Cross-cutting approaches dealing with uncertainty, robustness and designing for spatial quality

Work package leader : dr Frans Klijn

Content

1 Description work package

1.1 Problem definition, aim and central research questions

Flood risk management is not a goal in itself, but rather a means of achieving a sustainable development (De Bruijn, 2005; FLOODsite, 2009). Therefore, flood risk management strategies and individual risk management measures must be evaluated on their contribution to 'sustainability' (De Bruijn et al., 2008), for which many criteria are proposed (Oelfert, 2008). The operationalisation of some of those assessment criteria still poses difficulties. This goes for 1) criteria related to uncertainty, such as robustness, resilience and flexibility. It also applies to 2) criteria which intend to account for intangibles, such as scenic landscape qualities or 'spatial quality'. Making a step forward in the practical operationalisation of these concepts for the design and evaluation of flood risk management measures and strategies is the key objective of this WP.

Flood risk management is, by definition, a matter of dealing with probabilities and uncertainties. There are two fundamentally different ways of dealing with these uncertainties (cf. Dessai & Van der Sluis, 2007; Kwadijk et al., 2009), viz. by scenario analyses (forecasting the hydraulic effects of a number of different climate change scenarios), versus by assessing the robustness of the response system to – increasing – stress/ loading. The latter approach requires an operationalisation of the concept of robustness and the derivation of guidelines for how to make response systems more robust. Despite some preliminary work the exact meaning of the concept of robustness has not conclusively been explored yet. The robustness *concept* as such will be investigated jointly with Theme 2, but within this WP we shall focus on the *flood risk system* as the relevant response system and increasing *flood hazard* as the relevant stress. This challenge is addressed in project 6.1.

Projects 6.2 and 6.3 aim at a further operationalisation of the concept of 'spatial quality', which is quite popular, but has not been elaborated from a scientific point of view yet. The concept of 'spatial quality' attempts to grasp together the intangibles of natural, cultural and esthetic landscape values. The concept has emerged in the Netherlands' spatial planning in the 1980-ies and has since made a career in practical planning; it has even become the second goal for the Room-for-Rivers programme which is now being carrried out along the Rhine River branches (Rijkswaterstaat, 2007; Q-team, 2008, 2009). It is also likely to play a key role in the design, planning and evaluation of any future flood risk management strategy which involves physical measures affecting the environment, both in countryside and urban settings. Two projects within this WP will address this issue. Project 6.2 intends to shed light on the meaning of the concept of spatial quality, and more specifically on its implications for the (re-)design of flood defense measures in existing Netherlands' landscapes. This project will focus on countryside environments. Project 6.3, in contrast, will focus on urban environments. It will investigate the co-evolution of urbanization and flood risk management defense strategies – primarily flood defense in the last centuries.

The central research question of the work package can therefore be summarized as: how can the robustness of future flood risk management strategies be enhanced, and how can the spatial quality of countryside and urban environments be enhanced by a careful design and implementation of flood defense measures. In this sense, WP 6 aims at an overarching integration of all measures into comprehensive flood risk management strategies.

1.2 Interdisciplinarity and coherence between the projects

Project 6.1 on robustness is a PhD project which attempts to bridge disciplinary borders by involving civil and agricultural engineering (measures), flood risk assessment (economy), ecology and general systems theory (concepts) and decision theory. The research is carried out in co-operation with an ecologist (in Theme 2, Utrecht University), with the civil engineering branch of Twente University (promotor) and with a physical geographer (copromotor/WP leader).

Projects 6.2 and 6.3 connect landscape architecture (Wageningen UR) and urbanism (TU Delft) to each other and to civil engineering. The concepts and methods which will be applied will be attuned.

All three projects contribute to the drafting of comprehensive flood risk management strategies for different geographical settings, including flood protection, flood exposure control and flood consequence reduction.

1.3 Stakeholders

The WP primarily addresses the level of strategic and spatial planning and decision making. This means that the national authorities, especially the ministries of Housing, Spatial Planning and Environment, of Public Works and Water Management, and of Agriculture, Nature and Food Safety are the prime stakeholders, as these are jointly responsible for climate-proofing the country.

Regional authorities, however, will have to implement policies and measures and are hence have the most direct stake in FRM solutions which enhance the attractiveness of the area for companies and people. More specifically,

- project 6.1 will address cases in the hotspot areas Large Rivers and Rijnmond Region
- project 6.2 investigates countryside environments along the Wadden Sea, Large Rivers and SW-Delta
- project 6.3 takes hotspot Rijnmond Region (Greater Rotterdam) with Drechtsteden as case.

