is influenced by five dimensions; i.e. nature, society, economy, technology and management (Mayunga, 2007). The goal of this research is to gain insight in the weak links of flood disaster resilience and will lead to an improved level of flood resilience in the area of the case study.

The research underpins the high complexity and uncertainty of using quantitative methods to measure disaster resilience in integrated social-ecological systems. Therefore, the researchers use an index system that is used in various studies on resilience.

2.6 Conceptual framework

Spatial adaptation measures are physical responses to floods, with the intention of lowering the flood risk. These adaptation measures are spatial interventions deriving from the second layer of the Multi-Layered Safety approach, namely sustainable spatial planning. However, when the resilience approach is applied to this approach, the measures may change.

The resilience approach encompasses a holistic perspective on, in this case, spatial planning. It recognizes that the social-ecological systems that form society are interlinked and interact; the idea is that the boundaries of a system co-evolve with the system. Applying the resilience approach in spatial planning provides the opportunity to assess the impact of spatial adaptation measures on all the other aspects of the societal and physical environment. The 4+1 model describes aspects which can be used to measure the impact of a (flood) disaster and acknowledges the interaction between the systems. In figure 7 a visualization of this process is presented; if spatial adaptation is applied with the resilience approach, will this result in a flood resilient areas.

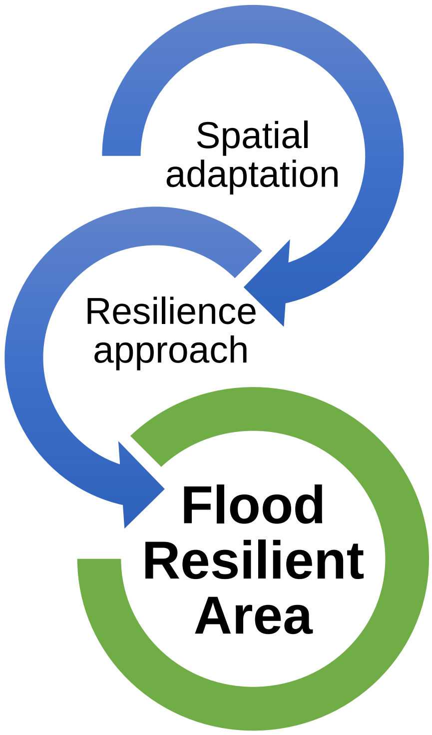


Figure 7 The conceptual framework; if spatial adaptation is applied from a resilience approach, flood resilience will be enhanced, this can be measured using an impact assessment (green circle).

To assess the impact of spatial adaptation measures on the physical environment, legal assessments can offer a framework for which can be adapted and transformed into a usable impact assessment. Therefore, the proposed impact assessment will be useful for policy makers and can be incorporated in policy.

3. METHODOLOGY

This chapter describes how the research is conducted and discusses why this approach is used. Also, the used research methods and method of analyzing the data is presented.

3.1 Research design

This research has a qualitative research design. The choice for a qualitative research design is based on two predominant arguments;

- High complexity; the high complexity of the research themes make it difficult to quantify data.
- Time limitations; the research must be executed within a timeframe of 4 months. Within this timeframe, it would be difficult to collect and quantify the data.

3.2 Data collection

To collect data three qualitative methods have been selected;

1. Literature research / desk research
2. Interviews
3. Case study
4. Consultation / reflection
5. Location visit

3.2.1 Literature research / desk research

- The literature used in this research is predominantly retrieved from scientific journals. The following online databases have been used to search for scientific articles; ScienceDirect, Springer, and ResearchGate.
- Governmental reports also were used as information source, regarding policy, statistics, and for inspirational purposes.
- Books were used to consult for detailed information about a topic.

3.2.2 Interviews

Interviews have been conducted with professionals from governmental organizations to discuss and validate the results of the literature research and field research. The interviews were planned late in the second phase of this research. Prior to the research extensive research has been done into the topics, to be able to ask thorough questions.

Name	Organization	Topic
Ben Sandee **Peter Driesprong**	Gemeente Reimerswaal	Land-use planning
Carolien Sinke	Gemeente Reimerswaal	Economics
Thomas van Sluijs	Gemeente Reimerswaal	Orientation showcase
Leo Caljouw	Provincie Zeeland	Social capital
Marion Pross	Provincie Zeeland	Ecology
Patrice Troost	VeiligheidsRegio Zeeland	Critical infrastructure

Maurits Schipper	Waterschap Scheldestromen	Water system

The interviews are summarized and included in appendix II. All the interviewees have approved the method and content of the transcripts. After the interview a summary of the interview is send to the interviewees. All the interviewees agreed with the summaries as included in appendix II.

3.2.3 Case study

The impact assessment is developed while researching the case study of Yerseke. Yerseke is a town in the municipality of Reimerswaal, which is a pilot area of the FRAMES project. Three selected spatial adaptation measures are subject of the case study. The case study tests and validates the impact assessment.

3.2.4 Consultation / reflection

During the research researchers of the HZ University of Applied Sciences of the research group Resilient Deltas have been consulted for advice and reflection. The researchers that have contributed are;

- Drs. J.M. (Jean-Marie) Buijs
- Dr. Ir. T. (Teun) Terpstra

During the process the researchers reflected on the results of the research. Both researchers are authorities in the field of flood resilience and flood preparedness.

3.2.5 Location visit

During the executing phase the pilot area (Yerseke) is visited to collect empirical data. Spatial adaptation measures in Yerseke are visited to gain better insight into how the visibility of the measures in the landscape.

3.3 Data analysis

Gathered data was collected and analyzed per subsequent research questions.

1) For research question one (finding the relation between flood resilience, spatial adaptation and showcase Yerseke), a combination of desk research and an interview was used into the topics of (1) flood resilience, (2) impact assessments, and (3) showcase Yerseke. Desk research provided a theoretical basis for the first part of the question. An interview with the municipality of Reimerswaal was planned to gain insight into the showcase Yerseke.
2) Subsequent research question two (the relation between flood resilience and impact assessments) is based on literature research and consultation of researchers of the research group Resilient Deltas of the HZ University of Applied Sciences. The researchers gave feedback on the literature review and provided useful insights.
3) The third research question (the indicators of flood resilience) is based on literature research, consultation of researchers of the research group Resilient Deltas, and professionals from various governmental organizations. Based on literature research a set of indicators was selected. Those indicators are discussed with the researchers. After discussing the indicators with the researchers, interviews were planned with professionals from the field to validate the indicators.

