Stimulating innovation in the Dutch water construction sector

Introducing a new innovation systems delineation: the Project-Based Innovation System

Master thesis

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Abstract

In this research, we attempt to determine on which properties policy makers should intervene to boost the innovative performance of the Dutch water construction sector. Therefore, we focus on the most promising source of innovation in this sector, i.e. infra projects. We use the innovation systems perspective to analyse the successful innovation processes of some of these infra projects to determine which properties are crucial to their success. However, innovation systems literatures do not provide a system delineation that focuses on this unit of analysis. Therefore, we introduce such a delineation ourselves: the Project-Based Innovation System (PBIS). In order to analyse the dynamics of the build up of such an innovation system we apply the System Functions approach and the concept of motors of innovation. However, before doing so, we test whether application of this approach and concept to the new PBIS delineation is justified and find that it is. We acquire data on the build up of PBIS using event history analysis. Moreover, we focus on the successfully innovative infra projects of the Maeslantkering and the multifunctional renewal of the Afsluitdijk. Our conclusions indicate that over the different successive episodes that characterise the build up of PBIS, different types of system functions and motors of innovation are crucially important to the successfulness of the innovation process. These functions are market formation, knowledge diffusion, guidance of the search and creation of legitimacy. Moreover, the motors of innovation that are identified in a developing PBIS are the Science and Technology Push motor and the System Building motor. We formulate some practical recommendations on how the manage these properties to improve the innovative performance of infra projects in the Dutch water construction sector.

Keywords: project-based innovation system, innovation system, system functions, motors of innovation, infra project, water construction sector, Maeslantkering, Afsluitdijk

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1. Introduction

The Netherlands is one of the world's best-protected deltas (Deltares, 2009). Nonetheless, research by the important Deltacommission (2008) indicates that climate change poses a significant threat. Accordingly, the 'Nationaal Waterplan' (2009) argues that innovations are required in the Dutch water construction sector (DWCS) to safeguard the long-term water safety of this country. However, according to the commission Wijfels (2004), which evaluated the Dutch knowledge infrastructure, there is something that they call the innovation paradox. The paradox is that on the one hand a large amount of fundamental research is done, but that on the other hand this knowledge is not applied in practice. This paradox is also true for the water sector (Wijfels et al., 2004) and explains its low innovativeness (Innovatieplatform, 2009). The goal of this research is to gain insights into the innovation paradox in order to determine how the innovative capacity of the DWCS can be increased.

If we want to research innovation in the DWCS, we should take into account the characteristics of this sector that are linked to the innovation paradox. A first characteristic is that the DWCS is predominantly a public sector and therefore its demanders are comprised of only a few aligned governmental institutes (on a national level the Ministry of Transport, Public Works and Water management and on the regional level the regional water management authorities, or water boards) that consequently are very powerful actors. Secondly, since this sector is predominantly a management sector of a crucial public need, namely water safety; the powerful actors responsible for satisfying this need tend to avoid risks, so that innovation does not get a chance (Van der Brugge, 2009). Finally, the dynamics within the DWCS can be characterized by the periodical construction and renovation of large infrastructural projects assigned by the government (Van der Brugge, 2009). In these respects, the DWCS differs from conventional private sectors like the energy sector, which are characterised by mass consumption markets. These characteristics are thought to hamper the innovative capacity of the DWCS (TNO, 2005; 2009). In addition, innovation in the DWCS takes place mostly in complex infrastructural projects that are not scalable and therefore its innovations cannot be easily reproduced, such as in the case of market sectors like the energy and the biopharmaceutical sector (Baayen, 2010).

To understand the DWCS's innovation paradox better, an in-depth analysis of the sector's innovation processes is required. This means that the innovation itself should not be perceived in isolation but as part of a larger system and that the innovation process is not linear, but the result of all kinds of feedbacks in the system. Hence, the innovation systems theory provides a useful perspective. Firstly, because this theory describes innovation as the result of an innovation system that is comprised of structural components (i.e. a network of actors and institutions). Secondly, because this theory describes how the dynamics of the innovation processes and build up of the innovation system are influenced by feedbacks in the system, called system functions (Hekkert et al., 2007; Negro, 2007; Suurs, 2009). Consequently, the innovation systems theory might be useful to understand why this innovation paradox exists.

The innovation system theory, however, has never been applied to the water construction sector before, which means that we should address this sector's specific characteristics. As we have seen, the characteristics of the DWCS suggest that we should focus our research on the unit of complex infrastructural projects, since that is where innovation takes place. This implies that we should perceive the infra project as an innovation system; a plausible assumption since a complex infra project is comprised of several actors in a network that, influenced by institutions, attempt to create innovation. Therefore, although the innovation systems theory has never been applied to this unit of analysis, in our view, this is legitimate since the structural components and the system functions may not be that different. Therefore, we use the innovation systems perspective, but we apply it to a new system delineation, namely to that of a complex infrastructural project.

Accordingly, we formulate the following main research question:

"What properties are crucial to the success of innovation systems of complex infra projects in the Dutch water construction sector as they develop over time and how should these properties be managed to increase the innovative capacity of this sector?".
In addition, we pose the following sub-questions:

- *"How do the structural components and system configuration of the innovation system of a complex infra project in the DWCS develop over time?"*
- *"What system functions and motors of innovation characterise the development or stagnation of the innovation system of a complex infra project in the DWCS over time?"*
- *"How can these system functions and motors of innovation be managed to improve the innovative capacity of the DWCS?"*
- *"How are novel project approaches adopted in a project-based innovation system?"*

Since we apply the innovation systems theory to this new system delineation, we should first investigate whether this is justified. Hence, we investigate whether there might be some changes in terms of the structure, functions and motors compared to the delineation of a Technological Innovation System on which the System Functions (Hekkert et al., 2007) and motors of innovation approach (Suurs, 2009) builds. Therefore, in our theory section, we elaborate on these consequences and on that basis, we formulate a number of hypotheses that we test in the case studies. Subsequently, two case studies are selected, the successfully innovative cases of the Maeslantkering and the multifunctional Afsluitdijk renewal.

The remainder of the thesis will be structured as follows: in section four, the methodology is discussed. Section five and six give concise descriptions of the case studies; analysis as well as some case specific conclusions. Moreover, elaborate results as well as a technical description of the cases are provided in Appendices I, II, III and IV. A cross case comparison is administered in section seven to identify which properties are important to the innovative success of a complex infrastructural project. Finally, section eight provides the conclusions and recommendations for further research.

2. Theory

In this section, we first give a short elaboration of why we use the innovation systems theory. In the second subsection, we discuss what types of innovation system sare identified in literature and what types of approaches are used to study the dynamics of these systems. From this, it follows that no existing delineations apply to our unit of analysis (a complex infra project), but that we can use the System Functions approach. Consequently, we introduce this new innovation systems delineation in subsection three, labelled a Project-Based Innovation System (PBIS), and position it among other innovation systems. However, because the innovation systems perspective and the System Functions approach have never been applied to such delineation, we explore what implications might be expected. In subsection four, we describe the expected changes in terms of a system's structural components. Subsequently, we stress what changes to expect in terms of system functions, i.e. what functions occur more or less often? While in the sixth subsection, we argue what motors to innovation are expected to take place in PBIS. Finally, we summarize what the application of the innovation systems perspective and the System Functions approach to a PBIS entails and conclude that such application must be feasible.

2.1 Why innovation systems theory?

This research has the aim of understading the innovation paradox in the Dutch water construction sector (DWCS) by in-depth researching the innovation process of complex infrastructural projects. To do so, not only should all the factors that influence the process be included in the analysis, but also the very dynamics by which the innovation process evolves; only then can be determined how innovation should take place successfully in complex infrastructural projects.

However, what theoretical perspective allows for such a comprehensive analysis? Innovation should not be studied as a linear process by its input, throughput and output indicators as in the linear model of innovation (Godin, 2006) and the stage-gate model by Cooper (1990), because it would give no indication of what factors influence these indicators, i.e. why R&D investments do not lead to innovative output. Beside the linear model of innovation, the more complex open innovation model by Chesbrough (2003), also does not provide a comprehensive analysis as it focuses more on the sources of innovation instead of the emergence and development of the process by which it is created. Moreover, the Large Technical Systems theory by Hughes (1987; 1983) also accounts for the complexity of the system in which innovation is generated, but does not prove a sufficiently refined method for studying the feedbacks that influence the dynamics of the innovation process.

The innovation systems theory seems more suitable. Firstly, because it accounts for the complexity of innovation, by stressing that, individual actors cannot innovate in solitude, but require a social network in which various types of organizations are embedded that exchange knowledge (Freeman, 1987; Lundvall, 1992; Carlsson and Stankiewicz, 1991; Edquist, 1997). Secondly, the innovation systems perspective also stresses the importance of influential institutions, defined as "the rules, regulations and routines that shape the possibility space of actors" (Suurs, 2009). These institutions can both drive and inhibit innovation. Consequently, an innovation system is defined by the network of relevant actors and institutions that generate innovation (Carlsson and Stanckiewicz, 1991). Thirdly, innovation system approaches have been developed and empirically tested, specifically to research the dynamics of the build up of an innovation system and its underlying innovation processes (Hekkert et al., 2007; Suurs, 2009; Negro, 2007). These dynamics are important to decide what factors determine the successfulness of the innovation process of a complex infra project. In conclusion, because the innovation systems theory accounts for the complexity of innovations and the influence of institutions, and because it provides possibilities to study the innovation process' dynamics, it provides the best perspective for in-depth studying complex infrastructural projects' innovation processes.

2.2 The different types of innovation systems

In innovation systems theory, different system delineations are maintained that build on the theory's perspective of a network of actors and institutions. Moreover, different approaches have been developed that attempt to research the dynamics of the build of an innovation system and its underlying innovation processes. In this section, we study innovation system literatures to identify which of these delineations and which of these approaches can be applied to our goal of studying the innovation system and its dynamics, of a complex infrastructural project.

2.2.1 What innovation system delineation can be applied?

The relevant actors and institutions of an innovation system are determined by the system's boundaries. Over the years, innovation systems have been delineated along various boundaries – both geographical and techno-economical; each delineation fitting a different a unit of analysis and purpose (Suurs, 2009). As a result, various types of innovation systems, each incorporating a different set of actors and institutions, are identified. Literature distinguishes between National Innovation Systems (Freeman, 1987), Sectoral Innovation Systems (SIS), Regional Innovation Systems (RIS), and Technological Innovation Systems (SIS), see table 2.1. We analyse these delineations to investigate which apply to our unit of analysis, a complex infra project.

Type of innovation system	**Abbreviation**	**Delineated to**
National Innovation System	NIS	the borders of a nation's state
Regional Innovation System	RIS	a specified region
Sectoral Innovation System	SIS	a sector
Technological Innovation System	TIS	a technology
Project-Based Innovation System	*PBIS*	*a complex infrastructural project*

Table 2.1, The different types of innovation systems

In 1987, Freeman introduced the concept of the National Innovation System (NIS), taking into account the differences in actors, networks and mainly institutions between nation's states in the formation of system boundaries. However, using such a high level of aggregation, we would lose our focus on the infra project.

Because the NIS neglects the fact that innovation systems differ significantly between industrial sectors and have become increasingly international (Carlsson et al., 2002), a shift was initiated towards innovation systems delineated to the geographical boundaries of a region, the RIS (Cooke et al., 1997) that focuses mostly on clusters (Saxenian, 1994; Porter, 1998). However, these clusters relate to the geographical location of organizations and not to the location of a demand or project as in our cases. Hence, in the case of a project, the location of participating organizations should not matter (although protectionism might be of influence in infra projects in the DWCS).

Furthermore, geographical boundaries are replaced by techno-economical boundaries by Breschi and Malerba's (1997) introduction of the Sectoral Innovation Systems (SIS). Focussing on an industrial sector, the SIS builds on Nelson and Winter's (1982) concept of a technological regime that is comprised of the technology implications, knowledge and routines. Furthermore, this regime is characteristic to a sector and determines its innovativeness. However, their focus on one sector is not applicable to our cases, since projects might encompass more than one sector, as is the case with the renewal of the Afsluitdijk (RWS et al., 2009).

Finally, the TIS is delineated to the realm of one technology. This delineation is on the one hand too narrow for our purpose since complex infra projects might involve multiple technologies (as in the case of the multifunctional Afsluitdijk renewal) and on the other hand too broad since a technology might compete in multiple large infrastructural projects.

In conclusion, current innovation systems literature provides no applicable system delineation that has a seamless fit with our unit of analysis. Therefore, we have to introduce a new system delineation that focuses on the network of actors and institutions that are relevant to the innovation process of a complex infra projects.

2.2.2 What approach can be applied to study the dynamics of an innovation system?

Within the innovation systems theory, some approaches have been developed with the specific purpose of studying the dynamics of the build up of an innovation system and its underlying innovation process. However, these approaches mostly originate from, and often are therefore tailored to, a specific system's demarcation. It is our goal to identify an approach that allows us to study the dynamics of an innovation system so that, in accordance with our research question, we may identify the factors that determine the success of the innovation process.

Based on the SIS demarcation, Malerba and Orsenigo (1996) attempt to gain insights in the development of industrial sectors by using Nelson and Winter's (1982) concept of technological regimes. Accordingly, over time these regimes may shift, which should explain the dynamics of developing SIS. However, Carlsson et al. (2002) stress that the SIS approach takes well-defined industries as its point of departure and therefore remains largely static. Consequently, it is not possible to analyze the dynamics of an emerging or transforming SIS (Carlsson et al., 2002). For this reason, the regime shifting approach is not applicable to our goal.

Another approach to researching the dynamics of an innovation system that builds on the demarcation of a TIS is called the System Functions approach, developed by Hekkert et al. (2007). By identifying seven interdependent system functions that through their interactions bridge the development of a system's structural components, the approach attempts to identify drivers, bottlenecks and also motors of innovation to this process (Suurs, 2009; Negro, 2007). Because this approach is extensively empirically tested (Suurs, 2009; Negro, 2007) and because it emphasizes the importance of system dynamics, it seems applicable to our purpose.

In conclusion, we attempt to apply the System Functions approach by Hekkert et al. (2007) and Suurs (2009) despite the inability to apply the TIS delineation to which the approach is associated.

Because we have no theoretical demarcation to which we can apply our theoretical perspective and approach, we are obliged to introduce a new innovation systems delineation and test whether application of the theoretical perspective and approach is justified.

2.3 Introducing and positioning a new innovation systems delineation

Because existing innovation system delineations do not have a seamless fit with our unit of analysis, a complex infra project, we introduce the concept of a Project-Based Innovation System (PBIS). Focussing on the innovation system of a complex infra project in the Dutch water construction sector, the PBIS is defined according to the lines of the innovation systems perspective as the network of actors and institutions that search, select, develop and implement innovation.

A PBIS originates from a demand for water safety that is unprecedented due to the specifics of the situation in which water safety is required. In a PBIS, networks of market parties, called consortia, search for and develop technological solutions in order to provide in this unprecedented demand. Subsequently, governmental actors select the most satisfying solution, which is further developed and implemented by its respective consortium. Examples of complex infra projects in the DWCS that comply with our definition of a PBIS are the 'Oosterschelde kering', the 'Hollandsche IJssel kering', the Maeslantkering, the 'Tweede Maasvlakte' and the multifunctional renewal of the Afsluitdijk.

In order to position the PBIS delineation in relation to existing system delineations, we shortly discuss their interrelatedness. Firstly, several sectors' SIS are located within a nation's NIS (Negro, 2007). Secondly, because a sector includes various technologies, a SIS can be seen as a bundle of interrelated and partially overlapping TIS (Hekkert et al., 2007; Negro, 2007). The other way around, a TIS often involves multiple SIS as well as NIS (Hekkert et al., 2007; Negro, 2007). Although a large infrastructural project is in geographical terms located within a nation and the nation's government facilitates the project, participating market parties and influential institutions also come from outside that nation (De Dommel, 2006). Therefore, we perceive a PBIS not to be delineated to the boundaries of a nation. On the one hand, a PBIS might focus on only one type of sector in various countries, like the project for the Maeslantkering focuses on the water construction sector. In this case, the PBIS might include comparable sectors over different nations, as the Maeslantkering project encompassed firms from outside the Netherlands as well (CSW, 1987), see PBIS 1 in figure 2.1. On the other hand, a PBIS might also involve different types of sectors over various nations, as in the case of the multifunctional Afsluitdijk renewal; see PBIS 2 in figure 2.1. With respect to the TIS delineation, the PBIS is comprised of all technologies that involve the provision of a technological solution to the PBIS. On the other hand, these technologies might also participate in multiple PBIS. A PBIS is by definition limited in time: once the project has been realized, the PBIS ends.