2 Project 6.1. Robustness analysis methods to support flood risk management policy making

Project leader: dr Frans Klijn

2.1 Problem definition, aim and central research questions

Decision-making about long-term water management is a complex process. It concerns designing, combining and deciding between various types of measures, together with different stakeholders and working on different scales. Moreover, it is considered more and more important to take into account long-term changes in the system that may influence the effect of measures.

Decision-makers use a variety of criteria such as costs and benefits to be able to choose between strategies. In order to deal with uncertainties about future developments, additional criteria such as robustness and flexibility are suggested. Since a few years, decision-makers in the Netherlands have been referring to the concept of robustness (see for example: ARK (2007), National Water Plan (2008), Ontwerp waterbeheersplan Zeeuwse eilanden (2008) and Ontwerp waterbeheerplan Brabantse Delta (2008)). They have the feeling that robust systems are preferable under the pressure of climate change, but cannot specify what makes a system more robust. Because a clear definition lacks, this leads to miscommunication among stakeholders resulting in a large range of robustness scores.

Because robustness is still not well defined, it is worth exploring its meaning and use for long-term flood and drought risk management. We hypothesize that the concept of robustness, when well defined, supports to explicitly deal with natural variability and future changes herein. This may support the development of strategies (combination of measures) and the decision between them.

The objective of the research is to improve the use of robustness in decision-making for long-term flood and drought risk management. We aim to enhance the applicability of the concept, by developing a practical method to assess alternative strategies for flood and drought risk management and guidelines to increase the robustness of systems.

The main research question is *whether and how the concept of robustness can aid decision-making about long-term strategies for flood and drought risk management.*

The following questions will be addressed:

1. What definition of system robustness is suitable for use in the management of flood and drought risk systems?
   1.1. How is robustness defined in ecological, social and economic literature?
   1.2. How does robustness relate to other, comparable, concepts such as vulnerability and resilience?
   1.3. How is robustness used in practice?
   1.4. Which definition is suitable for flood and drought risk systems?
2. Which indicators can be used to quantify robustness of flood and drought risk systems?

3. How can the robustness of flood and drought risk systems be increased?
   3.1. relation with Modern Portfolio Theory? (Jeroen Aerts)
4. What is the added value of robustness as decision criterion in flood and drought risk management?

2.2 Approach and methodology

This project will be carried out as a co-operation between themes 1 and 2; in this KfC theme, the robustness of flood risk systems will be assessed, whereas in KfC-theme 2 drought risks will be investigated. The operationalisation of the robustness concept is a joint effort between the two themes.

Approach:
To develop the conceptual framework for robustness, we will make an overview of definitions and usages in literature and practice. The working definition of system robustness which we shall begin with is: "the ability of a system to cope with disturbances". Robustness is comparable to the concept of ecosystem resilience (Holling, 1973) and can be increased by increasing the resistance, measured by the maximal amount of disturbance that is needed to cause the system to react adversely, or by increasing the resilience, measured by the amount of impact, the graduality of the impacts and the recovery capacity (De Bruijn, 2005).

As for literature research, we shall consider robustness of ecological systems, robustness of economic systems and robustness of social systems. As for practice, we shall study recent water policy documents from the Netherlands' government (i.e. Nationaal Waterplan) and from other Netherlands' authorities (e.g. waterboards; 'ontwerp waterbeheersplannen').

To test the conceptual framework for robustness, we shall first refer to the Westerschelde case study in FLOODsite (De Bruijn et al, 2008), in which several long-term flood risk management strategies were analysed and assessed. Next, we shall explore the differences between the concept of robustness for different systems and different spatial scales, e.g. robust defences, a robust dike ring area, or an entire robust flood risk system (several connected dike ring areas). To explore those, we shall apply the conceptual framework on a single dikestretch (Waterdunen – Hotspot SW Delta), a dikering area (Zeeuws Vlaanderen en Betuwe – Hotspots SW Delta en Large Rivers) and a complex flood risk system with several dike-ring areas (Rijnmond/ Drechtsteden – Hotspots Regio Rotterdam and Large Rivers).