4) The fourth research questions (applying the proposed impact assessment to showcase Yerseke) applies the developed IA to showcase Yerseke. During the interviews the showcase Yerseke has been discussed. In accordance with the interviewees the impact assessment has been filled-in and substantiated.

4. RESULTS AND DISCUSSION

4.1 The relation between spatial adaptation, flood resilience, and Yerseke

Climate change may affect areas and societies in various ways, with more intensive rainfall, drought, storms and coastal erosion (IPCC, 2014). Especially delta areas are vulnerable to these effects because of the aggregated effects of climate change, geo-ecological processes and socio-economic changes (Klijn, Kreibich, de Moel, & Penning-Rowsell, 2015). The high vulnerability of these areas suggests, that rather than waiting until global mitigation policies have any effect, we must adapt to survive. This research seeks to answer how spatial adaptation contributes to flood resilience and what the municipality of Yerseke does to improve its flood resilience.

4.1.1 Socio-spatial planning

Spatial adaptation measures are not one-size-fits-all measures, recognizing that each area is different, with different spatial characteristics and different people. In the Delta Decision Spatial Adaptation (2017) this is recognized. To attract more attention to this topic, the central theme of the Delta Congress 2016 was *Connecting the challenges, together on course!* One of the outcomes of this day was that civilians need to be involved in designing the spatial adaptation plans (Nationaal Delta Congres, 2016). Although spatial planning is traditionally a knowledge-based profession performed by educated professionals, contemporary scientists plead for community engagement in spatial planning (Natarajan, 2017). Spatial planners can learn from big potential of knowledge about areas from communities that have been using the space intensively. In current planning theory, community participation is a tool for community building, spatial considerations are a secondary objective. Involving a diversity of stakeholders in (planning) processes is a way to enhance social resilience (Leitch, Cundill, Schultz, & Meek, 2015).

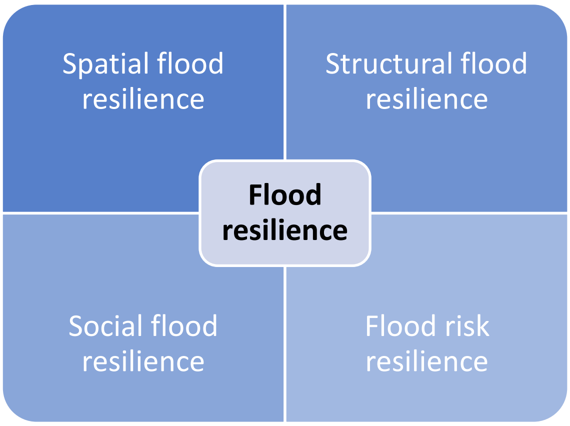
4.1.1 Flood resilience

The conceptualization of resilience has also been adapted into the field of flood risk management. In the basics, resilience comprehends a systems ability to absorb disturbances. Now what does this mean for spatial planning? Is it about wet-proofing houses and minimalizing damage after a storm? Or does flood resilience encompass more?

Tourbier (2012) defines flood resilience by combining the following aspects;

1) **Spatial flood resilience** implies the management of land by floodplain zoning, urban greening and management to reduce storm runoff through depression storage and by practicing sustainable urban drainage, best management practices, or low impact development. Ecologic processes and cultural elements are included.
2) **Structural flood resilience** refers to permanent flood defense structures such as levies, demountable structures that are partially installed, temporary structures that are removable, as well as dry- and wet flood proofing of structures to meet construction standards to deflect or resist pressure without breaking.

3) **Social flood resilience** referring to the building of robust institutions (including NGO's) and governance systems that underpin our capacity to prepare for and cope with uncertainty, change, and disasters when they occur.
4) **Flood risk resilience** implies the ability to withstand and recover from crises through financial insurance assistance and through assistance by governmental institutions, including the communication of information on flood proofing steps that individuals can take on their own.



The aforementioned types of flood resilience are building blocks of flood resilience. Each aspect contributes to a flood resilient area. The systems thinking approach learns that the focus should be on combining the four aspects of flood resilience; spatial resilience, structural resilience, social resilience, and flood risk resilience. The four aspects should always be considered as part of a bigger system, thus should always be considered inherent to each other, but not necessarily with equal emphasis. An important lesson learned from this approach to enhance resilience, is that measures should be packages including integral measures to be contributing to all the aspects of flood resilience.

4.1.3 Spatial adaptation measures in Yerseke

In the past decade Yerseke has been hit by multiple precipitation events that have caused some streets in the old town center to flood. In figure 8 a model is shown of a rain event with the intensity of 19,8 mm in one hour. The model shows that the sewage systems in the older and lower parts of Yerseke are overloaded and not able to discharge this amount of water.

During a similar rain event in June 2016 the sewage system was indeed overloaded and the indicated streets flooded. At the most severe points the water level on the streets was 40 – 50 centimeters and 50 – 100 houses experienced water damage inside the house.

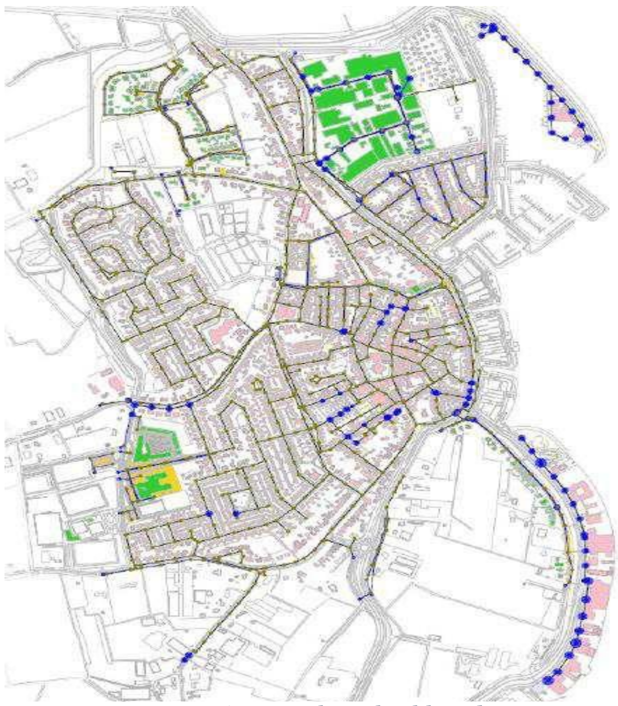


Figure 8 Sewage map in Yerseke. The blue dots represent bottlenecks in the sewage system during a rain event with an intensity of at least 19,8 mm/hour. (Reimerswaal, 2016)

To prevent the streets to flood during a rain event of this intensity, the municipality and water authorities designed a package of measures to prevent water from flowing into the houses in the future. Three measures are selected to be analyzed for the purpose of this research. The selected measures are;

- Wadi in the Marijkelaan
- Redevelopment Kerkhoekstraat
- Ditch in Molenpolderweg

In appendix I the three measures are described into more detail.