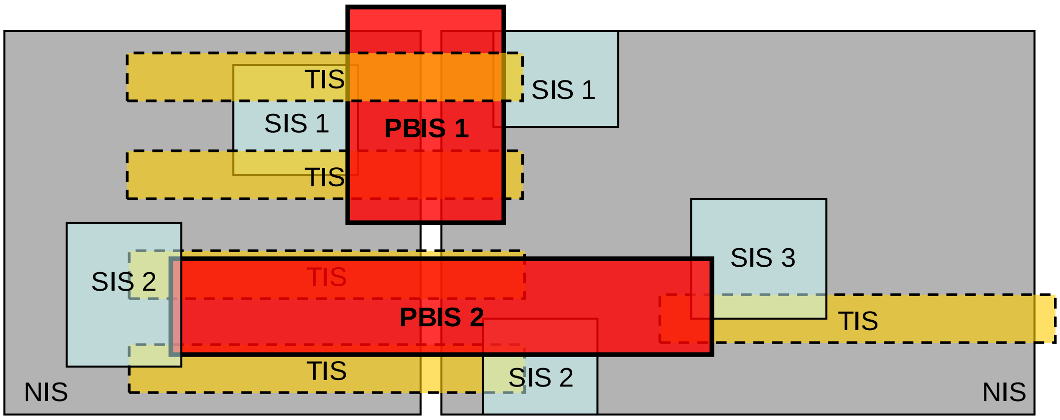


Figure 2.1, Potential overlap between the various systems of innovation

Although we have defined and positioned the PBIS, it is still unclear whether we can apply this delineation to the innovation systems perspective and System Function approach. Therefore, we investigate in the following subsections whether this application is justified. We do this according to the following structure. In subsection 2.4, we test the justification by stressing what irregularities might be expected in terms of the structural components when applying the innovation systems perspective to the delineation of a PBIS. Subsequently, we test the justification of applying the System Functions approach by arguing whether to expect that some system functions become very important or insignificant when applying the System Functions approach by Hekkert et al. (2007) to a PBIS. Then in subsection 2.6, we test the justification of applying Suurs' (2009) concept of motors of innovation by stressing which motors of innovation are expected to be present and which are not. Finally, in subsection 2.7, we conclude, based on these expectations, if application of the theoretical perspective and approach is justified and form hypotheses on the expected differences that are tested in the case studies.

2.4 The PBIS: expected changes in structural components

The structural components of an innovation system are its actors, networks, institutions (Carlsson and Stanckiewicz, 1991; Jacobsson and Johnson, 2000) and as Suurs (2009) adds, technology. We apply these structural components to the delineation of a PBIS, to obtain the same structured overview that it provides from other innovation systems. We investigate for each structural component whether to expect any changes when applying it to the PBIS; these expected changes are summarized in table 2.1. We will also discuss the configuration changes of these structural components according to the framework by Alkemade et al. (2007).

Component:	TIS delineation:	PBIS delineation:
Actors	Technology-enactor Technology-selector	Project-enactor Project-selector
Network	Technology oriented (including various projects over time)	Project oriented (including various technological solutions and technology)
Institutions	All institutions affecting the technology	All institutions affecting the project, especially search heuristics
Technology	One technology	Multiple technological solutions, each possibly comprised of multiple, sometimes supportive technologies

Table 2.1, Differences in structural components between a TIS delineation and a PBIS delineation

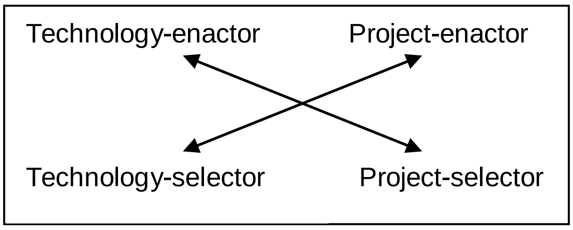
2.2.1 Actors

The actors included in a PBIS consist of any organisation contributing (with its knowledge and competences) to the project-based innovation system in focus, directly as either a developer or adopter of technological solutions, or indirectly as a regulator, financier, etc. This demarcation interprets Suurs' (2009) delineation of actors in a TIS. These actors, by taking choices and actions, actively account for the development of the innovation system (Suurs, 2009). The differences that can be expected in terms of these actors' roles, like government, interest groups and construction companies, can be best explained according to the system configuration, in part 2.2.5.

In order to determine why actors in an innovation system take actions, we adopt the enactors-selectors notion by Garud and Ahlstrom (1997), fruitfully applied by Suurs (2009) to study TIS. "Enactors are actors that are closely involved in the development of a particular technology and fundamentally dependent on its success, whereas selectors are actors that are engaged with that technology at a distance, for example, because they have access to multiple options and have the possibility to choose between these options" (Suurs, 2009, p. 43). Note that this definition is strongly influenced by the TIS's focus on technology.

Although such enactors and selectors can be identified in a PBIS as well, i.e. its consortia and government respectively, we intend to also base this notion on our unit of analysis, the infra project to gain more insights in the intensions of these actors. Hence our definition: "Enactors are actors that are closely involved in the development of a project and fundamentally dependent on its success, whereas selectors are actors that are engaged with that project at a distance, for example, because they have access to multiple projects or demands and have the possibility to choose between them". With this focus, project-enactors are the ones that develop the project – formulate demand; they are public actors that attempt to satisfy the project's underlying demand by triggering actors to participate in the project's innovation system and generate solutions. Project-selectors are the ones that are to be triggered to participate, i.e. private organizations that choose between projects when they decide in which to participate.

Hence, both types of enactors and selectors are expected to be present in a PBIS, although their roles are distinct. On the one hand, we expect that within a PBIS, actors who develop technology – the technology-enactors – also have to choose in which projects to participate – they are project-selectors, because they will not participate if they think their technology (that might still have to be developed) will not be adopted. On the other hand, the ones that develop a project – the project-enactors – are expected to chose between technologies since they only want the best solution for their project, i.e. they function also as technology-selectors.



In conclusion, we expect the enactor-selector notion to become more complex when applying it to a PBIS, as within a PBIS, technology is supplied by the technology-enactors and a technology is demanded by the project-enactors; technology-selectors as well as project-selectors attempt to align this supply and demand for technology. Moreover, project-enactors also function as technology-selectors and vice versa.

2.2.2 Institutions

The institutional component of the TIS comprises of all formal and informal institutions that affect the specific technology's development. Formal institutions are "rules that are codified and enforced by some authority" (Suurs, 2009, p. 44). Informal institutions can be divided into normative rules that relate to norms and values and are cognitive rules that can be regarded as social paradigms (Suurs, 2009), for example search heuristics and problem-solving routines (Dosi, 1982). A characteristic example of a search heuristic that is crucial to our notion of a PBIS is the specificity of and direction in which framework conditions are formulated during tenders. Because PBIS are characterised by a demand-pull for innovation, search heuristics might be an especially important institution in the PBIS. However, we do not expect any other changes, as important institutions like laws apply to any delineation.

In conclusion, in the application of the concept of institutions to a PBIS, we expect no implications, only that search heuristics become a more important institution.

2.2.3 Networks

The network component consists of various densely packed relationships between various types of actors and institutions with different roles in the innovation system (Markard and Truffer, 2008) and facilitates the transfer of knowledge (Jacobsson and Johnson, 2000). By aligning these different types of actors,a network allows for the innovation system to develop as a whole (Suurs, 2009). Much alike within a TIS, within a PBIS we expect to find a network comprising different types of relationships (Gelsing, 1989) between different types of actors. For example, within a PBIS, relationships exist between supplying market parties, the so-called consortia networks in which market parties unite to participate in a project's tender process (Altamirano, 2010). There are also relationships between supplying market parties and the demanding government, a buyer-supplier network that involves all consortia; this overall network encompasses the whole PBIS.

In conclusion, we expect the application of the network component to be justified to the PBIS and without any implications; therefore, this structural component can be treated similarly as in other innovation systems.

2.2.4 Technology

The structural component technology is included because, as Suurs (2009) stresses, technological performance can stimulate its own development, through the feedback mechanism of technological- and institutional change. However, in contrast with the TIS delineation, a PBIS includes not one technology but all the technological solutions that compete for implementation in the project.

We refer to a technological solution as the application of a technology or combination of several technologies that attempts to satisfy the PBIS's underlying demand. Multifunctional projects involve the integration of various distinctive technologies into a technological solution. Therefore, such a combination of technologies could be supportive of each other. If this is true, an interesting interplay of technologies could unfold within a PBIS that are on the one hand supportive of each other, i.e. technologies within a technological solution, and that are on the other hand in competition, i.e. the technological solutions that compete for implementation.

Hence, application of this system component to the PBIS provides a profound difference compared to its application to the TIS by Suurs (2009), as the latter includes only one technology. However, we see this as an opportunity provided by the PBIS delineation to attain more insights in the interplay of several technologies. We account for this interplay by describing the technical interrelatedness on the one hand and competitive stress on the other.

In conclusion, in applying the technology component to the PBIS, we expect some significant differences, which we account for by explicitly describing the technological interplay that takes place in a PBIS.

2.2.5 Configuration of the structural components

We describe a PBIS not only according to its structural components, we also make a clear distinction in the function of each structural component in the system, according to its system components, i.e. the configuration of the supply and demand side, intermediary and knowledge infrastructures, and the governmental component. Figure 2.3, a configuration provided by Alkemade et al. (2007), clearly depicts the structure of the system configuration of a TIS. Each of these system components is comprised of both actors and institutions and the system components are connected through the innovation system's network.

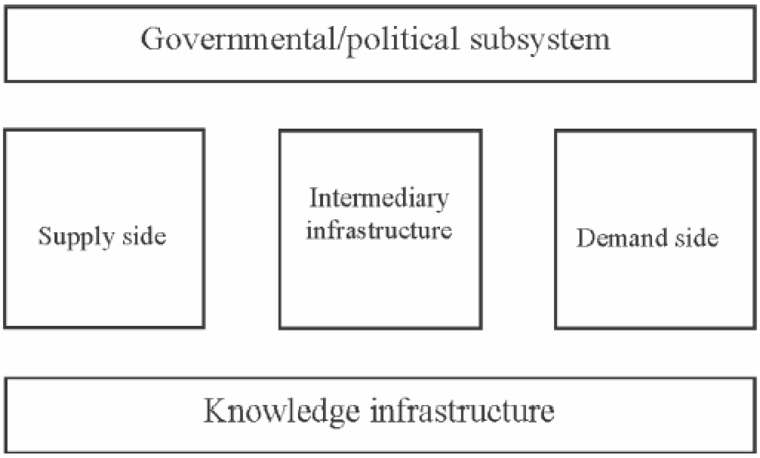


Figure 2.2, Components and structure of the TIS, Source: Alkemade et al. (2007)

The supply side covers all actors and institutions involved in the production and supply of technological artefacts and knowledge (Suurs, 2009; Alkemade et al., 2007), in a PBIS that is the supply of technological solutions. In the Dutch water construction sector (DWCS) these actors involve industrial organizations like BAM and Royal Haskoning, which together form a network, called a consortium to compete in an infra project (RWS et al., 2009). Examples of influential institutions are the routines through which these organizations are managed, e.g. the strategic choice to join a tender contest or not.

The demand side consists of the actors, institutions and technologies that acquire and use the technological solution (Alkemade et al., 2007). In the case of the PBIS, this system component can be divided into the buyer and end-user. The buyers are comprised of, on a national level the Ministry of Transport, Public Works and Water management and on the regional level the regional water management authorities, or water boards. This is where the PBIS deviates from TIS that is only applied to mass-market sectors and therefore have many more as well as private buyers. The end-users on the demand side are the actors affected by the technology, including interest groups like nature and cultural groups that oppose or support a technological solution. We refer to the different types of end-users as interest groups.

The governmental subsystem is comprised of the various governmental organizations, like ministries, provinces and municipalities, and institutions, like laws and regulations issued by the government (Suurs, 2009; Alkemade et al., 2007). In the PBIS, these governmental organizations comprise the same Ministry of Transport, Public Works and Water management and water management authorities. An example of an important formal governmental institution is the Law on the Dyke, which states that the chance of flooding of a dyke, under conditions for which it is built, might not exceed 1/10.000 per year (De Bruijn et al., 2009).

The knowledge infrastructure consists of all actors and institutions that support other system components by generating, assessing and transferring knowledge (Alkemade et al., 2007;

Suurs, 2009). In the PBIS, these actors are for example public research institutes, like TU Delft and the Governmental Works Department's various Services, and private research institutes like Imares and Deltares (RWS et al, 2009).

The intermediary structure consists of all the actors and institutions that support interactions between the previously mentioned system components (Suurs, 2009). An example of such an institution in the PBIS is the law that obliges large infrastructural projects to be put out to tender internationally (De Dommel, 2006). Examples of actors that support this intermediary structure are the project groups, instated by the government, that facilitate the development of large infrastructural projects; such groups are not found in other innovation systems.

Overall, we find that the PBIS differs in terms of its actors, not institutions, with other innovation systems in consequence of the characteristics of the DWCS. First and foremost, a PBIS is predominated by governmental actors, especially the Governmental Works Department, which are presented in all system components apart from the supply side. Secondly, unique consortia are identified on the supply side and thirdly, unique intermediary structures are found in the form of project groups. Nevertheless, this preliminary analysis of PBIS does indicate that all system components are fulfilled in the PBIS, which could be seen as the most important criterion for applying the innovation systems' structural components to the PBIS.

In conclusion, we justify the application of structural (and system-) components to the PBIS, although changes are expected regarding the notion of enactors/selectors, the technology component and the content of the system configuration. To research the extent of these expected changes, we formulate the following hypothesis to be tested in our case studies:
Hypothesis 1: "If we apply the structural components of the innovation systems perspective to the new system delineation of a PBIS, than we expect changes in the enactor/selector notion, in the technology component and in the content of the system configuration"

2.5 The PBIS: expected changes in system functions

After investigating whether the application of the innovation systems' structural components to the PBIS is justified, we now do the same for the system functions approach by Hekkert et al. (2007).

System functions are the activities of an innovation system's structural components that explain the dynamics of a developing innovation system and that visualize the system's performance (Hekkert et al., 2007). In contrast with the TIS delineation with which the System Functions approach is much associated, the goal of system functions in a PBIS are not to develop, diffuse and use a specific technology, but to search, select, develop and implement the most satisfying technological solution to the PBIS's underlying demand.

The System Functions approach identifies a number of interdependent system functions that through their interactions, allow for a dynamical view of an innovation systems' development. Fulfilment of a certain function is likely to have effect on the fulfilment of other functions; therefore, they can serve as drivers when they positively influence other system functions or serve as bottlenecks when they hamper the fulfilment of other system functions. By mapping how well system functions are fulfilled over time, it is possible to identify these drivers and bottlenecks that affect the development of an innovation system (Hekkert et al., 2007; Negro, 2007; Suurs, 2009).

Because system functions are perceived as the properties on which policy makers need to intervene in order to stimulate innovation (Bergek et al., 2007; Bergek et al., 2008), we hope to identify these drivers and bottlenecks to innovation in a PBIS. Accordingly, we might be able to decide what factors determine the successfulness of the underlying innovation process.

Although the exact number of system functions remain arbitrary (Bergek et al., 2008), in this research we focus on the seven system functions identified by Hekkert et al. (2007) as empirical research (Suurs, 2009; Negro, 2007) stipulates that these functions capture all relevant activities in the innovation system. We describe the system functions below and, for sake of clarity, abbreviate them to F1 unto F7, the number referring to the respective functions below. Moreover, for each function we discuss whether we expect it to be crucially important, just important or insignificant when applied to a PBIS delineation.

F1: entrepreneurial activities
The role of entrepreneurs is to use the potential of new knowledge, networks and markets in order to generate and exploit new business opportunities (Carlsson and Stankiewicz, 1991; Hekkert et al., 2007). Hekkert et al. (2007) stress that entrepreneurs can be either new entrants or incumbent companies who are intent to diversify their business strategy by joining the innovation system. They also stress that the entrepreneur's capacity to experiment, i.e. performing pilot projects, is pivotal to system development. However, one can imagine that the application of pilot projects is not feasible in a PBIS, because in a PBIS there is only demand for one unit of the technological solution and no mass market in which the costs of a pilot project can be earned back, which is the case in TIS. Consequently, we expect that entrepreneurial activities in terms of pilot projects will be insignificant in the context of a PBIS.

F2: knowledge development
Knowledge is seen as the most important resource of an innovation system and learning as the most important process (Lundvall, 1992). Both 'learning by searching' and 'learning by doing' are incorporated in this function (Hekkert et al., 2007). Because the creation of knowledge is important in any innovation system, we also expect it to be for a PBIS.

F3: knowledge diffusion
The exchange of knowledge is seen as the most essential function of networks; especially in the heterogeneous context of an innovation system (Carlsson and Stankiewicz, 1991). Diffusion of knowledge is required for the system to develop in sync. Effective exchange of knowledge is a precondition for 'learning by interacting' (Hekkert et al., 2007). Moreover, for PBIS these statements are especially true (Johannessen and Olsen, 2010), as Gann and Salter (2000) state, "Project-based firms rely upon combining technical expertise from other organisations in order to deliver their own technical capabilities, usually in one-off processes" (p.1). If the function knowledge diffusion so critically important to the actors in the PBIS, than we expect this function is to be crucially important when applying it to a PBIS.