Summary of approach (with theme 2):
Literature review (with theme 2): How is (system) robustness defined in literature and how is it used in practice?;
Development of a conceptual framework for robustness (with theme 2);
Individual discussions with hotspot representatives about the framework;
- Design of a framework to analyse the cases (with theme 2);

- Casestudies: application of conceptual framework on flood risk systems and drought risk systems:
    - System description;
    - Robustness analysis, including long-term developments;
- Design and assessment of strategies;
- Reporting insights in the form of guidelines (with theme 2);
- Workshop with hotspot representatives to discuss guidelines and casestudy-results;
- Adjust robustness framework (with theme 2).

2.3 Scientific deliverables and results

Two scientific papers in peer reviewed journals:

- one the conceptual framework and the Westerschelde case (together with theme 2);
- one on the application in one or two flood risk management cases.
- - ½ a PhD thesis (the remainder in Theme 2).

2.4 Integration of general research questions with hotspot-specific questions

The conceptual framework for robustness will sustain the assessment of flood risk management strategies for the future for various hotspot areas, especially for the case stduy areas which will be investigated:

- SW delta (along Westerschelde/ dike tract),
- Large rivers (especially Betuwe/ whole dike ring), and
- Rijnmond/ Drechtsteden (dike-ring system).

2.5 Societal deliverables and results

- Indicators to quantify the robustness of comprehensive flood risk management strategies and/or individual measures;
- Guidelines for the development of robust policy strategies for flood risk management.

The guidelines can be used by decision-makers who are concerned with the long-term planning of areas that are at risk of flooding and/or at risk of drought.

2.6 Most important references

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3 Project 6.2 Flood defense design for enhancing the spatial quality of countryside environments

Project leader: dr Frans Klijn

3.1 Problem definition, aim and central research questions

In the 1970-ies, the way embankments were reinforced along the Netherlands' major rivers caused massive societal outrage and opposition (e.g. Bervaes et al.,1993), because it was felt that the natural and cultural values of the landscape were lost or endangered. The opposition resulted in the installation of successive Committees (Van Heezik, 2006), who advised to reduce the protection standards so that the embankments could be kept lower, to pay more attention to the existing landscape values in the area and to better align the design of the embankments to the existing landscape character. This societal opposition exemplifies a general increase of attention for ecological and cultural landscape values in the 1970-ies and 80-ies (Feddes, et al.,1988; De Jonge, 2009; Van den Brink, 2009).The societal importance of landscape values and landscape identity gained more and more attention. In this period the concept of 'spatial quality' emerged and gradually gained terrain also among water management authorities (Van Heezik, 2006).

The concept of spatial quality was embraced by the national water management authorities to such an extent that it was even made the second objective for 'Room for the River' programme (Bosch Slabbers 2007; Terra Incognita et al., 2009). However, what spatial quality exactly means often remains unclear (Van Dam, 2002 ; Hooimeijer et al., 2001) and fluid: its meaning changes constantly. This makes it difficult to operationalise the concept in terms of measurable criteria or clear guidelines for design.

The expected climate change and sea level rise call for improvement, redesign and/or realignment of flood defenses, whether embankments, dams or storm surge barriers. The erection of such flood defenses in the past has shaped the country and is co-determinant for the character of these – often highly valued – landscapes. Introducing new or reinforcing existing embankments in these environments may affect the spatial quality, especially in countryside environments. This asks for due consideration of the requirements posed by the existing situation: does it require careful fitting in to protect the present character or does it call for a complete redesign of the 'landscape of the future' (Van Buuren et al., 2002). The key societal challenge therefore is: How to ensure that adaptation measures, especially various kinds of robust flood defenses, will not negatively influence the spatial quality but instead enhance it?

The ***aim*** of the project is to provide guidance to regional authorities and planners/ designers on the alignment and design of new or to-be-reinforced embankments from the point of view of enhancing the spatial quality of countryside environments.

The central ***research question*** is: How can new or reinforced flood defenses enhance the spatial quality on a national, regional and local level, on both the mid and long term? This main question is addressed by first questioning how existing flood defenses influence/ determine the identity of various present landscapes and by, the other way around, questioning which requirements the various existing landscapes put on the design of new or tobe- reinforced flood defenses (embankments, dams, etc.).