These three measures have been chosen because they are different types of adaptation measures, with different goal. The wadi is a spatial development and includes other functions (retain water), redevelopment of the Kerkhoekstraat is predominantly a technical measure solely for the purpose of draining water from its location (drain), and the construction of open water is to enlarge the buffer capacity (store).

When the selected measures are compared to the definition of flood resilience according to Tourbier (2012), it is clear that the measures include facets of three sides of flood resilience; spatial, structural and social resilience. Appendix I presents an elaborate overview of the spatial adaptation measures and how the measures aim to contribute to flood resilience.

4.1.3 Describing the relation

Flood resilience is the conceptualization of the definition of resilience, based on flood risk management. The definition of flood resilience is an interdisciplinary approach, integrating ecologic, spatial, structural, social, disaster relief and flood risk aspects into the definition of flood resilience.

Together with flood defense structures, social organization, and institutional response, is spatial resilience an integral and essential aspect of flood resilience. Therefore, the relation between spatial adaptation measures and flood resilience is evident; the smaller the impact of flooding on the physical environment, the smaller the impacts on the other aspects of the complex adaptive social-ecological system in which daily life persists. The Multi-Layered Safety approach recognizes this; by adopting spatial adaptation as second layer of the approach, the resilience of the system (*read physical environment and* society) is enhanced. Consequently, the conclusion can be drawn that spatial adaptation measures that increase spatial flood resilience do contribute to the resiliency of an area.

4.2 The flood resilience approach in impact assessments

Impact assessments of spatial interventions exist in many different form and are designed to measure the impact of a particular action on one or more aspects. Some types of impact assessments have a legal basis, for example the Environmental Impact Assessment or the Water Assessment. Different forms of impact assessments are elaborated in the theoretical framework. An integral part of this research is to seek for a framework that can be used to assess spatial adaptation measures in relation to flood resilience. The definition of flood resilience shows strong similarities with the 4+1 model.

4.2.1 Modelizing flood resilience in the 4+1 model

The table below compares the definition of flood resilience to the aspects of the 4+1 model.

Table 1: Comparing flood resilience and the 4+1 model

	Flood resilience		**4+1 model**
Spatial resilience	Management of land by spatial planning	**Land Use Planning**	How we use our landscape
Structural resilience	Permanent flood defense structures	**Critical Infrastructure**	The continuity of critical infrastructure during an impact
Social resilience	Building robust networks and institutions that underpin our capacity of preparation for disasters	**Social capital**	The relation between the strength of social networks and its capacity to be self-reliant
Flood risk resilience	The ability to withstand and recover from crises through financial insurance and assistance by governance	**Economy**	Keeping the economic potential of areas as close to its potential as possible
		Governance	The capacity of actors to work together and adequately react to calamities.

The table shows that there is a clear overlap between the definition flood resilience and the 4+1 model of resilient deltas. For example, land-use planning in the 4+1 model shows strong adherence with spatial resilience. Differences between the definition and the model should also be noticed. For example, the social aspect of the definition of resilience also includes facets of governance, which is a separate aspect in the 4+1 model. However, the main difference between the definition and the model is that the 4+1 model does not focus on floods, but encompasses disaster resilience, of which a flood is a type. By modelling disaster resilience, the 4+1 model turns the definition of resilience of an area into tangible aspects, with visible interrelations and associated indicators. Nevertheless, the findings of research question 1 show that using solely the aspects of the 4+1 model, nor the building blocks of flood resilience do not suffice in forming an integral assessment framework. The building blocks of flood resilience are too abstract and the 4+1 model is incomplete. Therefore, adaptations are suggested for the 4+1 model.

4.2.2 Reshaping the 4+1 model

The 4+1 model is designed to explain and measure the resiliency of communities, and therefore displays some shortcomings when used as framework to assess spatial measures;

1. In the comparison made above, governance resilience is about actions. However, these human-made governance systems can also be viewed as institution, networks, bureaucracies and policies as a part of a complex system in which adaptive agents respond to internal and external disruptions (Duit, Galaz, Eckerberg, & Ebbesson, 2010). The government aspect is

context related and is not directly affected by spatial measures and therefore irrelevant to include in the assessment framework.

2. The role of water is not ensured in the 4+1 model. Water is seen as an integral part of the landscape, so it is captured in the subsystem land-use, this causes the role of water to be insufficiently assessed in the assessment. The results of research question 1 show that spatial adaptation measures have a direct impact on the water system. Therefore, the water system can be seen as independent aspect.
3. Ecological values are insufficiently taken into account in the 4+1 model. The Resilient Deltas report (Fundter, et al., 2015) mentions biodiversity as sub-indicator of physical and environmental conditions. As proven in the past, spatial interventions can have a major impact on ecology. Studies show that landscapes (spatial plans) need to be designed from an ecological point of view to integrate ecological values in the design, otherwise the ecological values will deteriorate after a couple of years and the relation between the ecology and landscape patterns is lost (Opdam, Foppen, & Vos, 2001). This study shows that ecology is an important, and often underexposed, part of the physical environment. Based on these findings, ecology should be a separate aspect in the assessment framework.

Based on the latter remarks on the 4+1 model as assessment framework for spatial adaptation measures, a reshaped model emerges, consisting of the following six aspects;

- Water system
- Land-use
- Critical infrastructure
- Economics
- Social capital
- Ecology

These 6 aspects together will form the basis of the integral impact assessment to which spatial adaptation measures can be assessed in relation to floods resilience.