F4: guidance of the search
Since resources are limited and various technological opportunities exist to meet a given demand, selection is a prerequisite (Hekkert et al., 2007). By expressing their targets and expectations, governmental actors may steer this selection process. In the case of the PBIS, we expect this function to be crucially dominant, as the powerful government is known to steer the development of technological solutions by market parties and select between these solutions in an explicit way. Namely, through criteria referred to as framework conditions with which technological solutions have to comply. Therefore, we conclude that the function guidance of the search is expected to be crucially important when applied to the delineation of a PBIS.

F5: market formation
Within a TIS, the formation of niche markets and the creation of competitive advantage by favourable tax regimes provide protective market environments for new technologies to develop (Hekkert et al., 2007). However, in the case of PBIS, neither a mass-market nor a niche market is formed, only a temporary market, the project. In a PBIS, favourable market conditions can be formed through financial compensation offered by the government for the services of market parties. Hence, these conditions are not technology specific as in a TIS, but project specific. Another incentive for market parties to participate in a PBIS is the size of its underlying demand. Because complex infra projects by definition represent a strong demand, i.e. an expensive technological solution is demanded, and because the existence of a PBIS is based on this demand, we expect the function market formation to be crucially important when applied to a PBIS.

To specify between the previous two functions, Suurs (2009) states that market formation is a special form of guidance of the search, in which users are involved to generate a positive demand for the technological solution. However, because in a PBIS the users are also the governmental component that guides the search, it is important to explicitly distinct between the two functions F4 and F5 for the government. In this respect, market formation stimulates the development of technological solutions, without discriminating between technologies, whereas guidance of the search attempts to select the most viable technological solution and therefore does discriminate.

F6: resources mobilization
Both financial and human resources are a necessary input for all activities within the IS (Hekkert et al., 2007). Examples are funds and staff made available by industrial or governmental organizations to develop specific technological knowledge. Because resources are required to any type of innovation system, we also expect it to be important when applied to a PBIS.

F7: creation of legitimacy
Due to the influence of vested interests, a new system has to become part of an incumbent regime, or it has to overthrow it in order to develop. Advocacy coalitions can function as a catalyst in this sense, by attempting to persuade the guidance of search to go in the right direction and by lobbying for resources and favourable tax regimes (Hekkert et al., 2007). When new project approaches are developed or innovations are adopted in PBIS, we expect the creation of legitimacy through lobby activities to be crucially important. However, because project approaches only take place during the initiation of an infra project we do not expect this function to be more or less dominant when applied to a PBIS delineation.

In conclusion, although we expect some system functions to be more or less important when applied to the delineation of a PBIS, it is justified to apply Hekkert et al.'s (2007) System Functions approach, since all functions are expected to be present in a PBIS. To validate our expectations in our case studies, we formulate the following hypothesis:
Hypothesis 2: "If we apply the System Functions approach to the new system delineation of a PBIS, than we expect the functions entrepreneurial activities to be insignificant in terms of pilot projects; knowledge diffusion and –creation, guidance of the search and market formation to be crucially important; resources mobilization and creation of legitimacy to 'just' be important"

2.6 The PBIS: expected changes in motors of innovation

The concept of motors of innovation builds on the System Functions approach and encompasses a series of positive interactions between system functions that form a closed loop of positive feedback or a virtuous circle that constitutes the development of an innovation system. On the other hand, a series of negative feedbacks might form a vicious circle, resulting in system degeneration. This phenomenon is also referred to as cumulative causation (Suurs, 2009).

In his studies on the development of TIS, Suurs (2009) identifies four increasingly elaborate motors of innovation, each pertaining to a different stage of the innovation system's development, although not every motor is necessarily present in a system's development. In this subsection, we investigate which of these motors are to be expected when the concept of motors of innovation is applied to the delineation of a PBIS.

The first and least developed motor in an innovation system's development is the *Science and Technology Push motor*, which is dominated by the functions knowledge creation and –diffusion, guidance of the search and resources mobilization (Suurs, 2009). Other functions are absent or weak. This motor's positive feedback loop consists of positive research results [F4], leading to a guidance of the search [F4] and the allocation of resources [F6] to perform subsequent studies [F3] and conferences or workshops [F3] in this area. This could again have positive results [F4], so the whole circle can start over again. We expect such a motor to precede the initiation of a project, because it is plausible that a certain knowledge base and expectations are required before a complex infra project is initiated; the Science and technology Push motor can provide this. In conclusion, we expect the Science and Technology Push motor to be present in the development of a PBIS.

The second and more elaborate *Entrepreneurial motor* is stressed to replace the Science and Technology Push motor, maintaining its virtuous cycle and adding to it the functions creation of legitimacy and entrepreneurial activities (Suurs, 2009). The cumulative causation is created by new entrants or diversifying incumbent actors that start experimenting [F1] with new technology. If these lead to positive expectations [F4], actors lobby for support [F7] from other actors (e.g. government) to mobilize resources [F6]. This leads to more pilot projects being started [F1], and the positive feedback loop is completed. However, we do not expect to find this motor in the development of a PBIS because, as mentioned, we do not expect to find many pilot projects in a PBIS.

The *System motor* resembles the entrepreneurial motor, with some changes in guidance of the search and creation of legitimacy, as well as the inclusion of market formation (Suurs, 2009). In this case, enactors organize themselves increasingly in networks, by enacting new entrants, governments, intermediaries and stakeholders in their system [F1]. From this network, enactors attempt to develop the innovation system by enhancing the motor's virtuous cycles. We expect this motor to also be present in a PBIS, because in complex infra projects, several types of actors are involved in a network to create technological solutions of which one is selected and implemented.

The final *Market motor* is characterized by a strong fulfilment of all functions, except creation of legitimacy, which is no longer important due to the presence of a strong commercial market. This motor starts with the emergence of a commercial mass market [F5], leading to positive expectations [F4] and an increasing availability of resources [F6]. Consequently, more entrepreneurs enter the market [F1] and invest in resources [F6]. They thereby contribute to a strengthening of the market [F5], completing the virtuous circle (Suurs, 2009). Because the creation of a mass market is not likely within a large infra project, we do not expect this motor to occur in a PBIS.

In conclusion, we expect some motors of innovation not to be present when applied to the delineation of a PBIS, however, since this is also the case of some of Suurs' (2009) case studies application of the motors of innovation concept to the PBIS is justified. To validate our expectations regarding the occurrence of the motors of innovation, we formulate the following hypothesis:
Hypothesis 3: "If we apply the motors of innovation concept to the new system delineation of a PBIS, than we expect the Science and Technology Push and the System Building motors to be present, but not the Entrepreneurial and the Market motors."
Because our delineation and sector in focus is so different from the ones maintained by Suurs (2009), we consider the possibility of identifying new motors of innovation.

2.7 Summarizing hypotheses

In the previous three subsections, we have indicated that application of the innovation systems' structural components, the System Functions approach and motors of innovation concept are all applicable to the delineation of a PBIS. However, we did find that some differences were to be expected, which we summarize in brief.

With regard to the structural components, we find that the enactor/selector notion will become more complex when applied to PBIS; the institution search heuristics will be more prominent; competing technological solutions might not be comprised of one but multiple technologies. Finally, we expect the system configuration of a PBIS to be significantly different from that of a TIS, since PBIS are dominated by the government. Based on the most important changes we formulated the following hypothesis: *Hypothesis 1: "If we apply the structural components of the innovation systems perspective to the new system delineation of a PBIS, than we expect changes in the enactor/selector notion, in the technology component and in the content of the system configuration"*

With regard to the System Functions approach, we expect some system functions to become more and some functions become less dominant when applied to a PBIS instead of to a TIS. Therefore, we formulate the following hypothesis:
Hypothesis 2: "If we apply the System Functions approach to the new system delineation of a PBIS, than we expect the functions entrepreneurial activities to be insignificant in terms of

pilot projects; knowledge diffusion, guidance of the search and market formation to be crucially important to PBIS success; knowledge creation, resources mobilization and creation of legitimacy to be important"

With regard to the application of the motors of innovation concept, we expect some motors are present when applied to the delineation of a PBIS, whereas others are not. These expectations are summarized in hypothesis 3:
Hypothesis 3: "If we apply the motors of innovation concept to the new system delineation of a PBIS, than we expect the Science and Technology Push and the System Building motors to be present, but not the Entrepreneurial and the Market motors."

In this research's case studies, we test these hypotheses to check whether our theoretical assumptions are justified. If not, we must take heed that unanticipated interactions might explain these falsified hypotheses. Such interactions should be uncovered through a more thorough analysis of the data.

3. Case selection

In this section, we shortly discuss why Public Private Partnerships (PPP) are so important in PBIS; how they are established and what types of PPP exist. Moreover, we describe the trend towards more PPP in PBIS over the past 80 years by highlighting some cases in which innovative forms of PPP were introduced. From this description, it becomes clear why we select the cases of the Maeslantkering and the multifunctional Afsluitdijk renewal. In addition, we discuss the other reasons for our case selection.

3.1 What are PPP

A Project-Based Innovation System (PBIS) is comprised of many actors, both public and private. The cooperation between public actors and the private consortia in the context of a PBIS is also known as Public Private Partnerships (PPP). Over time, different forms of PPP have been administered in public sectors, with increasing involvement and responsibilities for market parties (Altamirano, 2010). The PPP approaches involve the stages of the infrastructure asset life-cycle, such as Design, Build and/or Maintain. Such PPP approaches are also referred to as innovative contracting (Altamirano, 2010), opposed to traditional contracting in which only the construction is put out to tender and room for innovation is limited (Rossum and van Ham, 2003). Moreover, recently PPP also plays an important role in the planning stage of especially complex infra projects. Independent of subsequent innovative contracts, such a form of PPP is called a competitive dialogue (OGC, 2006). The goal of such a competitive dialogue is to involve market parties to explore and develop the solutions that best meet the project authority's demand, so that they can use it as input to their plans (OGC, 2006), therefore it can be seen as a form of innovative contracting. These solutions are mostly innovative, as these complex projects involve an unprecedented demand, or 'demand-pull' for innovation.

Various literatures (World Bank Website, 2010; AECOM Consult, 2006; RWS, 2006; Witteveen and Bos, 2006) give numerous reasons for administering PPP in the public dominated DWCS. The financially oriented reasons are execution of projects within imposed budgetary constraints, utilizing private sources of finance via off balance sheet structures; higher value for the same money and project acceleration. Risk based reasons include risk division between public and private sectors; creation of legitimacy. Innovation related reasons involve incentives for process innovation and the provision of more innovative technological solutions.

3.2 The types of PPP and the stages of an infra project

In a PBIS, PPP takes place in a tender contest. A tender contest is defined as "a procedure with the goal to provide the tendering agency with a plan or design that, after appeal for competition, is selected by a jury, with or without the allocation of rewards" (BAO, 2005). Accordingly, we speak of a tender contest in case of a competitive dialogue or when an innovative contract for the infra project (that commonly regards its Design, Construct and/or Maintain stages) is put out to tender according to the European guidelines that oblige the international competition between market parties.

Tender contests might apply to the different stages of a project. We recognize the following successive stages within a PBIS: initiation, planning, design, construction and maintenance (see also figure 3.1). At the initiation stage, preparations are made for the successful project operation: the project authority or project's organizational structure is set up, the project's goal (ambitions) and structure are (as far as possible) defined, including the type(s) of innovative contract(s) that are put out to tender and the application of a competitive dialogue, and the project's budget (RWS, 2008).

During the subsequent planning stage, the project's demand is translated in terms of framework conditions that can guide the development of technological solutions in the subsequent design stage, and on which these solutions can be ranked (RWS.nl, 2010b). However, especially in the case of complex infra projects in which technical complexity exists, the project authority might not be able to define the technical means of satisfying their needs (OGC, 2006). Therefore, PPP in the form of a competitive dialogue might be applied during the planning stage of a PBIS (OGC, 2006). In a competitive dialogue, market parties might explore the technological options available to the unspecified demand of the project authority. Based on this exploration, the project authority might be better able to choose a technological direction and accordingly, formulate specific framework conditions.

During the subsequent design stage, these framework conditions are used as a point of reference for the identification, selection and development of technological solutions. The goal of this stage is to select the technological solution that best provides in the project authority's demand. Since the complex infra project of the Maeslantkering in 1987, this has been done through a tender contest, in which market parties identify, select and develop technological solutions that are selected by the project authority based on the framework conditions specified during the planning stage (RWS, 2008). Different types of innovative contracts might be put out to tender during this design stage that also involves the subsequent stages of construction – during which the winning technological solution is constructed, and maintenance – during which the constructed technological solution is maintained and possibly improved.

These contracts might be integrated, as a Design-Construct-Maintain (DCM) contract signed by one contractor, or the various project stages might be put out to tender separately and signed by various contractors, like in a Design-Bid-Build contract (Altamirano, 2010). Although Design and Construct (D&C) contracts exclude the maintenance stage, this stage is mostly included so that market parties are stimulated to develop a sustainable solution that incorporates the costs of maintenance (RWS, 2008).

3.3 The development of the DWCS over the past 80 years

The government has always dominated the Dutch Water Construction Sector (DWCS), of which until 1976 only the supply side was comprised of private organizations. In projects like the Afsluitdijk (completed 1933) and the Haringvlietsluizen (completed 1970), governmental project authorities developed the technological solutions, specified in framework conditions called "specification", that were subsequently realized by market parties (Schot et al., 1998). It was only with the construction of the ´Oosterschelde kering´ that market parties were involved in the development of the technological solution during the design stage (Schot et al., 1998), see figure 3.1. The successful completion of this project enabled more market involvement in future complex infra projects. Consequently, the Maeslantkering was the first project, in which market parties were fully responsible for the provision of a technological solution and therefore comprise an important part of the project's knowledge infrastructure. Accordingly, this was the first project in the DWCS that applied a Design-Construct and Maintenance (DCM) contract, see figure 3.1. With this successful project, innovative contracting commences in the DWCS and DC(M) contracts become a more common occurrence. However, with the current study for the multifunctional renewal of the Afsluitdijk, not only are the project stages design, construct and maintain out-sourced, but also the planning stage, in which ideas and framework conditions are generated (RWS et al., 2009). Consequently, this is the first project in the DWCS that uses the competitive dialogue, see figure 3.1 on the next page, which depicts market involvement in grey bars.

3.4 Case selection

We focus our research on the complex infrastructural projects of the Maeslantkering (1987-1997) and the current multifunctional renewal of the Afsluitdijk (2007-2010) for various reasons.

The first reason draws from the previous discussion that these cases both involve highly innovative project approaches, where the Maeslantkering was the first to apply a Design-Construct-Maintain contract in the DWCS, the renewal of the Afsluitdijk was the first to apply a competitive dialogue. The fact that these cases are regime breaking in their project approach implies that the initial resistance against such approaches needs to be overcome. We expect that the successful and extensive lobby activities by governmental enactors to overcome this regime, precede the adoption of such approaches and will strengthen the PBIS formed. Moreover, it makes explicit the degrees in which governmental support is required for the initiation of a large infrastructural project in the DWCS. Finally, project approaches have continuously changed over the past decades and are expected to continue doing so (Goossens, 2007); therefore, it is important to gain insights in the successful adoption of such innovative approaches.

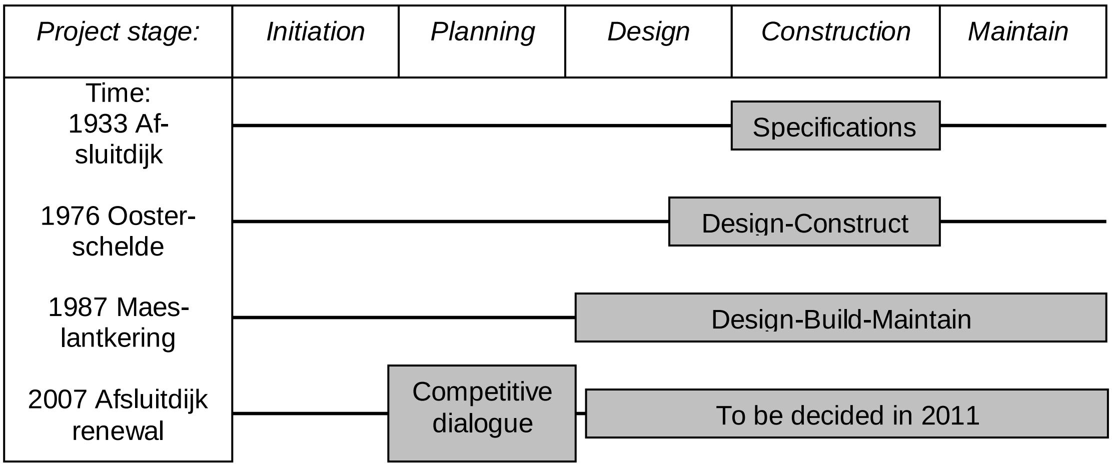


Figure 3.1, Pioneering forms of PPS related to the stages of complex infrastructural projects in the Dutch Water Construction Sector

However, more importantly, both cases include PPP through a tender contest, an episode in a complex infrastructural project that we expect to be crucial to its success. During this episode, technological solutions are developed that determine the continuation of the remainder of the project. Moreover, actors are involved and institutions and networks set up, that determine the strength of the PBIS. The presence of an elaborate tender contest episode in both cases, provides us with the opportunity to learn how such tender contests affect the successfulness of the innovation process of a complex infrastructural project.