This main question can be divided in a number of key questions, which represent as many chapters:

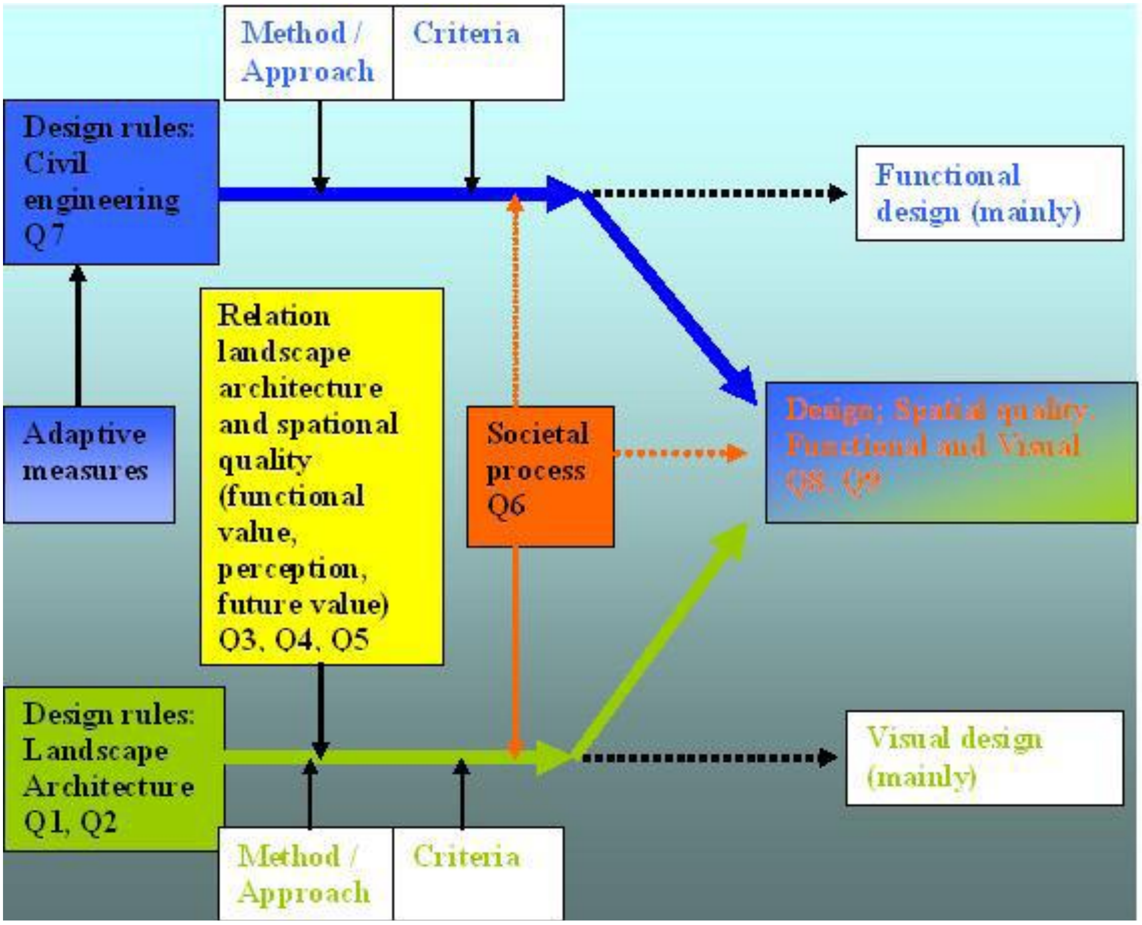
1. How have flood defenses shaped the various landscapes in the Netherlands (SW Delta, Wadden, Large rivers, different branches)? Descriptive.
2. To what extent do the defenses determine the identity of these landscapes? Analytical.
3. How is the concept of spatial quality defined and how has this definition developed over the past decades (since the retrieval of Vitruvius principles and via the 'Habiforum matrix' (Hooimeijer et al., 2001)). Specific for science, policymaking and practice? Differences and similarities?
4. Which criteria for spatial quality can be derived from these definitions?
5. How has the emergence of the concept of spatial quality influenced the design of flood defenses (in objective terms)and how are the resulting landscapes to be judged by the formal spatial quality criteria? Case studies in various countryside hotspot areas (Large Rivers, SW delta, Wadden Sea).
6. What has the role of local stakeholders and their awareness of spatial quality been on the design (as a product?
7. What kind of new flood defenses are taken into account in the context of adapting to higher flood water levels and wave impact? (joint inventory with project in WP 3: 3.1): type, technical requirements, profile, footprint, etc.
8. What are the identity-determining characteristics of various landscape types (Wadden coastal, SW delta, e.g. Beveland, Large Rivers different branches) and what requirements do these pose to the design of new or to-be-reinforced embankments? Similar for dams and barriers. How are these characteristics be valued and which ambitions as conservation, adjustment or development, can be achieved?
9. Which guidelines for environment-specific design (recommendations) can be given?