4.2.3 A legally defined assessment approach

In the National Climate Adaptation Strategy (NAS) 2016 the Dutch national government urges decentral governments to process adaptation strategies into their policies, and asks provinces to take lead in this process. The NAS acknowledges that spatial adaptation is intertwined in other policy areas and that gradual shifts in social-ecological systems are less obvious, but still have a large impact. For example, by corroding natural values, crops are increasingly exposed to pathogens and plagues, this impacts human health and food supply. This broad range of impacts proceeds on all scales in time and space. The goal of the NAS is to mitigate/adapt to the consequences of climate change and counteract deterioration of environmental quality and ecosystems by accelerating climate initiatives and interlace climate adaption across society. One of the means to achieve this is to integrate climate adaptation into policy. The impact assessment of spatial adaptation measures in relation to flood resilience contributes to this goal by assessing climate adaptation initiatives on a broad range of aspects. The new Dutch Environmental Act provides an opportunity to ensure this goal.

The new Dutch Environmental Act recognizes, like the NAS, the growing cohesion between complications in the physical environment. Since the past decennia is the relation between integral

water management and spatial planning strongly developed and emphasized. Integral water management derives from the notion that water systems are inseparable from other aspects of the physical environment. Partly because of climate change, it is important to shape our environment in a water conscious way and to minimize the impacts of floods.
This study into an integral impact assessment contributes to the goals of the Environmental Act in several ways. Firstly, the impact assessment provides an integral assessment framework by which the effects of spatial interventions can be measures on flood resilience, inherently with the aspects of the physical environment (land-use, water, society, nature, etc.). the new Act aims for the integral assessment of the effects of spatial plans. Nevertheless, in the new Act, more environmental policy is decentralized, from the national government to lower governing entities. This means that environmental considerations are now the responsibility of provinces and municipalities, implying that local differences in environmental policy will increase and considerations will diverge (Commissie M.E.R., 2016). Executing an integral assessment of spatial measures, whether focused on climate adaptation or not, will contribute to this goal. Secondly, the act aims to catalyze public and official processes and cooperation. By involving civilians, governing and non-governing bodies in the design phase of spatial plans (climate adaptation measures), communication and trust between the involved parties is expected to improve (*Kamerstukken II 2013/14, 33962, 46-47)*.

4.2.4 The assessment framework for spatial adaptation measures in relation to flood resilience

Considering the mentioned shortcomings of the 4+1 model, a new aspect system needs to be drafted. Paragraph 4.2.2 describes the adjustments that needs to be made, combined with the legal framework presented in paragraph 4.2.3, the impact assessment will consist of the following aspects;

1. Water system
2. Land-use
3. Critical infrastructure
4. Economics
5. Social capital
6. Ecology

These six aspects encompass the definition of flood resilience and fit within the context of the new Environmental Act. To determine the contribution of spatial adaptation measures to flood resilience a set of indicators is needed per aspects.

4.3 The indicators of flood resilience

Applying the indicators of resilience in a qualitative way recognizes that flood resilience is a dynamic and adaptive concept that operates on multiple levels. The indicators of flood resilience do not only take into account the spatial-facets but equally consider the social, economical, and institutional facets. By assessing spatial adaptation measures with a flood resilience approach the indicators assess measures beyond their impact on the physical environment. As mentioned before, the physical and societal environment in which spatial adaptation measures operate is a complex adaptive system, which is characterized by dynamics, rather than an equilibrium and stability (Duit, Galaz, Eckerberg, & Ebbesson, 2010). For this reason, this research chooses a qualitative approach, because quantifying resilience is two-fold; it is easier to make decisions based on numbers, but quantifying resilience also means decontextualization of the definition, implying that contributing factors are not considered in synergy. Marine, fluvial and pluvial floods diverge fundamentally in impact, scale, consequences, and measures to prevent them from happening. Therefore, it is important to mention is that the selected indicators of flood resilience concentrate on pluvial floods.

Flood resilience operates on different scales of space, time, and social organization (Resilience Alliance, 2017). For example, the indicators of the water system can be explained on local level, but also on regional or provincial level, this applies to all the indicators. The scale of the spatial measure determines how the indicators should be explained. Hence, the impact assessment should always go along with an explanation of how the indicators are used and on what scale it operates. For example, a spatial measure can influence the vulnerability of the critical infrastructure on regional scale, but influences biodiversity on a smaller scale.

Table 2: The aspects and indicators of flood resilience

Aspect	Indicator
Water system	Water quantity
	Water quality
Land use	User value
	Experienced value
	Future value
Critical infrastructure	Vulnerability critical infrastructure and services
	Vulnerability traffic and transport
Economics	Business climate
	Business continuity management
Social capital	Social cohesion
	Situational awareness
Ecology	Biodiversity
	Specie abundance

The latter aspects and indicators have been selected with professionals from various governmental organizations in the Province of Zeeland. In appendix II the interviews are presented.

4.3.1 Indicators water system

Water systems can essentially be divided into two aspects; quantity and quality. The resiliency of this system lies in its capacity to overcome disruptions, which can be in both the quantity (either excess or shortage) and quality (pollution or deteriorating quality). Spatial measures to improve flood resilience have a direct impact on one, or both, aspects of the water system.

Water quality

Water quality is a broad definition, depending on a big variation of indicators, like temperature, pH, conductance, nitrate level, and transparency. The standards of water quality are established in the European Water Framework Directive (Directive 2000/60/EC). Also, the effects on flora and fauna are important aspects of water quality. On district level, water quality can have direct environmental and social impacts and thus should be assessed. Experts on water quality can estimate the impact of a spatial measure on the water quality, based on the design of the measure and putting it in the right context.

Water quantity

Water quantity refers to a good balance between water excess and shortage. Water should always be available in the right proportions, during periods of excess and during periods of drought. Therefore, the best way to deal with water on land is to store it in the soil. This is considered the best kind of storage because it has a huge storage capacity and it also makes the area resilient to drought. The essence of dealing with water quantity is increasing the infiltration capacity the target area, thus by valuing the water quantity indicator the contribution to the infiltration capacity is preeminent.

"We don't want to store water in the drainage system, but rather in the soil. We must shift towards semi-natural solutions"

- Waterschap Scheldestromen

4.3.2 Indicators land-use

In the Netherlands, spatial quality has been the most important goal of spatial planning. Striving for spatial quality involves designing an area for optimal use, that is robust and sustainable, and has esthetic value. Or, in other words, creating an environment with a high user value, experience value, and future value (Needham, 2007).