However, our two cases have also been selected because the Maeslantkering case provides a good opportunity to study a completely and successfully finished project, while the multifunctional Afsluitdijk renewal provides a contemporary case that allows us to give and indication of the way projects are approached today. Moreover, the latter case will show us which organizations and institutes are currently prominent players in complex infrastructural projects, how they interact and what type of role they fulfil in such projects. Especially important is that the Afsluitdijk renewal case depicts the contemporary trend towards multifunctionality in these types of large infrastructural projects (RWS et al., 2009; Van Ast, 2000).

This multifunctional trend affects the third reason that supports our case selection, namely that the Maeslantkering case demands unprecedented technological solutions that are comprised of one technology: a navigable storm surge barrier. It is therefore more easily applicable to the System Functions approach by Hekkert et al. (2007), since the PBIS that constitutes the Maeslantkering case can be perceived as a bundle of competing emerging Technological Innovation Systems – each supporting a technological solution in development – that are connected through a network of shared actors and institutions. In addition, this would imply that once a technological solution is selected, the PBIS would be comprised of only one emerging Technological Innovation System and therefore completely resemble such a system. However, the multifunctionality of the Afsluitdijk renewal case implies that technological solutions are comprised of more than one technology. Accordingly, a technological solution is comprised of various (potentially) supporting technologies and can therefore not be seen as the product of one Technological Innovation System, but of the integration of the product of several. Hence, the PBIS of the Afsluitdijk renewal cannot as easily be related to the Technological Innovation Systems delineation and is therefore not as readily applicable to the System Functions approach. In conclusion, this case selection allows us to test if the System Functions approach is applicable to any type of PBIS, regardless of its resemblance to the Technological Innovation Systems delineation.

A fourth reason for our case selection is the fact that both cases are seen as icons of the DWCS and successful projects (InnovatiePlatform, 2009), making them valuable cases to learn from and to study how projects are ideally managed in the DWCS.

4. Methods

In order to investigate the previous cases empirically and within their real-life-context, we make use of two longitudinal, qualitative case studies (Yin, 2003). These qualitative case studies allow us to gain a better understanding of why a project-based innovation system (PBIS) occurred as it did and it allows us to understand and describe the causality of its underlying phenomena (Yin, 2003).

To identify the properties that determine the successfulness of innovation in infra projects and decide how to manage these properties to boost the innovative performance of the DWCS, we intend to describe the build up of a PBIS in terms of their structural components and system configuration, their drivers and bottlenecks and their motors of innovation. Although the build up of a system in terms of its structural components and system configuration (Alkemade et al., 2007) can be derived directly from literatures, the identification of drivers, bottlenecks and motors to innovation requires a broader database in which the causal relationships between system functions are retained.

To attain such a database, we apply an event history analysis, which has been successfully applied by Suurs (2009) to the context of a Technological Innovation System. However, we assume it to be applicable to PBIS as well, since the goal of the analysis is to describe the emergence of an innovation system in terms of events. Events are what the structural components of an innovation system do, or what happens to them (Hekkert et al., 2007). By systematically mapping the events that affect the PBIS over time in a database, event history analysis enables the identification of system functions and their respective causal relationships, allowing for to the identification of drivers, bottlenecks and motors of innovation. Moreover, this type of analysis 'guarantees' the meaningfulness of the concepts used, as the system functions were continuously checked against raw empirical data (Suurs, 2009); hence, the approach ensures a high internal validity. Accordingly, event history analysis allows us to test whether the system functions chosen are also applicable to the PBIS, as Hekkert et al. (2007) state "When many events are difficult to allocate to either one of the seven functions, this is a clear indication that the list of functions is not complete or all together senseless" (pp.16).

We expect some significant changes when applying the structural component technology to the PBIS delineation. One the one hand, we expect to find competing technological solutions, which we account for by describing how the winning solution was selected and stating on what technical- and (if relevant) political grounds the selection was made. Such an approach underlines the interdependency of system functions, i.e. guidance of the search and the structural components technology and their respective enactors. On the other hand, we expect to find supporting technologies integrated in the technological solutions of the multifunctional Afsluitdijk renewal case. We account for this also by describing the technological interdependencies and how they affect the decision making process; in doing so we prevent complications. For example, Otto (2009) describes the shared and competing system functions for each technology; however, in the multifunctional Afsluitdijk case this is not feasible due to the amount of technologies.

To structure our research and to enhance the comparability of the drivers, bottlenecks and motors to innovation of our cases, we divide our cases in time intervals that are characterized by events that take place, the so called episodes described in the previous section. Because these episodes account for the differences in innovative contracts that might be applied during a complex infrastructural project, they can be used to compare complex infrastructural projects with distinctive project approaches. We maintain the episodes described in section 3.3: the emerging demand episode, during which a PBIS emerges and a demand for an infra project arises. The tender contest episode, during which innovative contracts are put out to tender or a competitive dialogue takes place. More than one such tender episode might take place during a PBIS. Tender contest episodes might be applied in different project stages, like initiation, planning and design, depending on the project approach taken. The up-scaling episode, during which the winning technological solution is elaborated into an executable design. The construction episode, during which the technological solution is realized. We do not include the maintenance episode, because at this time, the innovation is done and the

PBIS's network is reduced to only a subsidiary organization that maintains the technological solution. We study the sequence of system functions and the changes in structural components for each of these episodes so that the findings of both cases can be compared and the factors that determine the successfulness of the innovation process of complex infrastructural projects can be identified.

In order to enhance the reliability of our research, we provide an overview of the data that is clear and accessible to validation and/or falsification by both reviewers and readers. To create such a data overview that preserves the causal relations between events, we describe the entire sequence of events relevant to system development and accordingly, refer to the respective system functions by denoting the system function number in brackets in the text. In this notation, the system function numbers refer to the system functions as described in the theory section. For example, if we refer to a study that has been performed we write **[+F2]** behind the study event. Moreover a '+' indicates a positive fulfilment of events, while '–' indicates a negative or lack of fulfilment, for example a negative expectation.

We attempt to acquire the data primarily through literature studies, mostly of technical journals and reports, as such sources are often more objective than interviews (Yin, 2003). However, because literatures might not always be available, we complement our data with interviews. Moreover, it is sometimes important to acquire the perception of the actors involved in an innovation system, because it is their perception that guides their actions and therefore determines the sequence of system functions. In order to enhance the validity of these data, we use multiple sources of evidence (Yin, 2003), i.e. we interview nineteen individuals that are important to the development of the PBIS. These interviewees comprise all the different types of relevant actors, including at least one of each important system component (see Appendix V and VI for the list of interviewees and their roles in both cases). Moreover, we cross-reference the data from the various interviewees and from literatures, to distil the underlying facts. Finally, we enhance validity by allowing our interviewees to review our data, analyses and the conclusions we draw.

Based on the acquired data we attempt to visualize the development of the PBIS in terms of both configuration of structural components and system functions. Although data regarding the structural components and system configuration can be directly applied, indicators are required in order to measure the fulfilment of system functions. Hence, the events are translated into indicators before they are related to system functions; this way an system functions database can be attained.

We use the indicators provided by prominent system functions literature, i.e. Suurs (2009), Hekkert et al. (2007), Bergek et al. (2006) and Negro et al. (2008), to measure functions of innovation. An overview of these indicators and a short description of the respective events, is given in table 4.1.

Due to our application of the system functions approach to PBIS, we expect – as mentioned in the theory section – no entrepreneurial activities to take shape in experiments. Moreover, due to our PBIS delineation, the qualitative fulfilment of the guidance of the search has become important, as it selects between the various competing technological solutions. Hence, a '+' or '-' – guidance in favour of the PBIS or against it – does no longer suffice. Finally, market formation takes shape in subsidies for joining the project's tender contest; not developing an emerging technology. Any unexpected implications due to the application of this operational scheme developed in terms of a TIS delineation, to a PBIS delineation will be discussed in our reflection on the method section.

Nr.	System function	Event type	Description of event
F1	Entrepreneurial activities	New entrants (+) and entrants excluded as a result of selection by technology-selectors (-)	Market parties that enter or leave a PBIS and contribute(d) by developing a technological solution on which they are fundamentally dependent
		Large scale experiments and tests/pilots projects	A technological solution that regards the PBIS in focus, is explored within a physical societal context (so no laboratory model research)
F2	Knowledge development	Studies	Any type of study, like feasibility-, desktop- and assessment studies, but excluding experiments in a physical societal context
F3	Knowledge diffusion	Meetings	Workshops, conferences, brainstorm sessions
		Publications	Documents that are publicly shared or shared between certain actors
		Network size and intensity over time (incl. collaborations)	The amount of network participants and their extent of cooperation
F4	Guidance of search	Positive (+) or negative (-) promise or and if applicable, broad or narrow targets	Promises or targets by actors with the power to influence institutions that affect the respective project and its technological solutions (including framework conditions)
		Positive (+) and negative (-) expectations regarding the technology	Expressions regarding the technological solution's potential
		Positive (+) and negative (-) outcomes of a study	Results of studies or experiments/pilots
F5	Market formation	Number, size, likeliness and type of markets formed	The (number and) size of demand that is pronounced; the perception of the market that is formed; additional advantages of the market formed, like exposure
		Creation of protective spaces (+); lack of (-)	Subsidies to consortia provided for joining tender contests; institutional arrangements like IPR. Or the lack thereof (-)
F6	Resource mobilization	Investments in terms of human resources (+) or lack of (-)	The amount and quality of human resources allocated to the project, including experience and educational level; the lack thereof (-)
		Financial investments (+) or lack of (-)	Direct investments and/or subsidy programmes attributed (+) or stopped (-) to the project by any actor; the lack thereof (-)
		Material investments (+) or lack of (-)	The amount and quality of materials and machinery attributed (+) to the project by any actor; the lack thereof (-)
F7	Creation of legitimacy	Lobby activities pro (+) and contra (-)	Pressure on actors with power to change institutions
		Network formation; creation of support	Triggering external organizations to complement the project. This differs from F1 because these external organizations complement the project without becoming fundamentally dependant on its success or because the enacted organizations are not new to the such types of projects in the DWCS. Additionally, support given by actors relevant to the project, like interest groups.

Table 4.1, Allocation scheme of system functions and their respective indicators

5. The case of the Maeslantkering

This section on the case of the Maeslantkering is structured as follows. We first provide a concise description of the most important results of the case that shape the Project-Based Innovation System (PBIS). Moreover, a description of the various technological solutions that were created during the project´s tender contest, as well as an elaborate storyline-description of the events that constitute this case are provided in Appendices I and II respectively because these sections do not directly contribute to our research goal, but merely serve as an illustration for the interested reader. Subsection 5.2 provides the analysis of the Maeslantkering case from an innovation systems perspective. Finally, subsection 5.3 provides some preliminary, case-specific conclusions.

5.1 Description of the Maeslantkering case

The PBIS we focus on in this case regards the realization of a Navigable Storm Surge Barrier (NSSB) in the New Waterway, i.e. a barrier that can open and close so that when opened, shipping activities are not hampered and when closed, water safety is provided against storm surges. To structure our data, the development of this PBIS is divided into four successive episodes, namely, emerging demand, tender contest, up scaling, and construction; see figure 5.1. Accordingly, the PBIS of this case appears once the demand for such a barrier in the New Waterway emerges and ends once the barrier has been realized. Hence, the PBIS does not only encompass the actual project, but also the emergence of this project. Appendix II provides a more elaborate version of the results that follow.

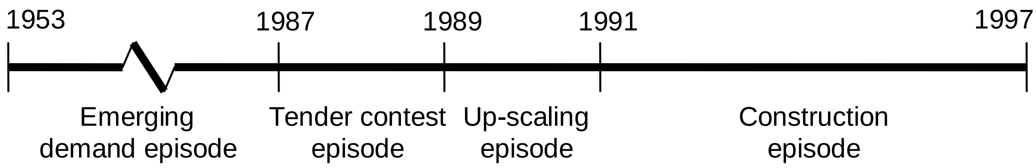


Figure 5.1, Timeline of the episodes of the Maeslantkering case

The emerging demand episode describes the emergence of the PBIS for a NSSB in the New Waterway area. This episode (1953-1987) describes the sequence of events that have enabled the project and its innovative tender contest for the barrier to commence.

It starts with the 1953 storm surge, leading to the Delta Act and a demand for water safety in the New Waterway area [+F5] (Schot et al., 1998; De Groot, 1995). A governmentally funded [+F6] study [+F2] was done to explore the potential of a navigable storm surge barrier (NSSB) in the new waterway, but it was expected to be too technically advanced [-F4] (CSW, 1987; Van Oorschot and Pruijssers, 1995). Moreover, due to initial resistance towards NSSB, especially by the Rotterdam Europort [-F7] whose planned growth would be inhibited by such a barrier (Toussaint, 2010), the government decided to go with dyke reinforcement along the New Waterway (CSW, 1987). However, as dykes were reinforced, it turned out that the dykes needed to be higher than initially expected, causing cities to be levelled; nature and cultural heritage to be destroyed *[-F4 TIS]* (Toussaint, 2010; VenW and BMK, 1995). During the years 1976-1986, the 'Oosterschelde kering' was constructed, generating a lot of knowledge [+F2] and positive expectations [+F4] on navigable storm surge barrier technology (Vrijling, 2010; Van Oorschot, 2010). Because of decreasing expectations regarding dyke reinforcement as a feasible solution for water safety in the New Waterway and due to a series of explorative studies [+F2] that resulted in increasing expectations [+F4] regarding the NSSB technology, Hoogland was able to convince [+F7] the minister of Public Transport, Public Works and Water Management to commence a project on the feasibility and possible realization of a NSSB in the New Waterway (Hoogland, 2010; Visser and Huis in 't Veld, 2010). For this project, Schreuders proposed a Design-Construct-Maintain contract to be put out to tender for the first time in the history of the DWCS (CSW, 1987).

The second episode represents the tender contest for the Design-Construct-Maintenance contract, ranging from 1987 to 1989 and describes how, over three rounds of competition, six technological solutions were narrowed down to one.

It starts with the extensively lobby activities [+F7] by Schreuders to gain the support of higher government, governmental knowledge institutes and universities (Schreuders, 2010; Hoogland, 2010). With their support, Schreuders instated the project-organization, comprised of the CWS commission responsible for the tender contest and a supporting network of knowledge groups that could verify knowledge, create framework conditions on which market parties had to base their solutions on and select between these solutions (CSW, 1987). After the tender contest's advertisement in May 1987, 33 market parties subscribed for the tender contest [+F1] (six of which also participated in the construction of the 'Oosterschelde kering'), triggered by the possibility of winning the realization of such a large project [+F5] (Nederend and Koopmans, 2010; Van Oorschot, 2010; Den Ouden, 2010). Moreover, they formed five networks of organizations, called consortia, to combine their capabilities, see figure 5.2 (CSW, 1987). During the tender contest's first round of competition, lasting three months, the consortia's work groups comprised approximately 20 experts that shared and created knowledge [+F2,F3] to search for and develop a technological solutions (Den Ouden, 2010; Nederend and Koopmans, 2010). Their most important guidelines were the framework conditions developed by the organizational structure [+F4] (SNW, 1987). For joining the tender contest, each consortium gained 250.000 guilders compensation (SNW, 1987), while their actual costs were over a million guilders [-F5] (Nederend and Koopmans, 2010; Van Oorschot, 2010; Den Ouden, 2010). At the end of the three-month period, six technological solutions were developed – on which more can be found in Appendix I; the organizational structure intended to choose one solution, but found that too little knowledge was available [-F2] to make such an important decision [-F4]. Therefore, they excluded only one unrealistic design [+F4] (see figure 5.2) and demanded that the consortia further developed their solutions in a successive round of competition (CSW, 1987).