3.2 Approach and methodology

Approach:
Q 1 and 2 shall be answered by a study of old maps and literature
Q 3 and 4 shall be addressed by a literature search and interviews with some keynote persons
Answers to Q 5 and 6 shall be gained from interviews in case study areas (KfC hotspot related).
Q 7 implies an inventoryand description in co-operation with WP 3.1 (Wageningen UR)
The answers to Q 8 and 9 rely on a confrontation of the answer to Q 7 (what kind of defenses) to the combination of the results of Q 1, 2, 3, 4 and 5.

The figure below shows the relationship between landscape architecture and civil engineering. The integration of these two disciplines, civil engineering and landscape architecture, is relatively new. Until the 1970-ies, embankments were purely functional, providing flood protection. After the societal uproar, the landscape and its values became more and more important. This importance started a trend: from attention to 'fitting-in' the embankments and dams into the landscape ('intelligent dike designs", van den Brink, 2009), via landscape quality plans, to spatial quality frameworks for the Large Rivers. These trends will be described in successive chapters in the order of the key questions above.

The figure below shows how the questions are related.



The concept of Spatial Quality will be investigated by reviewing scientific, policy and practice papers. The material will be analyzed, the definition will be traced to the original sources, and the used criteria will be evaluated on homology, soundness, and consistency in terminology.

3.3 Scientific deliverables and results

The main deliverables encompass:

- a treaty on historic developments and current trends in the design of embankments and other flood defense structures
- an (inter)national review of the development of the concept of spatial quality
- guidelines on which design methodology to use
- 3 peer reviewed papers (in e.g. Journal of Landscape Architecture, Landscape and urban planning, or Landscape research) focusing on:

- the development of views on flood defense design: on the transformation from purely technical designs for flood protection only towards integrated designs for protection and spatial quality purposes at the same time;
- the development in views on the meaning of spatial quality, an overview of the evolution of a concept from Vitruvius' principles to the present opinions on spatial quality and related methodologies for assessment and design.
- An assessment of current design procedures and design guidelines (matrices, key qualities, etc.).

3.4 Integration of general research questions with hotspot-specific questions

The general research question applies to several KfC-hotspots faced with the challenge to re-design and/or realign flood defenses. Specific hotspots which will be taken as case study area are the Wadden Sea, the SW Delta and the Large Rivers area.

The issue in the Wadden Sea area is to identify what determines the present spatial quality, including the historical and identity-determining characteristics of the different landscapes of Friesland, Groningen and the Wadden islands. What does this mean for possible design requirements for to-be-reinforced embankments?

In the SW delta the issue is how to integrate spatial quality with flood defense design and spatial planning related to embankments of the different (former) islands. In this area design exercises have taken place based on the Habiforum Matrix. These exercises and their results will be described and analysed as to what they have yielded in terms of spatial quality and to what the approach may mean for further spatial design questions.

Along the Large Rivers, presently many regional projects are being implemented based on at the same time ensuring flood protection and enhancing the spatial quality (Room for the Rivers-programme). These projects deliver a base of practical experience on how to deal with spatial quality in a concrete planning process. The question is whether and to what extent this knowledge is scientifically-based, what criteria are being used and whether it is possible to build a grounded theory about spatial quality related to embankments.

3.5 Societal deliverables and results

Spatial quality is a concept which gains importance day by day. Not only for making integrated spatial plans, but also for the design of engineering solutions. An example of this is the second goal of the Room-for-the-Rivers programme.
The concept of spatial quality can be approached from two sides: reasoned from a spatial context: how does a measure influence the existing or potential spatial quality, or reasoned from the measure: how does the requirement to improve the spatial quality influence the technical design and on what scale or term.

3.6 Most important references

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4 Project 6.3 Reconstructing delta cities dynamics and spatial quality in the Rijnmond-Drechtsteden

Project leader: prof. ir. C.M. de Hoog

4.1 Problem definition, aim and central research questions

This project focuses on the joint development of delta cities and flood defence in past and future.