User value

User value refers to the functions of the area. This may be living, recreation, or business. Spatial developments can change the user value by adding or removing users functions to an area. Usually adding functions which have a combined direct function for people positively contribute to user value.

Experienced value

Experienced value refers to how people perceive and experience an area. However, this can greatly vary per person; there are differences in what is perceived as a positive and what is a negative spatial development. The essential question by assessing this indicator is; does this spatial measure make this area more pleasant for living, working and/or recreation? To evade date, assessing experienced value should always be done with the main function and users of the area in mind. Rules of thumb can be applied to determine whether the spatial development positively or negatively contributes to an area.

Future value

Future value refers to sustainability in time and adaptability. Sustainability in time says something about securing a good environmental quality and that the space is usable for varied societal activities. The added functions should also add a lasting contribution to the economic and social-cultural development of the area. The area should also be flexible to be able to adapt to the future spirit of the age and the associated functions. On top of that, it must be possible to manage and maintain the area with acceptable costs (Dauvellier, 1991).

4.3.3 Indicators critical infrastructure

The critical infrastructure of an area is a collective of various attributes; physical resources, services, information, technology facilities, networks and infrastructure assets, whether physical or virtual (Kiel, Petiet, Nieuwenhuis, Peters, & van Ruiten, 2016). The dependency of our society and economy on the critical infrastructure is obvious; damages and black-outs in the critical infrastructure have disrupting and far reaching consequences for society and the economy. "*Infrastructure can be decisive in the scale of a disaster; it can have an aggregative effect or can limit the consequences".* Safety can be divided into 7 themes; natural environment, built environment, technological environment, critical infrastructure and services, traffic and transport, health, and societal environment (VeiligheidsRegio Zeeland, 2016). The vulnerability of two of these themes; (1) critical infrastructure and services and (2) traffic and transport, have been selected as indicators, because these themes display a strong correlation with the aspect *Structural flood resilience* of the definition of flood resilience (Tourbier, 2012).

Vulnerability critical infrastructure and services

Critical infrastructure are companies and governmental organizations that deliver products that are essential for daily life for most people (VeiligheidsRegio Zeeland, 2016). These types of infrastructure are considered critical if one of the following criteria is met;

- Disruption or failure of a critical sector, service or product that causes economical or societal disruption,
- Disruption or failure that directly or indirectly leads to a lot of victims,
- Disruptions that costs a lot of time and resources to recover.

Crisis types that are categorized in the theme critical infrastructure are;

- Disruptions in energy supply
- Disruptions in freshwater supply
- Disruption in sewage water drainage
- Disruption in telecommunication and ICT
- Disruption in waste disposal
- Disruption in food supply

Vulnerability traffic and transport

Traffic and transport are a part of the critical infrastructure that refers to the physical aspects related to transport via air, road, rail and water. Transport can be transport of people, products or services. Vulnerability of this type of infrastructure is decisive in determining the magnitude of the disruption (Fundter, et al., 2015).

4.3.4 Economic indicators

Economic resilience is defined as the capacity of an economy to reduce vulnerabilities, to resist shocks and to recover quickly (OECD, 2016). The essence lies in keeping the effects of an impact as close to its economic potential as possible.

Business climate

Interfering in a good business climate can be a decisive motivation whether to implement a certain spatial measure or not. A business climate is established by analyzing the economic projections for the area. Expected economic growth, increasing economic activities and rising real estate prices are examples of a good business climate.

Business continuity management

The more people settle in an area vulnerable to floods, the more business activity takes place, the more a flood affects the economy and thus society (Svetlana, Radovan, & Jan, 2015). The term Business Continuity Management (BCM) is used to refer to a business its capacity to continue its activity during, or shortly after, a disturbance. Spatial adaptation can contribute to this mission by lowering a company's vulnerability or shortening the recovery time.

4.3.5 Social indicators

During a flood disaster, the people usually have to deal with the situation themselves during the first couple of hours. Community resilience refers to a community's resilience to lead itself and overcome changes and crisis (Cohen, Goldberg, Lahad, & Ahronson-Daniel, 2016). This form of resilience encompasses social aspects related to the community. Aspects related the physical environment are additional.

Situational awareness

Studies show that people in flood prone areas are not always aware of the risks they encounter (O'Sullivan, et al., 2012). Together with the knowledge that civilians are inclined to leave the responsibility of floods with the authorities (Shaw, Scully, & Hart, 2014), does this mean that there is a diminishing capacity of communities to deal with floods. Spatial measures can contribute to this awareness by informing the community.

Social cohesion

Social coherence is the willingness of a community to work together for collective wellbeing, and is determined by the social networks. Social networks are the relations between the individuals, groups and organizations. The structure of these networks determines the efficiency, vulnerability and fragmentation of the networks (Fundter et al., 2015).

4.3.6 Ecology

Integrating ecology in the design of landscapes is absolutely necessary. The basis for this is to develop the landscape based on ecological values, instead of designing a landscape with ecological elements that seem to contribute to the physical environment for a couple of years. Natural processes should be used to connect ecological values to other elements of the environment (Opdam, Foppen, & Vos, 2001). The following two indicators say something about how the ecological values of the area develop after spatial intervention.

Biodiversity

Biodiversity refers to the level of variety of species in any given area. This concerns both flora and fauna. Spatial interventions can alter the biodiversity by intervening in the habitat of certain species. If the living conditions change also the biodiversity changes. Biodiversity can be measured by counting the variety of species in a certain area. Experts (ecologists) can estimate in the design phase of a project if/how the spatial development alters the biodiversity.

Species abundance
Besides biodiversity there is the amount of a species present in the given area; this is abundance. Specie abundance says something about the living conditions of a certain area for a specific specie. If the living conditions for a type of specie is favorable, the specie with thrive and multiply. Abundance is an important principle of enhancing resilience, it directly influences the adaptive capacity of a system (Kotschy, Biggs, Daw, Folke, & West, 2015).

4.3.7 Valuing the indicators
In the previous paragraph, generic indicators of flood resilience are described. This set of indicators recognizes that situational differences exist between locations where the assessment can be applied. These regional differences imply that a qualitative manner of valuating the indicators is needed, because the aspects of flood resilience carry different ways on different locations. For example, in a town center the social capital is more important than on a business park, here the economics aspect is predominant.