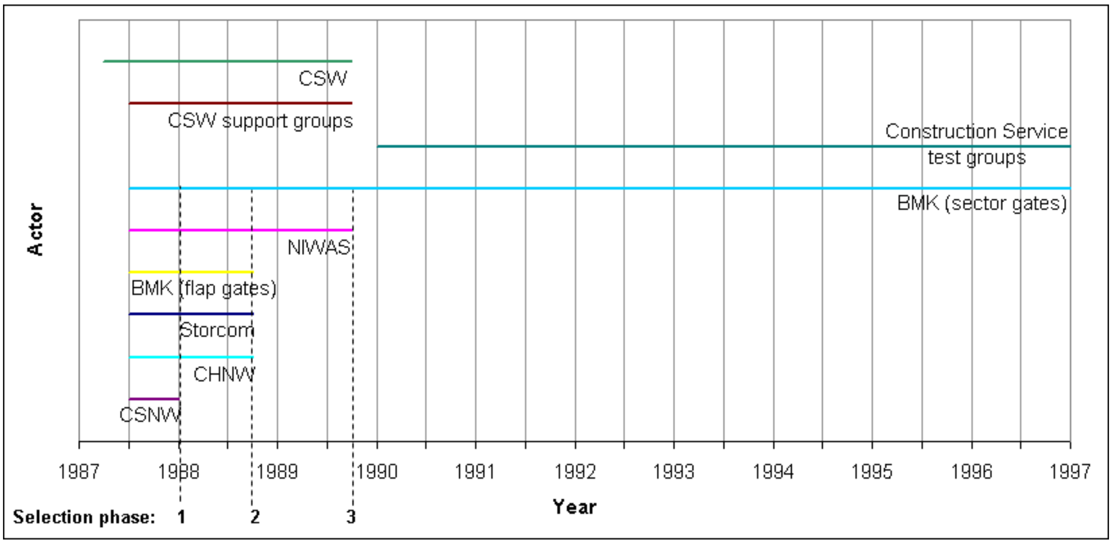


Figure 5.2, Tender contest related actors and their period of activity in the PBIS for the Maeslantkering

This resulted in another three-month period, during which the four remaining consortia further developed their solution, by allocation funds [+F6] for knowledge sharing and –creation [+F2, F3] to support their solution; these actions were guided by more specific demands [+F4] (CSW and RWS, 1988). Based on the consortia's results, the organizational structure chose in September 1988 for the sector gates designs and thereby excluded three more designs, see figure 5.2 [+F4] (CSW and RWS, 1988). Because both the BMK and the NIWAS consortium provided this design and it was unsure which was the best [-F2], a third round of competition commenced.

This round lasted a year and for the first time, the consortia cooperated with the organizational structure in creating and sharing knowledge [+F2, +F3] (whereas the latter's function was until then restricted to knowledge verification). The consortia's work groups increased to forty experts and even more funds were invested during this round for studies and conferences, accounting for up to ten million guilders over the entire tender contest episode for the BMK [+F6] (Van Oorschot, 2010). However, the losing consortium at this stage would only be compensated with half a million guilders [-F5] (Visser and Huis in ‘t Veld, 2010). Furthermore, the consortia also outsourced some studies [+F2] to external knowledge organizations like TNO and KEMA [+F7] (Visser and Huis in ‘t Veld, 2010). In October 1989, the organizational structure pointed the BMK out as the winner [+F4] (Smit-Kroes, 1989).

The third episode starts with the contract agreement between BMK and the ministry of Public Transport, Public Works and Water Management in 1989 and describes the two-year process of scaling up and elaborating the design until it ends with the start of the barrier’s construction.

The signing of the contract in October 1989, which was heavily debated as the minister of Public Transport, Public Works and Water Management demanded that the barrier’s costs should be reduced by thirty million guilders (Van Oorschot, 2010; Nederend, 2010). This resulted in a contract of approximately 740 million guilders [+F5] (VenW, 1990) and the exclusion of the barrier’s stabilizing valves [+F4] (Nederend and Koopmans, 2010; Van Oorschot, 2010). During this episode, Construction Service’s test groups were instated to validate the creation of the work scheme by the BMK [+F2, F4] and thereby replaced the initial organizational structure of CSW and support groups; see figure 5.2 (Van Oorschot and Pruijssers, 1995; Vrijling, 2010). Early January 1990, the BMK started working out their technological solution that was no more than a design, into a detailed construction scheme (VenW, 1990) using a crew of 100-150 experts [+F6] (Nederend and Koopmans, 2010). A series of studies [+F2], among others the Hydrological Laboratory, indicated that the barrier would not function properly without its stabilizing valves [-F4] (VenW, 1990). Despite this setback, development of the technological solution commenced through various studies [+F2]. However, the progress of the BMK was continuously disrupted as the Construction Service’s test groups would not validate their construction scheme [-F4] (VenW, 1991a, b), resulting in mutual distrust [-F7] (Van Oorschot, 2010; Olierook, 2010). After numerous alterations of this scheme, it was accepted in November 1991 [+F4], meaning the initiation of the construction episode (VenW, 1992a).

The final episode, construction, concerns both the elaboration of the base design into the construction scheme and in parallel the construction of the barrier from 1991 to 1997. During this period, research was still focusing on some technical and design aspects.

During this episode, different project groups were assigned by the BMK [+F6] – the total number of attributed employees rising to between 200 and 400 – to at least seven different studies [+F2], each elaborating a different aspect of the construction scheme, so that once in early 1992 the first study was finished, construction could start right away (VenW, 1992b). External knowledge institutes like TNO, KEMA and the Hydrological Laboratory were involved in this process [+F7] (Van Oorschot, 2010; Nederend and Koopmans, 2010). It became apparent that technical problems [-F4] resulting from the minister’s decision to exclude the barrier’s valves had resulted in a year delay, as well as extensive costs[1] (Nederend, 2010). Therefore, the BMK lobbies the government [+F7] for over a year for contract revision (Maij-Weggen, 1993a), resulting in a 59.1 million guilders fee and a postponement on the delivery of the barrier to late 1997 [+F5] (Maij-Weggen, 1993b). Moreover, project leaders were replaced on the side of both the BMK and the Construction Service, resulting in a better cooperation and knowledge sharing [+F3] (Olierook, 2010; Van Oorschot, 2001). Due to learning from barrier tests [+F1], some components of the barrier were replaced [-F4, +F2], like the glide lacquers to prevent friction in the barrier’s hinge-sockets (Olierook, 2010; Nederend and Koopmans, 2010). Finally, the barrier was completed at the cost of 960 million euros and officially opened in May 1997. Overall, the interviewees, as well as a personal letter by the Director-General of the Governmental Works Department confirm that the project was a success and resulted in an innovation so advanced, that it would never have been built by the more risk-averting government.

[1] Although the exact amount of costs increase resulting from the minister’s decision cannot be determined unambiguously, the total cost increase is estimated at 200 million euros, which for the larger part is in consequence of inflation (VenW, 1997).

Although five years of maintenance of the barrier were included in the Design-Construct-Maintain contract that was put out to tender for this project, we do not include this episode in our research because the maintenance was done by an subsidiary of the BMK consortium and included no network aspect as in the previous project's episodes. Therefore, it constitutes less of PBIS and is less interesting to research. In addition, the innovation process of the main technological innovation is at this stage already finished.

5.2 Analysis of the Maeslantkering case

In this analysis section, we interpret the data from an innovation systems perspective, i.e. we describe the build up of innovation system in terms of structural components and system configuration, system functions and motors of innovation. The figures 5.3, 5.4 and 5.5 provide an overview of the changing structural components over the various episodes of the PBIS. Moreover, in subsection 5.2.5, we provide a summary of the PBIS' development and an overview if its system functions as depicted in figure 5.6.

5.2.1 Analysis emerging demand episode

The storm surge of 1953 initiated a strong demand for a solution to water safety in the New Waterway F5] and is the major driver in this case. This solution can either be provided by the incumbent technology of dyke reinforcement or by the new technologies that are labelled as Navigable Storm Surge Barriers (NSSB). On the one hand, this potential demand for an NSSB in the New Waterway is what constitutes the emergence of a PBIS: an innovation system with the goal to create a novel technological solution (an innovation) to satisfy the unprecedented demand for water safety in the New Waterway without radically affecting the incumbent dykes and hampering shipping activities. On the other hand, the technology of dyke reinforcement can be seen as a mature Technological Innovation System (TIS) because this technology is independent of a specific infra project; over hundreds of years as it has been applied numerously in various infra projects and been improved incrementally.

Because initially, the demanders chose the TIS of dyke reinforcement, the PBIS' demand side generated by the storm surge of 1953, comprised of potential end-users (local residents and organizations) and buyers (government) is weak; see figure 5.3 that depicts the system's configuration at the end of this episode. Therefore, legitimacy is lacking [-F7] for the development of the PBIS and forms a bottleneck to innovation.

This bottleneck of legitimacy is alleviated through two events. Firstly, the governmental demand side also develops a formal institution, the Delta law, that provides an opportunity to break through this bottleneck of lacking legitimacy and guides the search [F4] in favour of the PBIS for a NSSB to develop in the New Waterway. As a result, government allocates human resources [F6] to create a knowledge infrastructure (see figure 5.3), which facilitates a series of studies [F2] on the technical and economical feasibility of building a NSSB in the New Waterway. The positive results of these studies [F4] were diffused among different levels of government [F3], resulting in allocation of some additional resources [F6] and subsequent guided [F4] studies [F2], which again resulted in the diffusion of positive expectations [F4, F3] and subsequent guidance of search [F4]. Hence, a virtuous cycle is completed. The sequence of the functions F2, F3, F4 and F6 in combination with the previously described positive feedback loop resembles what Suurs (2009) calls a Science and Technology Push motor.

Secondly, while this motor is running, the competing TIS of dyke reinforcement is already implementing its technology resulting in extensive setbacks. Accordingly, it suffers, due to learning by doing [F2], from numerous negative expectations [F4], leading to an increasing loss of legitimacy [F7] from the demand-side. This way, continuous setbacks that cause such negative recurring interaction indicate the presence of a vicious feedback cycle or 'motor of system degeneration'. Therefore, actors start supporting the PBIS for a NSSB [+F7] at the cost of the TIS of dyke reinforcement [-F7]. In conclusion, due to the Science and Technology Push motor of the PBIS and the degenerating TIS, the initial bottleneck of support from advocacy coalitions is overcome.

However, due to a lack of 'learning by doing' [F2] that could only be attained by physically applying the technology of NSSB in a societal context [F1], expectations on the technical feasibility of such a barrier remained too low for a project to commence (Nederend and Koopmans, 2010; Toussaint, 2010). It should be stressed that the lack of entrepreneurial activities (that is idiosyncratic to the Dutch water construction sector) that normally follows the first cycles of the Science and Technology Push motor (Suurs, 2009), hampered this motor's progression into the Entrepreneurial motor. Accordingly, it was a comparable project, the construction of the 'Oosterschelde kering', that led to the necessary boost in the knowledge developed [F2] and positive expectations [F4] on NSSB technology.

Consequently, an important project-enactor emerged from the PBIS' knowledge infrastructure that initiated a final study [F2], which resulted in the necessary positive expectations [F4] for him to convince the minister of the Ministry of Public Transport, Public Works and Water Management [F7] to commence a project for the exploration and possible realization of an NSSB in the New Waterway. Schreuders was appointed by the minister to facilitate this project, see figure 5.3.

In conclusion, the development of the PBIS is caused by the demand for water safety [F5], the main driver during this episode. However, due to bottlenecks formed by support from advocacy coalitions [F7] and learning by doing, the PBIS was not able to develop swiftly. The work of the Science and Technology Push motor and the degenerating motor of the competing TIS overcome the first bottleneck. The implementation of the NSSB technology in the 'Oosterschelde kering' overcomes the second bottleneck, due to its technical relatedness with the PBIS. Consequently, the PBIS is able to progress to its subsequent episode.

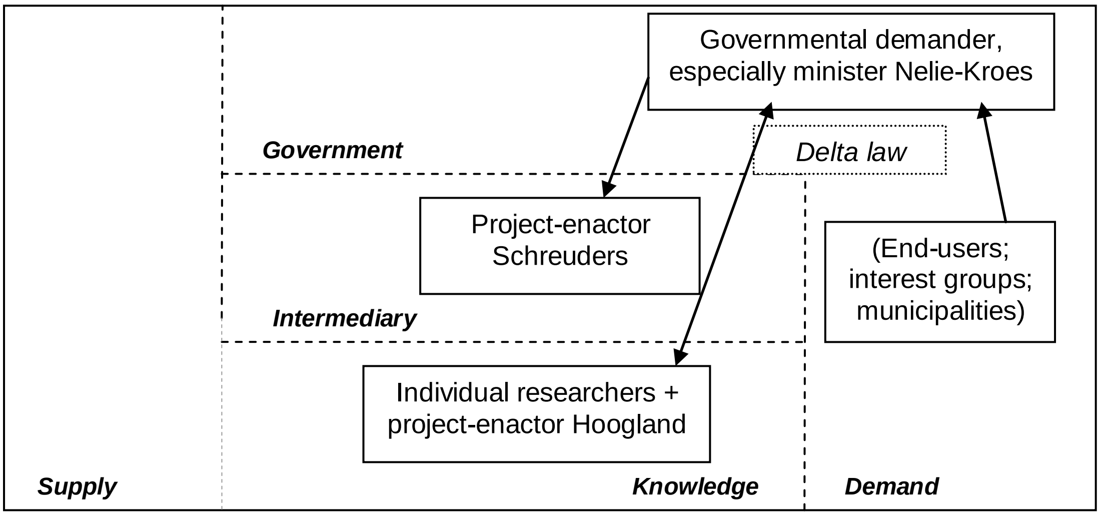


Figure 5.3, System configuration of the PBIS for a NSSB in terms of most important institutions (italic) and actors (normal) during the emerging demand episode

5.2.2 Analysis tender contest episode

To acquire sufficient support during the project's initiation stage for the regime-breaking project approach of the tender contest that applies the Design-Construct-Maintain contract, as well as to create a knowledge infrastructure for the PBIS, project-enactor Schreuders lobbied extensively towards government. Firstly, he acquired strong support [F7] of the minister of Ministry of Public Transport, Public Works and Water Management, who assigned other project-enactors to his cause. Subsequently, through personally aimed lobby activities, as well as a group meeting with other stakeholders, Schreuders managed to alleviate the barrier posed by the opposition and created support for the new tender type. In addition, it enabled him to create a knowledge infrastructure comprised of experts from various governmental 'Services', like the Construction Service that had the task of validating knowledge, forming framework conditions to guide the search in the PBIS and to develop a reference technological solution, see figure 5.4. Schreuders himself instated and chaired the CSW commission that adopted the role of intermediary organization, since it facilitates the knowledge diffusion between each of the other system components. Moreover, this commission is responsible for the selection of the best technological solution to the project's demand and facilitation of the project. The governmental demander's role is mainly fulfilled by the Governmental Works Department, as it is responsible for safeguarding the Dutch water safety. We find that because end-users lack the necessary technical knowledge, they are allowed no voice in this decision-making process, indicating they have no role of significance on the demand side. In conclusion, through extensive lobbying a network is set up, aimed at supervising the search and identification of a technological solution to provide in the PBIS' underlying demand, see figure 5.4.

Subsequently, the CSW forms a substantial market [F5] by putting out to tender a Design-Construct-Maintain contract with the expected worth of approximately 700 euros, to trigger market parties to join the PBIS. These market parties can be perceived as *project-selectors*, since they can decide in which infra projects to participate. Based on the positive expectations [F4] generated by the formulation of this market, i.e. the money promised to the project by government, 33 organizations enter the PBIS [F1]. These market parties start lobbying [F7] among other private organizations to organize themselves in a network called a consortium that has the goal to generate- and diffuse knowledge to develop a technological solution for the PBIS' underlying demand; therefore, these consortia form the supply side of the PBIS. After a round of prequalification, one consortium is excluded and five remain.

At the end of the project's initiation stage and with the inclusion of the supply side, the PBIS' network is complete in terms of system components and ready to search for, select and develop technological solutions. This network formation, with the goal to develop the PBIS as a whole, indicates the presence of a System Building motor to innovation (Suurs, 2009).

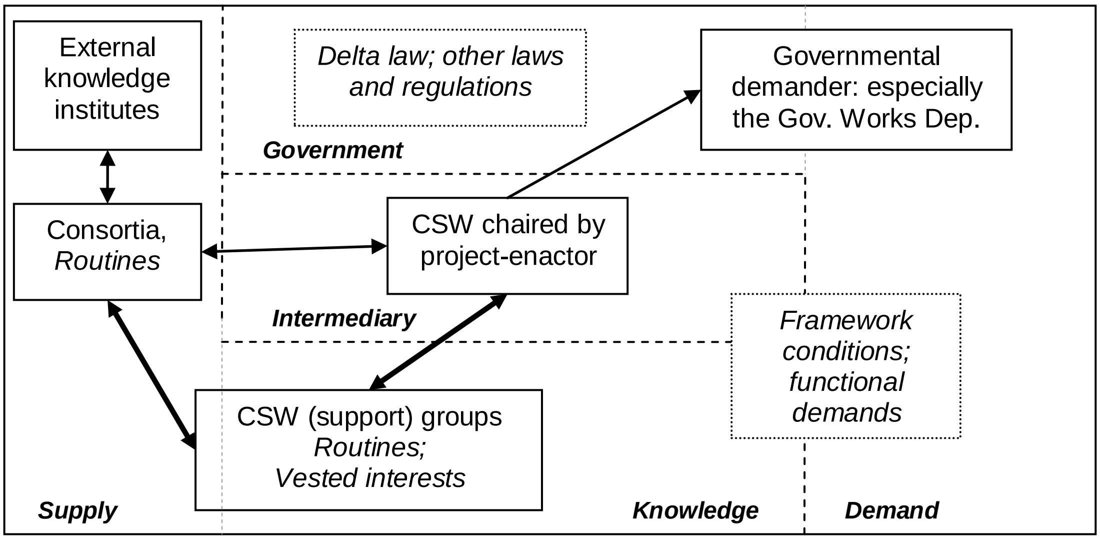


Figure 5.4, System configuration of the PBIS for a NSSB in terms of most important institutions (italic) and actors (normal) during the tender contest episode

As the project's tender contest stage commences – which in this case combine the conventional project stages of planning and design, both the consortia and CSW groups initiate their studies regarding the development of a technological solution [F2]. They first explore opportunities for technological solutions and select the ones they perceive as the best. Hence, at this stage, the consortia are to some extent *technology-selectors* until they select and start developing a technological solution and become fundamentally dependent on its success, in which case they become *technology-enactors* (Suurs, 2009).