'Dike ring 14' is the largest dike-protected area in the Netherlands. This dike ring comprises several historical dikes, which protect the core of Holland since the 12th century: the Schielandse Hoge Zeedijk along the Maas and the Hollandse IJssel and the dikes along the IJ. The majority of the mediaeval Dutch cities were situated in this core, well protected against floods. The digging of the Nieuwe Waterweg and the Noordzeekanaal in the 19th century, parallel to the historical dikes, amplified the meaning of this core of Holland. In the 20th century this core was heavily urbanised into what we now call *Randstad Holland*. The dike ring is still well protected, partly by the Maeslant storm surge barrier, but sea level rise means a challenge for the future development of the harbour of Rotterdam and the cities along the estuaries and downstream parts of the rivers.

During the 20th century many changes occurred in the area south of the river Maas, both in the network of main waterways and in urbanisation. In the Rijnmond-Drechtsteden area new channels were dug more to the south, such as the Nieuwe Merwede and the Bergse Maas. Hollands Diep en Haringvliet became the main discharges for the river Rhine. The old river branches kept their role as waterways and discharge routes for the rivers. They also kept their role as undisturbed shipping routes to the hinterland. Simultaneously the area was heavily urbanised, especially from the 1960's onward. The Rijnmond-Drechtsteden area south of the river Maas counts now 780.000 inhabitants and 345.000 houses. Moreover the area counts some 330.000 jobs. Industries here realise a huge part of the Gross Regional Product. Crucial for the operation of the area are the large port-, railway-, highway-, drinking water- and energy infrastructures. Despite the early attempts to control the spatial development – the first regional plans in the Netherlands were made for this area –, the Rijnmond-Drechtsteden area became strongly fragmented. Nevertheless it contains interesting spatial contrasts.
The sea level rise and the increasing river flows confront the area now with new challenges: how to protect the area against flooding without raising dikes and demolishing high quality buildings around and outward the dikes and in the same time without disturbing shipping routes?

The **aim of the project** is to construct a sustainable future for the Rijnmond-Drechtsteden area as a hinge area between the core of Holland and the SW delta, both from a flood defence and an urbanisation point of view.

The **central research questions** are:

1. How has the hinge between the core of Holland and the SW delta developed in the past? What was the relationship between the move of the main waterways to the south and the urbanisation

process and what were considerations of the designers of flood defences and of regional and urban plans; which qualities were aimed at and which were actually realised?

2. What are possible development models for protecting the Rijnmond-Drechtsteden area against flooding?
3. How effective are these models in strengthening spatial quality and to what extent do they guarantee a sustainable development?

4.2 Approach and methodology

1. The first research question will be addressed by making an Atlas with a historical reconstruction of the development process and spatial qualities in the Rijnmond-Drechtsteden area. The Atlas will contain:
    - An analysis of the urbanisation process around the rivers, connected to developments in river flows and river morphology, transport, industrialisation, drinking water supply.
    - An analysis of the designs of waterways, flood barriers and embankments: Kanaal door Voorne-Putten, Nieuwe Waterweg, Nieuwe Merwede, Bergse Maas, Hollandse IJssel barrier, Haringvliet sluices, Brielse Maas, reservoirs, barriers, dams, locks.
    - An analysis of the most important spatial urban and regional plans: from Rose's Watercity, via the first Dutch regional plans for the island of IJsselmonde designed by Verhaagen, till the recent entries for the Eo Wijers competition.

   Methods: research of literature, mapping, disassembly of designs.

2. To answer the second research question future development models will be made for the spatial development of the area 2050-2100-2200.
   Methods: design of urban and regional development models based on different principles dealing with sea level rise, higher peaks in river flows and ongoing urbanisation, such as 'Dams', 'Afsluitbaar Open Rijnmond', 'Adaptief Bouwen', 'Superdikes', 'Alblassermeer'.

3. To answer the third research question an evaluation will be made of the regional development models, focused on spatial quality.
   Methods: evaluation on the three main criteria of spatial quality: 'utilitas' (multifunctionality, accessibility), 'venustas' (identity, variation on different scales, continuity), 'firmitas' (robustness).

4.3 Scientific deliverables and results

Two papers in scientific journals
Part of a PhD thesis.

4.4 Integration of general research questions with hotspot-specific questions

How future flood defence in the area Rijnmond-Drechtsteden area will be organised directly influences the possible future of urbanisation in the Rijnmond area; more specific (1) the future of the port, the railway terminals and the transport to the hinterland, (2) the possibilities for the re-development of urban areas along existing and future embankments, (3) the meaning and accessibility of large open space.

4.5 Societal deliverables and results

Contribution to the societal debate on the sustainable development of the Rijnmond-Drechtsteden area.

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