The impact assessment aims to provide a qualitative insight into the impacts of spatial adaptations on the six aspects that influence flood resilience, and therefore uses a qualitative way of valuating the indicators, so no indication is given about the importance of the aspect.

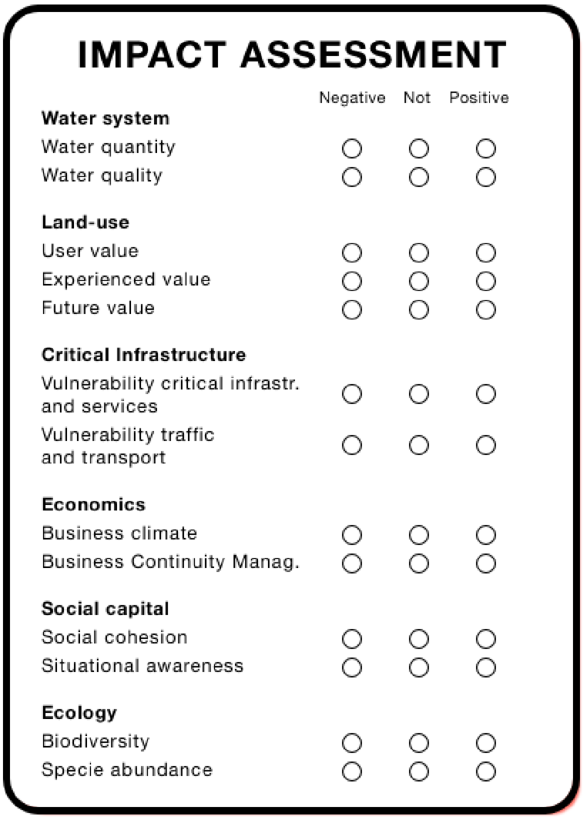
-	o	+

- = negative contribution
o = no impact
+ = positive contribution
By using these three qualitative ways of determining the contribution of a spatial adaptation measure no indication is provided about the extent of the impact. Other ways to assess the indicators have been considered (valuating the indicators on a numbered scale of 1 – 5, and choosing between --, -, o, +, ++) but were rejected. The numbered scale does not acknowledge local differences between the aspects and implies that all the aspects carry the same weight, and the scale with 5 symbols leaves too much room for considerations and thus allow personal differences.

4.3.8 Using the impact assessment

Using the impact assessment runs according to six steps (Mackenzie Valley Environmental Impact Review Board, 2007);

1. *Scoping*; a preliminary analysis that prioritizes the indicators and selecting professional experts of each aspect for assessing the indicators.
2. *Profiling baseline conditions;* focus on the gathered data and assess the current status of the physical and environmental assessment.
3. *Predicting impacts;* discuss the impact of the spatial measure on the indicators of flood resilience with the selected experts. The experts can estimate the effects of a spatial measure on their aspect of expertise.
4. *Identifying mitigation:* if the spatial adaptation measure is expected to affect the physical or societal environment negatively, design strategies to reduce, avoid or manage the adverse impacts.
5. *Evaluating significance;* evaluate if the proposed mitigation strategies will tackle the negative impacts, otherwise reconsider the measure.
6. *Implementing & monitoring;* implement the measure and monitor the effects. Gathered information is useful for future impact assessments.



IMPACT ASSESSMENT

	Negative	Not	Positive
Water system			
Water quantity	○	○	○
Water quality	○	○	○
Land-use			
User value	○	○	○
Experienced value	○	○	○
Future value	○	○	○
Critical Infrastructure			
Vulnerability critical infrastr. and services	○	○	○
Vulnerability traffic and transport	○	○	○
Economics			
Business climate	○	○	○
Business Continuity Manag.	○	○	○
Social capital			
Social cohesion	○	○	○
Situational awareness	○	○	○
Ecology			
Biodiversity	○	○	○
Specie abundance	○	○	○

4.4 Impact assessment: spatial adaptation in Yerseke

Together with the experts that validated the aspects and indicators the showcase Yerseke was assessed according the described methodology. The experts were asked to indicate if the chosen spatial measures would contribute (positively or negatively) to the aspects or not at all (no impact).

Because the impact assessment is qualitative, the indication is always specific to a certain context and is always conditional. Meaning that the indication is always; 'yes, but…'.
In the following three paragraphs, the showcase with the measures is presented and discussed using the indicators and given value. In appendix III the impact assessment is conducted according to the steps as described in paragraph 4.3.8 and elaborated into more detail.

The selected measures are;

- Wadi in the Marijkelaan
- Redevelopment Kerkhoekstraat
- Ditch in Molenpolderweg

Table 3; Impact assessment Yerseke

Aspect	Indicator	Wadi	Street	Ditch
Water system	Water quantity	+	+	+
	Water quality	o	o	+
Land use	User value	+	o	+
	Experienced value	+	o	+
	Future value	+	+	+
Critical infrastructure	Vulnerability critical infrastructure and services	o	o	o
	Vulnerability traffic and transport	o	o	o
Economics	Business climate	o	o	o
	Business continuity management	o	o	o
Social capital	Social cohesion	+	o	o
	Situational awareness	+	+	+
Ecology	Biodiversity	+	o	+
	Specie abundance	+	o	+

4.4.1 Wadi in the Marijkelaan

The wadi in the Marijkelaan is constructed to serve as water buffer for the old center of Yerseke. In the wadi, the water can infiltrate in the soil, and therefore contributes to the water quantity in a positive way. Because the water stands still in the wadi for only a short time before it infiltrates, it does not influence the quality of the water.

IMPACT ASSESSMENT

	Negative	Not	Positive
Water system			
Water quantity	○	○	✓
Water quality	○	✓	○
Land-use			
User value	○	○	✓
Experienced value	○	○	✓
Future value	○	○	✓
Critical Infrastructure			
Vulnerability critical infrastr. and services	○	✓	○
Vulnerability traffic and transport	○	✓	○
Economics			
Business climate	○	✓	○
Business Continuity Manag.	○	✓	○
Social capital			
Social cohesion	○	○	✓
Situational awareness	○	○	✓
Ecology			
Biodiversity	○	○	✓
Specie abundance	○	○	✓

Constructing a wadi, combined with a park that includes benches and elements of a playground for children, contributes to the user value and experienced value in the district. Before the wadi was constructed there were parking spots located, the parking places are moved to another location. The wadi combines water safety, recreation, education, and nature, and thus contributes to the experienced value.