During this episode, the consortia develop their proposals according to the following recurring sequence of events. The consortia allocate resources [F6] to fund and perform studies [F2] and initiate conferences [F3] that result in expectations [F4]. Accordingly, if these expectations comply with the guidance of search [F4] enforced by the CSW structure, subsequent studies [F2] and conferences [F3] follow. Moreover, some of the necessary competences that are not possessed by the consortium are acquired by involving external organizations [F7] and paying them for their services [F6], thereby reinforcing the PBIS' supply side structure (they create, but do not validate knowledge), see figure 5.4. Through these feedback cycles, the consortia develop technological solutions that each requires further development once selected for a subsequent round of competition. We find that the consortia that attributed the best resources [F6], i.e. the most experienced, numerous and devoted personnel, developed the best technological solutions.

Because of the initial broad guidance of the search [F4] and because the interaction between the CSW groups and the consortia is retained to the validation of knowledge (and not its mutual exchange) [F3], the consortia's creative capacity is fully exploited, allowing them to develop very divergent technological solutions. However, to allow the promising solutions to be optimally explored, the winning solution is not appointed until the third selection phase. Therefore, subsequent increasingly narrow guidance of the search was required to enable the *technology-selector* CSW to narrow the initial six technological solutions and their respective consortia down to the best one [F4,-F1], as depicted in figure 5.2. Consequently, we perceive this guidance of the search and knowledge diffusion as drivers as they enabled the pursuit of various solutions and accordingly, provided the basis for a more thorough selection by the CSW that prevents early lock-in on a sub-optimal solution.

We find that at the start of this episode, the System Building motor has replaced the Science and Technology Push motor of the previous episode. The presence of this motor is supported by the fact that institutions are aligned to enable the system to develop as a whole, e.g. uniform framework conditions are defined to align supply with demand [F4] and market entry is supported through subsidy schemes [F5]. Moreover, what Suurs (2009) describes as the most important goal of the System Building motor, forming and reinforcing a strong market to adopt the developed technology, was achieved when during the tender contest in 1988 the national government officially committed to building a NSSB [F5]. However, what we perceive as the most important goal of this motor with the focus on PBIS, is the generation of a technological solution to satisfy the demand that underlies the PBIS. Hence, the goal is opposite to that of a System Building motor, when focussing on a TIS. Finally, all system functions are fulfilled during this episode, which is another characteristic of this motor.

5.2.3 Analysis up-scaling episode

During this episode, the concept design is elaborated into a construction scheme. At the start of this episode, we find that a powerful governmental actor who possesses no technical knowledge, has too strong an influence on the direction of search [bottleneck F4], and that this hampers system growth due to lock-in on a sub-optimal configuration of the technological solution, leading to an increase in costs and a delay in time. This powerful guidance of search draws directly from the network aspect of the PBIS' System Building motor, because the network that is characteristic to this motor is arranged in such a fashion that it provides extensive power to the individual that controls the network; it is this individual that guided the search into an unfavourable configuration.

However, this imbalance of power is partly restored with the signing of the contract between government and the BMK for the construction of a NSSB [F5]. The government's technology-selector role is now less prominent, as it has become dependent on one technological solution and can no longer choose among others (without breaking contract and generating extensive costs). However, the technology-enactor role of the consortia remains, as does the project-enactor role of the government, but since they share the same purpose now, to develop the technological solution that has been selected, their roles coincide. In conclusion, as technological alternatives diminish, the project-enactor and technology-enactor roles start to coincide.

During this episode, the CSW groups are replaced by another Construction Service group that should guide the search [F4] and validate the knowledge created by the BMK, called the test group, see figure 5.5. However, no fruitful cooperation between the BMK and the test group was established, due to the inability to align interests and create support [bottleneck F7]. Although the lack of mutual knowledge sharing [F3] served in the previous episode to prevent premature convergence of technological solutions, at this stage the lack of mutual knowledge diffusion between the BMK and the test group can be seen as a bottleneck to system development. Figure 5.5 also shows the presence of the Rotterdam municipality as end-user, since preparatory activities need to be tuned in with them. Moreover, the figure shows that although the network structure of the previous episode is forfeited, governmental actors again set up a new but less complicated network structure to facilitate the development of the market party's technological solution.

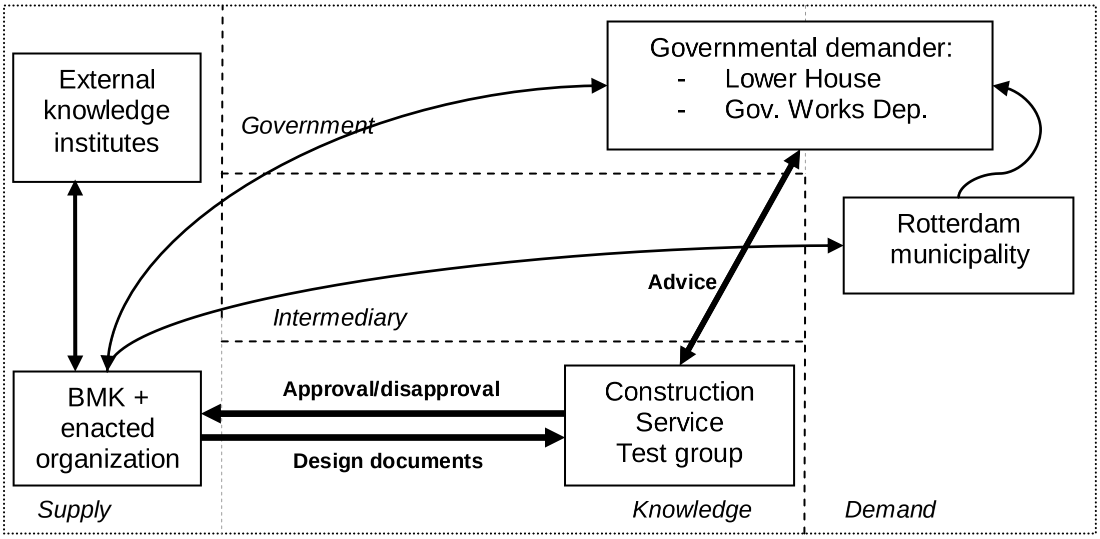


Figure 5.5, Important actors with dominant communication links in terms of system configuration in the contract episode (Interactions that are more frequent are depicted by a thicker line)

Despite the early lock-in on a sub-optimal configuration of the technological solution and lack of cooperation between the construction service and the BMK, especially the BMK contributes to PBIS development, driven by market formation [F5]. Mobilization of resources [F6] allows the BMK to perform research [F2] by elaborating the design according to the specified functional demands [F4]. In some cases, these studies resulted in negative findings [-F4], causing additional investments [F6] in subsequent studies [F2] that focussed on new solutions [F4]. Studies were performed until the BMK believed it complied with the standards set by the government [F4]. However, the test group rejected their first designs [F3, -F4] and asked for further elaboration without guiding the BMK's search [bottleneck F4]. Accordingly, the BMK allocates more resources [F6] and initiates more studies, until they develop a more detailed design that is accepted by the test group. At the same time, the Governmental Works Department lobbies for legal permits [F7] required for the construction of the NSSB. Hence, all system components (but the intermediary structure) contribute to the development of the PBIS as a whole.

In conclusion, all functions but entrepreneurial activities [F1] are fulfilled in this episode and the system develops as a whole – in which still external organizations become involved, which implies that the System Building motor is still driving PBIS development. However, this motor is slowed down by the bottlenecks creation of legitimacy, knowledge diffusion and guidance of the search. Despite these setbacks, the driver market formation stimulates the BMK to continue development.

5.2.4 Analysis construction episode

During this episode, construction of the NSSB commences in parallel with the further elaboration of the construction scheme, both still triggered by market formation [F5]. The converging role of governmental agents and consortia as project- and technology-enactors respectively remains, although their underlying incentive, i.e. cost minimization and profit maximization causes some stress on the system. Accordingly, the function creation of legitimacy is an important driver at this stage, because after continuous lobbying [F7] for more resources [F6] that should prevent the BMK from going bankrupt and a new cooperative arrangement with the test group [F3], the BMK attained this through a contract revision [F5]. From this contract revision on, the bottleneck of knowledge diffusion [F3] turned into a driver for system development, as extensive cooperation between the test group and the BMK followed, resulting in enhanced technological development. In spite of the contract revision, nothing changes in terms of system configuration, the only the relation between the test group and the BMK.

The BMK increasingly attributes resources [F6], as the construction of the barrier demands the most financial- and human resources. On the one hand, they invest in knowledge creation and -diffusion [F2, F3] and increasingly involve external organizations and experts in the process of elaborating the construction scheme. On the other hand, they invest in the construction of the barrier and increasingly coordinate their actions with the end-user, the Rotterdam municipality, as to not hamper their shipping activities. Moreover, at a certain stage, tests with the actual barrier become feasible, which lead to learning by doing [F2] that guide the search [F4] and cause enactors to initiate subsequent studies [F2] and organize conferences [F3] to improve the technology's performance. Moreover, legal regulations and material prices render some solutions obsolete, so that new investments [F6] must be made to initiate carefully guided [F4] studies [F2] that lead to new solutions.

In conclusion, the function creation of legitimacy [F7] formed an important driver during this construction episode, as it alleviated the bottlenecks of resources mobilization (i.e. excessive costs), guidance of the search and knowledge diffusion and even turned the latter into a driver to innovation. Moreover, the alleviation of these bottlenecks strengthens the System Building motor that continues to run, as now all system functions are fulfilled by the network of actors that support the development of the PBIS. Finally, market formation is still a driver to innovation.

5.2.5 Summary of the PBIS development

The case of the Maeslantkering has provided us with insights on the emergence and development of PBIS for the realization of a NSSB in the New Waterway. We find that a Science and Technology Push motor, as well as the degeneration of the competing incumbent TIS of dyke reinforcement strengthened an emerging demand for the PBIS. Through these mechanisms, the initial bottleneck formed by a lack of legitimacy was overcome. Moreover, we conclude that a comparable NSSB project has generated a lot of knowledge and positive expectations, alleviating the existing bottleneck of learning by doing. These processes resulted in the initiation of a project with the goal to study and potentially realize the construction of a NSSB in the New Waterway.

We find that the project's tender contest resulted in the initiation of a well performing System Building motor, as a network was set up that involves all system components and attempts to develop the PBIS as a whole by fulfilling all seven system functions. Project-enactors lobby the public organizations to support this network and involve consortia (project-selectors) by forming a market. Accordingly, consortia search for (technology-selectors) and subsequently develop technological solutions (technology-enactors). The lack of cooperation between consortia and CSW groups and a broad guidance of search during this period drives innovation by allowing the consortia to develop diverging solutions, providing a basis for a more thorough selection by the CSW. To enable the optimal exploration of promising technological solutions, the CSW requires three rounds of selection to point out the winning solution, using increasingly narrow guidance of the search. This selection mechanism is an important driver to innovation, but the main driver during this episode is market formation.

The up-scaling episode points out that a too strong guidance of search by technology-selectors with insufficient knowledge can lead to lock in on a sub-optimal configuration of the chosen technological solution. The most important driver to innovation throughout the up-scaling episode is market formation, which drives the remaining consortium to develop its technological solution even during setbacks. Furthermore, although the lack of mutual knowledge sharing served in the previous episode to prevent premature convergence of designs, the inability to cooperate forms a bottleneck of knowledge diffusion and guidance of the search in the up-scaling episode. These bottlenecks are caused by a lack of legitimacy. Consequently, the System Building motor continues running, but less smoothly.

Through extensive lobbying towards the government, the BMK manages to lift these bottlenecks of knowledge diffusion and guidance of the search during the construction episode. Moreover, it also prevents a bottleneck of resources mobilization from occurring.

Accordingly, creation of legitimacy and knowledge diffusion turn into drivers to innovation, by speeding up the development process due to the combination of the competences of the Construction Service and the BMK consortium. Moreover, market formation remains a driver, as it stimulates the BMK to keep the development of their solution going, despite of setbacks in legal issues.

With respect to the system functions, we integrate all data points relevant to the PBIS for a NSSB in the New Waterway, into figure 5.6 below, in order to provide an indication of the system's development, according to its successive episodes. Because the data incorporated were not specific enough to show the precise month of fulfilment, we have incorporated all data per episode. Moreover, we have used the annual amount fulfilment of system functions, to control for the differences in time span between the episodes, e.g. episode one lasts 34 years and episode two only two years.

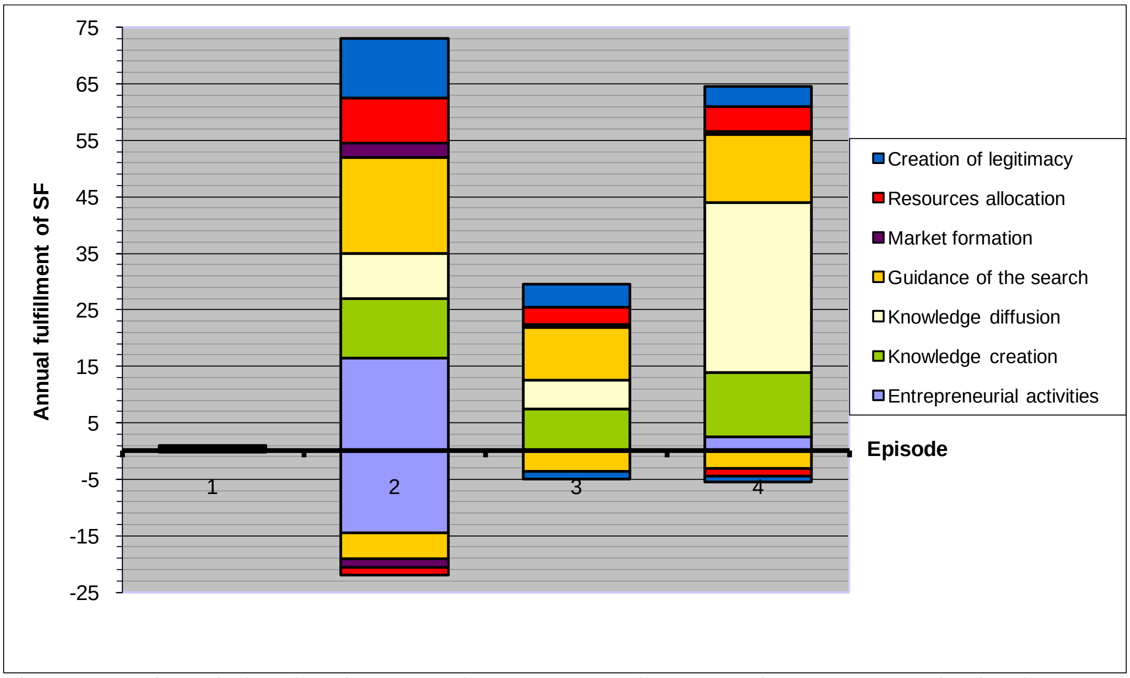


Figure 5.6, The relative development of System Functions over the sequence of episodes

The figure clearly underlines the extensive system growth as soon as the project starts during the tender episode (hence the steep growth during episode two). The figure shows that this increase can be attributed mainly to the entry of new organizations [F1], a consequence of market formation, and guidance of search, formed by the technology-selectors (governmental groups) and the expectations of the consortia. The data show that guidance of the search remains one of the most prominent functions over time, and that also negative expectations are continuously generated throughout the PBIS, but that they are infrequent compared to the positive expectations/guidance of the search. Entrepreneurial activities (market entry exclusively) on the other hand are reduced at the end of episode two, as the number of entrants declines over the various phases of selection (see negative F1).

The figure shows that during the project, the PBIS develops steadily in terms of knowledge creation. Moreover, the data clearly illustrate the change in cooperation between the consortia and Construction Service in the fourth episode (construction), represented by the steep increase in knowledge diffusion between episode three and four. Moreover, the lack of legitimacy that underlies this lacking cooperation is clearly depicted in the negative creation of legitimacy during episode three and four.