One of the goals of the wadi is to make water visible on the street when it rains, to contribute to people's awareness of the vulnerability to floods. During the interviews this is confirmed by Leo Caljouw of the Province of Zeeland, "*Making water visible on the street raises awareness".* A summary of this interview is included in appendix II.

On top of that, by turning a paved area into a green zone, the wadi contributes to the ecology indicators of the impact assessment. A detailed assessment of the indicators is included in appendix III.

Figure 9 The wadi is currently under construction (May 2017) (picture taken during location visit)

4.4.2 Redevelopment Kerkhoekstraat

The redevelopment of the Kerkhoekstraat in Yerseke includes repaving the street with water permeable stones. These stones increase the infiltration capacity of the street and are therefore a positive contribution to the water quantity. The water quality is not influenced.

IMPACT ASSESSMENT

	Negative	Not	Positive
Water system			
Water quantity	○	○	✓
Water quality	○	✓	○
Land-use			
User value	○	✓	○
Experienced value	○	✓	○
Future value	○	○	✓
Critical Infrastructure			
Vulnerability critical infrastr. and services	○	✓	○
Vulnerability traffic and transport	○	✓	○
Economics			
Business climate	○	✓	○
Business Continuity Manag.	○	✓	○
Social capital			
Social cohesion	○	✓	○
Situational awareness	○	○	✓
Ecology			
Biodiversity	○	✓	○
Specie abundance	○	✓	○

In the Kerkhoekstraat, no functions were added or removed and the esthetics of the street did not change. Either the user value and experienced value are untouched. The future value of the street has increased because the new hardening makes the street more sustainable and ready for the future.

In this part of the center the spatial measure has no significant impact on the critical infrastructure, economic activity, or ecological values, so these aspects remain unchanged. The situational awareness is positively influenced because the restructured street clearly shows that it is adapted to future weather circumstances.

A detailed assessment of the indicators is included in appendix III.

Figure 10 Permeable hardening in the Kerkhoekstraat (picture taken during location visit)

4.4.3 Ditch in Molenpolderweg

Constructing a ditch in the Molenpolderweg contributes positively to the water system. By digging this ditch, the water buffer and infiltration capacity of Yerseke are increased, and provided that the ditch is at appropriate depth, the water quality will also increase.

Although the ditch does increase the experienced value and future value, because of the esthetic value of water in the build environment and sustainability of Yerseke, it does not contribute to the user value of because it has no direct user function of people.

Critical infrastructure and economics are not impacted because these aspects are not present in the near proximity of the ditch. Situational awareness of the ditch and overflow are influenced because the measures influence the public perception on flood resilience in the town of Yerseke.

IMPACT ASSESSMENT

	Negative	Not	Positive
Water system			
Water quantity	○	○	✓
Water quality	○	○	✓
Land-use			
User value	○	✓	○
Experienced value	○	○	✓
Future value	○	○	✓
Critical Infrastructure			
Vulnerability critical infrastr. and services	○	✓	○
Vulnerability traffic and transport	○	✓	○
Economics			
Business climate	○	✓	○
Business Continuity Manag.	○	✓	○
Social capital			
Social cohesion	○	✓	○
Situational awareness	○	○	✓
Ecology			
Biodiversity	○	○	✓
Specie abundance	○	○	✓

The ecological indicators are likely to point towards a positive contribution to ecology, provided that the ditch is constructed at the right depth that plants can settle.

A detailed assessment of the indicators is included in appendix III.

Figure 11 The Kon. Julianastraat on the left and the Molenpolderweg on the right

4.5 Discussion

The impact of spatial adaptation measures on flood resilience, can be assessed by using an assessment framework based on 6 aspects of the physical and societal environment. The findings of this research present an assessment framework based on combined literature research, a case study, and interviews with experts. Paramount in the research question are the first words, i.e., *how can*. *How*, refers to the utilized method to assess the impact of spatial adaptation measures.

In the first subsequent research question the relation between flood resilience and spatial adaptation measures is highlighted to justify the relevance of this research. Consequently, the second subsequent research question searches for an impact assessment framework that can be operationalized to assess flood resilience. Thereupon the assessment framework is supplemented with indicators of change. Finally, the usability is tested by assessing three spatial adaptation measures in the town of Yerseke. Therefore, the research provides an unabridged answer to the formulated research questions.

In the introduction, the problem statement delineates a knowledge-gap between academic research to flood resilience and the decision-making process that leads to spatial adaptation measures; measures are not designed in accordance with the definition of flood resilience. This research proposes a practical assessment framework for spatial planners to consider the impact of spatial adaptation measures on flood resilience. The assessment framework has been drafted in conjunction with professionals who work with (at least one of) the aspects of flood resilience. A striking observation from the interviews with professionals is their nescience of (flood) resilience theory. This observation underpins the necessity of this research.

Three spatial adaptation measures in Yerseke have been selected to test the impact assessment. With selecting the three measures, the origin of the measures has been taken into account, based on the Dutch three-step-strategy; each selected measure represents a step. Other adaptation measures have been considered, but rejected because they were solely technical and are not expected to have spatial impacts other than enlarging the drainage capacity in Yerseke.

Table 4; Overview IA scores

	+	o	-
Wadi in Marijkelaan	8	5	0
Redevelopment Kerkhoekstraat	3	10	0
Ditch in Molenpolderweg	8	5	0

Noticeable findings of this research surface when the proposed impact assessment is applied to the showcase Yerseke. The three selected spatial adaptation measures are of different origin. Thus, differences in impact are expected to appear when the impact of the measures on flood resilience is compared. However, the impacts of the three spatial measures are very similar; none of the spatial adaptation measures affects the selected indicators of economics and critical infrastructure. A likely reason of this outcome is the scale and location of the measures. In the case study, *Regional flood disaster resilience evaluation based on analytic process (2016)*, the indicators of the economic dimension have a low value in the Shucheng County in China, also an area with little economic activity. This puts the results of the impact assessment in line with the expected outcomes.

The main conclusion of this research is that even though spatial adaptation measures are designed with a shared purpose, measures affect flood resilience differently. This knowledge can be put into practice if decision makers approach the tool is (1) incorporated into spatial policy, or (2) used as a tool to assess the integral impact on this physical environment and (3) start the conversation about the spatial adaptation with a broad scope.
By applying the impact assessment on the case study of Yerseke, it can be concluded that the wadi and the ditch have the most beneficial impact on flood resilience in Yerseke. Especially concerning land-use, social capital and ecology do the measures contribute positively. None of the implemented measures affect the critical infrastructure and economics.