The fact that market formation was the most important driver to PBIS development over all episodes cannot not be traced in figure 5.6, due to lack of qualitative figures. Contrarily, the function even has a relatively high amount of negative fulfilment, this is caused by the sub-optimal market conditions of the project: no export possibilities; bad Intellectual Property

Rights arrangements; little financial compensation for market parties' endeavours. The negative resources allocation also indicate that financial resources were not abundant during the tender and underline that the same problem is prevented during the construction episode through lobby activities.

Finally, the figure gives a somewhat distorted view with respect to the function resources allocation, since our qualitative study indicates that resources mobilization should be the highest in episode four, but instead this qualitative representation of the data implies that this would be episode two. This is caused by the lack of a qualitative label on these data points; therefore, we rely primarily on our qualitative analysis.

5.3 Case specific conclusions: the Maeslantkering case

In this section, we will first discuss the changes of applying the innovation systems' structural components, system functions approach and motors of innovation concept to the delineation of a PBIS by validating and or falsifying our hypotheses. Subsequently, we will conclude whether this application is justified. The actual answer to our research question is provided in section eight, after comparing the two case studies in our case comparison section.

5.3.1 Conclusions regarding the structural and system components

We will first reflect on the changes the structural components went through as the PBIS developed and relate these changes to our first hypothesis, which states that *"If we apply the structural components of the innovation systems perspective to the new system delineation of a PBIS, than we expect changes in the enactor/selector notion, in the technology component and in the content of the system configuration"*. An overview of the structural components of the developing PBIS of the Maeslantkering is depicted in table 5.1 below.

As the table shows, we conclude that the roles of project-enactor and -selector and technology-enactor and –selector have changed significantly over time. We find that governmental agents remain project-enactors over the entire length of the project, and that consortia remain technology-enactor once they choose to join the tender contest and choose what technological solution to pursue. However, we find that both the project-selector and technology-selector roles are temporary and limited to the tender contest episode. Within this tender episode, we find that governmental agents are both project-enactors and technology-selectors at the same time, but that consortia are project-selectors, technology-selectors and technology-enactors in succession. In conclusion, the enactor/selector notion has changed significantly when applied to the PBIS, but its application is justified as we have clearly described the consequences of this change.

We conclude that, in compliance with our theoretical deductions, there is indeed an institutional tendency towards search heuristics during the tender contest episode, but that there are no further changes when applied to the context of a PBIS. Moreover, as expected, the network component also showed no significant changes. Also in line with our expectations is the change brought about by applying the technology component to the PBIS delineation, which encompasses the inclusion of multiple (six) technological solutions instead of a focus on one.

With respect to the configuration of the structural components, the figures 5.3, 5.4 and 5.5 in our analysis section clearly show that as expected, the government has a very powerful role in the PBIS and occupies all system components but the supply side. However, every system component is occupied during the tender contest and only the intermediary structure is neglected during the subsequent episodes of the PBIS, implying that this configuration is indeed insightful when applied to a PBIS delineation.

In conclusion, we may verify our first hypothesis and conclude that application of the innovation system perspective' structural components and system configuration is justified to the new delineation of a PBIS and provides valuable, but static insights on the development of such a system.

		Episode 1, emerging demand	Episode 2, tender contest	Episode 3, up-scaling	Episode 4, contruction
Actor	Gov.	project-enactor	Project-enactor and technology-selector	Project-enactor	Project-enactor *Coincides with*
	Consortia	No role	Project-selector → techn-selector → technology enactor	*Coincides with* Technology-enactor	Technology-enactor
Institution		Lock-in on dyke reinforcement	Search & select radically new techn; strong competition	One techn. focus despite setback; no trust; vested interest	One focus; Mutual trust
Network		None	Broad network; diverging goals	Narrow network; weak links; coinciding goal	Narrow network; strong links; coinciding goal
Technology		Developed techn. dyke reinforce.	6 radical new, undeveloped techn.	1 radical new, developing techn.	1 radical new, developed techn.

Table 5.1, Changes in terms of system components over time in the Maeslantkering case

5.3.2 Conclusions regarding the drivers and bottlenecks to innovation

We now reflect on the changes in system functions brought about by the application of the System Functions approach of Hekkert et al. (2007) to the new system delineation of a PBIS. Therefore, we test our second hypothesis: *"If we apply the System Functions approach to the new system delineation of a PBIS, than we expect the functions entrepreneurial activities to be insignificant in terms of pilot projects; knowledge diffusion, guidance of the search and market formation to be crucially important to PBIS success; knowledge creation, resources mobilization and creation of legitimacy to be important".* An overview of the drivers and bottlenecks, which give an indication of the importance of the system functions that emerged during the Maeslantkering case is provided in table 5.2; their respective project stages are included to enhance comparability with the case of the differently structured Afsluitdijk renewal..

	Episode 1, emerging demand	Episode 2, tender contest	Episode 3, up-scaling	Episode 4, construction
Project stage	Pre-project	Initiative, planning and design stage	Design stage	Construction stage
Driver	F5	F3; F4; F5; F7	F5	F3; F5; F7
Barrier	F7; F2		F3; F4; F7	(F6)
Motor	STP motor	System Building motor	System Building motor	System Building motor

Table 5.2, Drivers, bottlenecks and motors to innovation of the Maeslantkering case

Based on this table and our analysis, we conclude that the crucially important functions are market formation, knowledge diffusion, creation of legitimacy and guidance of the search, because each of these functions have formed either a bottleneck or driver to the successfulness of the project more than once. Accordingly, there should be interventions on these functions in order to support the successfulness of PBIS' underlying innovation processes. Moreover, the indicator pilot projects of the system function entrepreneurial activity's are indeed insignificant in the context of a PBIS, as they are only administered a few times at its final stage. Finally, the functions knowledge creation and resources allocation are not crucially-, but also important to the successfulness of the PBIS, as these functions were only of temporary influence.

These findings do not verify our hypothesis, as we did not expect the function creation of legitimacy to be this important over the remainder of the project. However, our application of the System Function approach remains justified and proves to be insightful in monitoring the development of the PBIS and in identifying the functions that are crucially important to the success of this system.

5.3.3 Conclusions regarding the motors of innovation

In reflection on what motors of innovation (Suurs, 2009) to expect when applying this concept to PBIS, we test our third hypothesis: *"If we apply the motors of innovation concept to the new system delineation of a PBIS, than we expect the Science and Technology Push and the System Building motors to be present, but not the Entrepreneurial and the Market motors"*. Based on the overview of the motors of innovation and the episodes in which they were present is given in table 5.2, we confirm this hypothesis. Indeed, since entrepreneurial activities do not take the shape of pilot projects in the PBIS and because no mass markets can be monitored (not even over the subsequent thirteen years that follow the case) the Entrepreneurial and the Market motors do not occur in a PBIS. Despite the absence of these motors it is still justified to apply this concept by Suurs (2009) to the PBIS delineation, as it has proven insightful to understand the dynamics of developing PBIS.

5.3.4 General conclusions

The above indicates that the application of the innovation system perspective and its approaches to the PBIS delineation has successfully provided insights on the dynamics by which a PBIS develops. However, in order to determine which functions are characteristically important to the successful development of a PBIS and how to manage these functions, we will first study the multifunctional Afsluitdijk renewal case, so that the findings for each case can be compared and our research question can be answered.

6. The case of the Afsluitdijk renewal

This section maintains the same structure as the previous one. We start this section with a description of the various designs that compete during the tender episode, which is given in Appendix III. Moreover, this section provides the results to our third hypothesis regarding the supportive effects between technologies in the technological solution for a project. Subsequently, Appendix IV gives an elaborated presentation of the results, i.e. the events that constitute this case. Subsection 6.1 analyses these results in terms of the system functions and figures 6.1, 6.2 and 6.4 depict the changes of the most important structural components in terms of system configuration. In subsection 6.2, we provide some preliminary, case-specific conclusions.

6.1 Description of the Afsluitdijk case

The PBIS we focus on in this case regards the realization of a multifunctional renewal of the Afsluitdijk, i.e. an Afsluitdijk that provides various demands beside water safety, like nature, sustainable energy (and storage) and landscaping. To structure our data, we divide the development of this PBIS into two episodes, emerging demand and tender contest, two project stages and two phases, depicted in figure 6.1. The PBIS emerges with the upcoming demand for a multifunctional Afsluitdijk renewal and continues to develop in the planning stage's tender contest episode at the time of writing. Although subsequent stages will follow, i.e. a tender contest for the implementation rights, construction and possibly maintenance, development is at the time of writing still in and therefore limited to, the planning stage (Santhagens and Oosting, 2010). A more elaborate version of the results that follow are provided in Appendix IV.

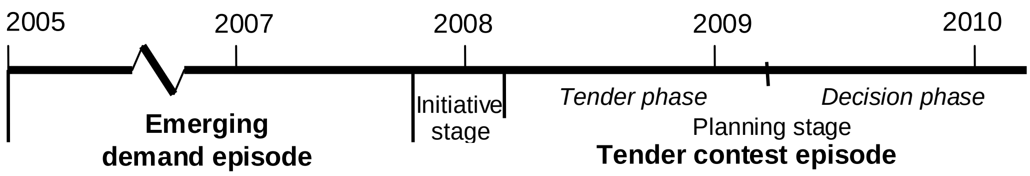


Figure 6.1, Timeline of the episodes of the Afsluitdijk renewal case

The emerging demand episode (2005-2007) describes the cascade of events that represents the emergence of the PBIS for a multifunctional Afsluitdijk renewal, and which enabled the subsequent tender contest to commence.

The episode starts in 2005 when the water safety tests [+F2], dictated by the Law on the Dyke, indicate that the Afsluitdijk no longer provides sufficient water safety (Noord-Holland, 2006). Accordingly, this demand for water safety [+F5] can be satisfied by simply renewing the dam so that it provides water safety, or by renewing the Afsluitdijk in a multifunctional way so that it provides additional demands like nature and renewable energy as well; the latter represents the PBIS we focus on (SMO, 2008). Studies [+F2] and workshops [+F3] were commissioned by the Governmental Works Department and administered by private organizations to explore the possibilities for a multifunctional Afsluitdijk that generated generally positive expectations [+F4] (Witteveen en Bos, 2006; SMO & Provincie Fryslând, 2007). Moreover, a recent political trend towards multifunctionality in infra projects that is also made explicit in official documents, e.g. the Water Vision (DG Water, 2007), supports the PBIS [+F7]. Because of the previous developments, the government decided to 'promise' – instead of officially reserve – a budget of 750 million euros for the multifunctional Afsluitdijk renewal [+F5] (Waterforum online, 2006). Accordingly, the DG Water commissions a project – the OIVA – to explore the possibilities for a multifunctional Afsluitdijk, so that realization might follow in the future (SMO, 2008). This project is executed by the Governmental Works Department in collaboration with provinces and municipalities.

The second episode (2007-2010), tender contest, is comprised of two project stages, see figure 6.1. The first stage is project initiation, during which an organizational structure is set up, demand is specified and ideas are generated. The project's subsequent planning stage is comprised of two phases 1) the tender phase, during which eight technological solutions are developed and narrowed down to four over one round of selection and 2) the decision phase, during which the remaining four solutions need to be elaborated, verified and eventually narrowed down to one.

The project's initiative stage starts with extensive lobby activities [+F7] by project-enactor Leendertse towards six types of key-individuals, to gain support at various levels of government and from the InnovationPlatform (Leendertse, 2010). This support was used to create the project's organizational structure comprised of various groups and an advice commission (see Appendix IV for elaboration) that could steer the development of the technological solutions in the right way and select the best one [+F4] (Leenderste, 2010; Driebergen; 2010; Santhagens and Oosting, 2010). During the project's official start in November 2007, the institution SMO was issued to rubricate all ideas regarding the multifunctional Afsluitdijk renewal through five workshops [+F3] (SMO, 2008). At the same time, the organizational structure formulates the framework conditions and basic demand, as well as the ambitions regarding the additional demands to be fulfilled in the multifunctional project [+F4] (RWS et al., 2009).

The project's planning stage starts with the prequalification for the tender contest. Due to the tender contest's advertisement and the information day [+F3, F4] in March 2008, 34 market parties joined [+F1], despite the unfavourable Intellectual Property Rights agreement (Lenferkink et al., 2009). They were triggered by either the ability to acquire exposure in such a prominent infra project or by the opportunity to proliferate at an early stage and increase the chance of winning the expected 750 million euros contract that would be put out to tender after this initial tender contest [+F5] (Lenferink et al., 2009; Vermey, 2010). In consequence of these different incentives, the market parties formed eight consortia [+F7] (See figure 6.2), which were either design-based or construction-based, i.e. including beside consultancies and landscape artists also construction firms (RWS et al., 2009). For joining the tender contest's first round of competition, these consortia acquired 35.000 euros [-F5] (RWS IJSSELMEERGEBIED, 2008), which was perceived as low compared to the consortia's cost of on average 100.000 euros [+F6] (Vermey, 2010; Boddeke, 2010; Fieselier, 2010). After attributing a project group of approximately eleven individuals [+F6], the consortia developed technological solutions, building mostly on existing knowledge shared among the consortia members [+F3]. To support the development of these solutions, dialogue sessions were held [+F3] in which the consortia could ask the government questions regarding their preferences [+F4] and regarding the solutions [+F3]. After a four-month period, eight technological solutions were developed that each combines multiple and supporting technologies, see Appendix III for a technical elaboration (RWS et al.,2008). Aided by the advice of several external institutes and slightly influenced by the lobby activities of some consortia [+F7] (Leendertse, 2010; Vermey, 2010), the organizational structure narrowed these solutions down to four by in June 2008, see figure 6.2 [+F4].

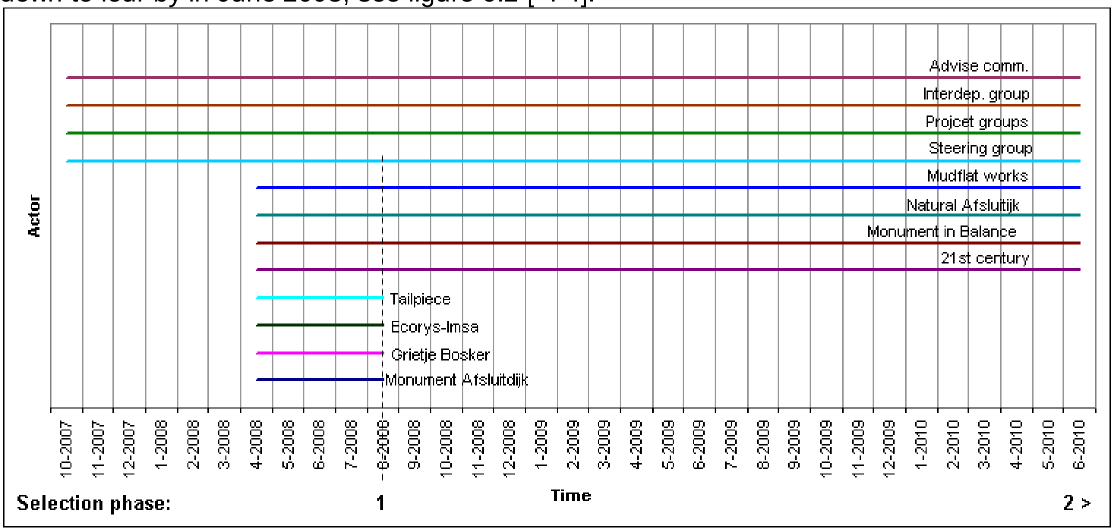


Figure 6.2, Tender contest related actors and their period of activity in the PBIS for the multifunctional Afsluitdijk renewal

In the tender contest's second, three-month lasting round of competition, the consortia again allocate resources of approximately 120.000 euros [+F6] to fund studies [+F2] and conferences [+F3] for the development of their technological solutions. Moreover, this development is guided by specific guidelines provided by the organizational structure [+F4] (RWS et al., 2009). The consortia acquire 70.000 euros for participating during this round [+F5]. Moreover, indifferences regarding Intellectual Property Rights cause the consortia to lobby successfully for better marketing conditions [+F5] (Leendertse, 2010). Beside the four solutions by the consortia, the organizational structure's experts also create two basic solutions [+F2], to get an idea of the costs of the barrier without providing in additional needs. On December 1 2008 all consortia's technological solutions are handed in and presented to the organizational structure [+F3] for selection. However, knowledge is too limited [-F2] for a quick decision, therefore a lengthy decision period commences.

During the planning stage's decision phase, the six technological solutions are further developed, for which the government has attributed 4,3 million euros [+F6] (Vrugt and van de Beek, 2009). The technological solutions are researched [+F2] by various expert organizations and institutes on areas like renewable energy and water safety, e.g. ECN and TU Delft (RWS et al., 2009). Furthermore, expert sessions [+F3] are held and the consortia are asked specific questions [+F4], on which they have to perform studies to elaborate and support their technological solutions [+F2] (Vrugt and Van de Beek, 2009). However, in this case, the consortia are paid full price for their efforts (Santhagens and Oosting, 2010; Van der Meulen, 2010). All findings are integrated and complemented in an environmental effects report and a cost-benefit analysis on which the project-organization will base its decision regarding the winning technological solution (Projectteam, 2010). This decision is estimated to be due in 2011 (Santhagens and Oosting, 2010; RWS.nl, 2010a).