A practical implication of the proposed assessment method is the valuation of the indicators. A plus, minus or a not is awarded to indicate the contribution of an indicator to flood resilience. However, this method of indication does not provide insight in the extend of the impact. This may provide the readers with a distorted image of the impact of the spatial measure. This practical implication leads to recommendations for further research.
Theoretical implications of this research mainly concern the demarcation of the indicators. The indicators should be unambiguously defined to assess various spatial measures equally.

This research is partially the evaluation, reformulation and application of, among other the 4+1 model, other researches into a model. This model qualitatively assesses the impact of spatial adaptation measures from a resilience approach. Nevertheless, a very practical development would be to quantify the indicators to gain new insights into the impact on flood resilience.

5. CONCLUSION & RECOMMENDATIONS

This chapter provides the answers on the research questions and draws conclusions based on the answers of the questions and other findings of this research. In last paragraph, recommendations for users of this tool and recommendations for further development of this research are discussed.

5.1 Answering the questions

5.1.1 What is the relation between flood resilience and spatial adaptation and which spatial measures are implemented in Yerseke to enhance flood resilience?

The relation between flood resilience and spatial adaptation lies in the definition of flood resilience. Flood resilience assembles spatial, structural, social, and flood risk resilience. Therefore, spatial planning is an integral part of flood resilience. In Yerseke a package of measures is designed to prevent pluvial floods in the future. The three selected measures are;

- Wadi in the Marijkelaan
- Redevelopment Kerkhoekstraat
- Ditch in Molenpolderweg.

5.1.2 Which spatial impact assessment method is compatible with the flood resilience approach?

The flood resilience approach provides a broad, integral perspective on the physical and societal environment in relation to floods. In 2015, the research group Resilient Deltas of the HZ University of Applied Sciences presented the 4+1 model in which the building blocks of a disaster resilient society are elaborated. With the necessary alterations, this model provides a foundation to use as impact assessment. The emerged impact assessment assesses the impact on flood resilience on the following aspects; (1) water system, (2) land-use, (3) critical infrastructure, (4) economics, (5) social capital, and (6) ecology.

5.1.3 What are the indicators of flood resilience?

The indicators of flood resilience are categorized per aspect;

- Water system: water quality & water quantity
- Land-use: user value, experienced value & future value
- Critical infrastructure: vulnerability critical infrastructure and services & vulnerability transport and traffic
- Economics: business climate & business continuity management
- Social capital: social cohesion & situational awareness
- Ecology: biodiversity & specie abundance

5.1.4 How do the measures of the municipality of Reimerswaal to prevent pluvial flooding in Yerseke score in the proposed impact assessment?
According to the impact assessment, the wadi in the Marijkelaan and the ditch in the Molenpolderweg are equally suitable spatial adaptation measures to enhance flood resilience in Yerseke. Both measures are awarded 8/13 plusses and 5/13 zeros. The redevelopment of the Kerkhoekstraat contributes less to flood resilience because it has been awarded with 3 plusses and 10 zeros.

None of the measures is expected to have a negative impact on flood resilience.

5.2 Conclusions
In conclusion, the answer to the research question is discussed;

How can spatial adaptation measures be assessed to gain insight into their contribution to flood resilience?

Spatial adaptation measures can be assessed based on their impact on water system, land-use, critical infrastructure, economics, social capital, and ecology, by using the indicators of change of each of the latter aspects. The assigned value of the indicators provide insight into the contribution to flood resilience; this may be positive, negative or no impact.
When the outcomes of the impact assessment are reviewed, it should be kept in mind that the weight of the aspects and the relation between the aspects is not taken into account.

Furthermore, the following conclusions can be drawn based on the application of the impact assessment on the showcase Yerseke;

- Constructing a wadi and a ditch in Yerseke contributes foremost to flood resilience in the town of Yerseke, compared to redeveloping the Kerkhoekstraat and constructing a ditch in the Molenpolderweg.
- The impact of the three selected spatial adaptation measures do not have an impact on the critical infrastructure and economics in Yerseke.

5.3 Recommendations
Recommendations that lead from this research can be divided into recommendations for further research and recommendations for application of the tool, aimed at policy makers.

5.3.1 Recommendations for further research
- Further research into broad applicability is recommended. The impact assessment should be tested in different regions and countries to discover regional differences.
- Test the impact assessment on spatial adaptation measures at different scales to assess the usability for application on a bigger scale. Further research into the application of the tool on different scales is recommended to substantiate its theoretical value.
- The impact assessment can also be applied in reverse order, first analyze the current state of flood resilience in the entire town of Yerseke, and design spatial adaptation measures

accordingly. Further research into this reversed order of application is recommended to validate this theory.

5.3.2 Recommendations for application

- The impact assessment is a qualitative assessment framework to assess the impact of a spatial adaptation measure in a broader sense; it does not consider the costs of a measure. Spatial adaptation measures that contribute to flood resilience to a large extend can be very expensive, for that purpose a costs/efficiency analysis should be carried out.
- Use the impact assessment to start the conversation with other domains work towards an integral spatial adaptation measure.
- Discuss if any linkage opportunities pop-up, for example, try to connect ecological and social values and link them to the water system. Linkage opportunities usually boost spatial quality because they increase user and experienced value.

5.3.3 Recommendations for Yerseke

- The spatial adaptation measures in Yerseke do not contribute to critical infrastructure in relation to flood resilience. If the municipality want to strengthen all the aspects of flood resilience in Yerseke, she should design a measure that also incorporates critical infrastructure.
- The spatial adaptation measures in Yerseke do not contribute to the economy in Yerseke. If the municipality want to strengthen all the aspects of flood resilience in Yerseke, she should design a measure that is also beneficial to the business climate or business continuity management.
- To improve its overall flood resilience, Yerseke must act on a bigger scale. The current spatial adaptation measures are small scale solutions. However, since the zoning plan has fragmented the area of Yerseke in areas with a specific destination, a small-scale solution will not contribute to all the aspects of flood resilience. Therefore, it is recommended to draft a vision for the entire town of Yerseke on how to enhance flood resilience based on the aspects of the impact assessment.

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