The interviewees stress that the tender contest for the multifunctional Afsluitdijk renewal was a success as the technological solutions developed were so innovative that they would not have been developed by the government or by any single organization (Santhagens and Oosting, 2010; Van der Meulen, 2010).

6.2 Analysis of the Afsluitdijk renewal case

In this subsection, we analyse the build up of the PBIS for the multifunctional Afsluitdijk renewal, according to its structural components and system configurations depicted in the figures 6.3, 6.4 and 6.5 that each provide an overview of the changing structural components over the various episodes and phases of the PBIS. We intend to emphasize the consequences of applying the structural component technology to the PBIS of this case, because due to its multifunctionality, technological interactions are expected. Furthermore, the system functions and motors of innovation discussed in each of the following episodes explain these changes in structural components and system configuration. Finally, subsection 6.2.3 provides a summary of the PBIS' development.

6.2.1 Analysis of the emerging demand episode

As the results show, governmental institutions in the form of increasingly stringent safety measures, combined with the first complete series of safety tests in 2005 according to the Law on the Dyke, triggered the demand for an improved Afsluitdijk [F5]. This demand can be satisfied in the conventional way, by heightening and reinforcing the Afsluitdijk, or by installing a multifunctional Afsluitdijk, i.e. a dam that provides also in demands beside water safety, like renewable energy, nature, landscaping and transportation. In this case study, we focus on the PBIS that has the goal to realize a multifunctional Afsluitdijk renewal.

Because of the emerging demand, government attributed funds for a study on technical and economical aspects of a multifunctional dam by Witteveen and Bos [F2] and for conferences devoted to public opinion and ideas [F3] by SMO. Hence, these organizations comprise the supply side and intermediary infrastructure respectively, see figure 6.3. These studies and conferences resulted in positive expectations [F4] and support [F7] for the possibilities for a multifunctional dam. Moreover, an increasingly formal governmental institution supports [F7] the multifunctional approach in complex infra projects like the renewal of the Afsluitdijk.

However, the results also indicate that attempts have been made before the initiation of the Research Integral Improvement Afsluitdijk (OIVA) project to make the Afsluitdijk multifunctional. In this case, the government debated about the installation of wind turbines on the Afsluitdijk. Various explorative studies indicated that this would cause severe damage on the ecological habitat of the Afsluitdijk area [-F4]. As a result, environmental groups lobbied [F7] towards the government to abandon their plans, which were also in conflict with various institutions (see figure 6.3 in italic font). Consequently, not only the plans were abandoned, but also new institutions were instated that inhibited the installation of windmills on the Afsluitdijk. This illustration shows that when attempts are made for multifunctionality, the effect on other demands should be taken into account, or a series of negative feedback will occur that degenerates the system. Other ideas for a multifunctional dam are the plans by Lievense and Ockels, but since these plans were developed before the safety test of the Afsluitdijk in 2005, their plans did not appeal to a demand.

Because of the positive expectations and the governmental institution that guides the search towards a multifunctional Afsluitdijk renewal, DG water commissions a project with the goal to study the possibilities for a multifunctional Afsluitdijk renewal so that realization might follow.

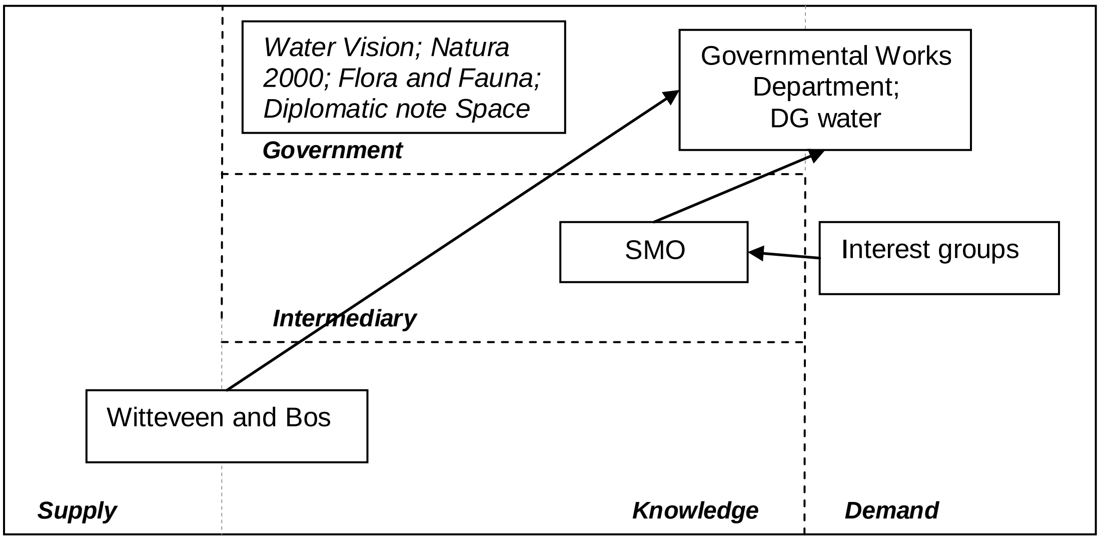


Figure 6.3, System configuration of the PBIS for a multifunctional Afsluitdijk renewal in terms of most important institutions (italic) and actors (normal) during the emerging demand episode

During this relatively short episode, the functions that are mainly fulfilled are knowledge creation and –diffusion, guidance of the search, allocation of resources and creation of legitimacy. These functions were driven by market formation that provides an opportunity to develop the PBIS. We find that the allocation of resources led to both knowledge creation and –diffusion, which subsequently resulted in positive expectations [F4]. Moreover, an informal governmental institution stimulated the government's expectations [F4] regarding a multifunctional approach to renew the Afsluitdijk. The fulfilment and sequence of these functions indicates the presence of a Science and Technology Push motor (Suurs, 2009), although no extensive feedback loops can be identified. We find that no significant bottlenecks have hampered the emergence of a project for a multifunctional Afsluitdijk. However, the example of wind turbines illustrates that institutional bottlenecks will arise, once technological solutions have negative effects on some additional demands like nature. The main drivers at this stage are market formation and the positive expectations as this combination eventually resulted in the decision to initiate the OIVA project.

6.2.2 Analysis of the explorative Research Integral Improvement Afsluitdijk (OIVA) episode

Because of the differences between the stages and phases that constitute the tender contest episode, we structure our analysis according to these time intervals.

6.2.2.1 Analysis project's initiation stage OIVA

The project-enactor Leendertse lobbies strategically towards key governmental agents at different levels of governance – national, regional and municipal – to acquire support [F7] for his innovative tender contest in the project's planning stage. Secondly, he lobbies towards the Innovation Platform and the 'Quicker and Better' project board of the Governmental Works Department – two programmes that require an icon project for the new project approaches they stand for – and makes the OIVA their icon project to increase the project's support and publicity [F7]. Together, these actors and Leenderste instate the OIVA's organizational structure and chair the various groups and commissions that it comprises. Beside governmental agents, the organizational structure is also strengthened by the inclusion of technical, societal and administrative experts that come not only from governmental agencies, but also from universities and knowledge institutes. As figure 6.4 shows, the organizational structure comprises the system components governmental demand side, intermediary structure and knowledge infrastructure. The actors on the governmental demand side are responsible for satisfying the project's underlying demand. The intermediary structure is tasked with the facilitation knowledge diffusion, to ensure that the demand for and supply of technological solutions are aligned. The knowledge infrastructure has the goal to verify these solutions. Moreover, the entire organizational structure is tasked with the selection of the most satisfying solution. It is apparent that the government has a prominent role in this system configuration.

In preparation of the project, SMO is commissioned to initiate workshops with experts and interest groups (see figure 6.4) that generate a lot of existing and new knowledge [F2] that is to be used by the consortia [F3]. Moreover, these workshops provide support for the study among interest groups and in the media [F7]. In addition, framework conditions and additional demands are formulated broadly by the organizational structure to not hamper the innovative capacity of the consortia and allow them to develop diverging technological solutions [F4]. Furthermore, beside creating room for innovation, Leendertse attempts to provide the consortia with incentive to innovate by lobbying towards the government to make them officially reserve – instead of informally promising – the 750 million euros that are promised for the multifunctional renewal of the Afsluitdijk [F5]. Through this process and by emphasizing the profits of exposure of developing such an icon project as the Afsluitdijk [F5] on the information day, he triggers 34 market parties to join the tender contest [F1].

At this stage, the PBIS is establishing an increasingly large network to support its development, implying that a System Building motor is starting to replace the existing Science and Technology Push motor. Moreover, this change is supported by the driver market formation that stimulates project-enactors to lobby for the formation of such a network. Hence, both the functions market formation and creation of legitimacy are important drivers to innovation at this stage.

6.2.2.2 Analysis project's planning stage OIVA, tender phase

Eighteen of the 34 market parties are new to infra projects in the DWCS and only sixteen are incumbents. The high amount of organizations new to the DWCS is caused by the multifunctionality of the project's underlying demand, which triggers the inclusion of other sectors like the energy sector and thereby causes the entry of firms active in these sectors as well. The 34 market parties create eight networks called consortia. Half of these consortia compete in the tender contest for reasons of exposure; they consist of landscaping artists and consultancies. The other half of these consortia compete to increase their chances of realizing the 750 million euros project by getting involved in the project in an early stage and by relying on intellectual property rights. Therefore, they also comprise banks, energy firms and construction firms. With the inclusion of the market parties, the project is complete in terms of system components even at the OIVA's planning stage, see figure 6.4, hinting towards the presence of a System Building motor.

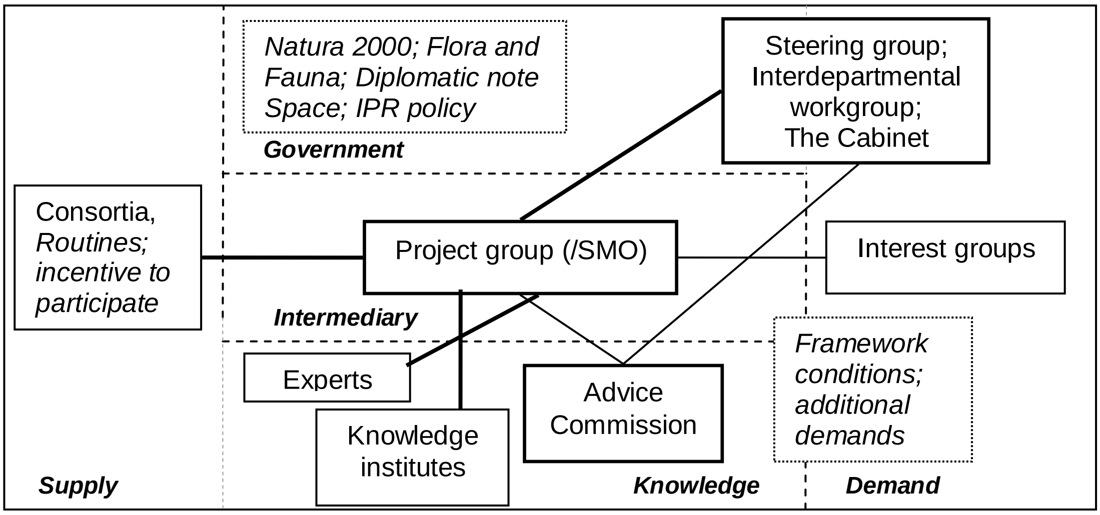


Figure 6.4, System configuration and interactions during the OIVA planning stage's tender contest

During the tender contest, the consortia develop their technological solution by attributing funds and allocating personnel [F6]; we find that the consortia that attribute a dedicated team are more successful in coordinating the development of a technological solution [F6]. Moreover, we find that the cost of developing a technological solution during this first round of competition is much higher (approximately three times) than the funds provided by the government to participate in the tender contest round [-F5]. Accordingly, these resources are used to develop the technological solutions through conferences [F3], in which the experts and project group of the OIVA's organizational structure as well as interest groups might also be present. Besides knowledge diffusion, which was especially important since most technological solutions rely on the new combination of existing knowledge, knowledge was also created [F2] to support the technological solutions. This knowledge creation and -diffusion was heavily influenced by the guidance of the search effectuated by the organizational structure, in the form of framework conditions, ambitions and through conferences. However, the guidance of the search was not sufficiently strong during this first round of competition and therefore served as a bottleneck to innovation, as the technological solution by the Tailpiece consortium is completely misaligned with the project's underlying demand.

Moreover, at the end of the first competition round, the consortia were enabled to convince the government of their solution [F7]. However, by exploiting the personal political network of Ockels, whom is seated in the Natural Afsluitdijk consortium, this consortium was the most successful. Hence, political lobbying is an important function for the consortia to ensure a competitive advantage. However, from the viewpoint of a PBIS, such lobby activities can form a bottleneck to system development, as its negative effect on well performing guidance of the search (selection) might lead to lock-in on a suboptimal technological solution. In this case, the effect was minimal, as the OIVA's organizational structure decided to explore a risky but promising technological solution was preferred over the political distress of abandoning that solution; therefore, this function is not perceived as a bottleneck to innovation. Contrarily, the involvement of numerous knowledge institutes as well as interest groups in this project puts pressure [F7] on the organizational structure to select the more innovative technological solutions. Accordingly, the decision to take risks for the sake of profitable innovation are shared by a much broader audience that all reviewed the technological solutions, making innovation more legitimate. Therefore, the function creation of legitimacy, of which the interviewees stress that it normally functions as a bottleneck to innovation since project managers have no incentive to select innovative, but risky solutions, can be seen as a driver that determines the success of innovation in infra projects in the DWSC.

After four months, the consortia had developed eight technological solutions. These technological solutions comprise various technologies. Appendix III, which gives a thorough description of these designs, shows exactly how these solution's underlying technologies support each other's performances. We find that technologies might support each other by reducing each other's cost price (energy lake – second dam) or stimulating each other's performance (Mudflats-Blue energy). Moreover, between technological solutions, technologies might compete, which is illustrated by the fact that different types of dam reinforcement can be maintained: no reinforcement (e.g. mudlfats), reduced reinforcement with spill over (e.g. 21st century; Natural Afsluitdijk), complete reinforcement with no or few spill over (e.g. 2100-Robust) or an innovative storm-shield (e.g. Monument Afsluitdijk). Therefore, the technologies that are involved in a PBIS might both compete and support each other.

The eight technological solutions are first published and verified through studies [F2] by the organizational structure and external knowledge institutes that support the PBIS' knowledge infrastructure. Subsequently, they are narrowed down to four solutions [F4, -F1] by the organizational structure, based on the advice provided also by external institutes. A selection of four diverging technological solutions is made so that each type of solution might be further explored; such selection mechanism is seen as a driver to innovation during the tender contest.

During the second round of competition, the four remaining consortia acquire twice as many funds for participating [F5], while the resources [F6] attributed by the consortia during this round increase only slightly. During this stage, most of the consortia's resources are attributed to knowledge creation, as the guidance of the search by the organizational structure requires specific and state-of-the-art knowledge to support the technological solutions. Moreover, knowledge diffusion [F3] and the guidance of search [F4] that follow from the meetings between the project organization and the consortia become increasingly numerous, important and technology-based. During this second round of competition, the organizational structure also initiates two studies on the creation of the reference designs [F2].

Although Intellectual Property Rights policy has over the years been improved in the DWCS, it still hampers some market parties to enter the PBIS and provides a point of debate for two of the four remaining consortia during this round of competition. These consortia successfully lobby the government [F7] for better rights, resulting in an agreement for financial compensation when government uses these rights. Although this institutional bottleneck hampers market formation [F5], this function is still an important driver to system development, because it nevertheless resulted in the entry of many market parties and keeps stimulating these parties to further develop their technological solutions.

Beside technological interaction within solutions, we also find that these solutions extensively diverge and intend to explain why. The technological solutions were published after the first round of competition; therefore, the technological solutions tend to converge to some extent as the consortia might mimic each other's best ideas. Nevertheless, the technological solutions of the second part of the tender contest diverge extensively for various reasons. Firstly, during the selection of the four proceeding consortia, the OIVA's organizational structure attempts to retain optimal divergence of the technological solutions, so that each type of solution can be developed before making a final decision. Secondly, the incentive to participate in the tender contest and the composition of the consortia differs (i.e. design- or construction based), causing the direction of the technological solutions' development to be guided by vested interests, e.g. dredging firms use a lot of sand in their technological solutions for profit. Thirdly, the consortia have different points of departure, for example, Natural Afsluitdijk focuses on the energy lake developed by Ockels, whereas Afsluitdijk 21st century focuses on Alkyon's plan Waterlilly, two completely different technological solutions. Fourthly, the consortia interpret institutions (both formal- and informal-) differently, e.g. Mudflats Works believes that they can build on the Waddenzee side, while the other consortia do not. Finally, the architectural principles of the consortia's landscaping artists also differ. This technological divergence of the solutions can be perceived as a success-factor to the innovation process, since it allows for a more thorough decision making process [F4] that prevents early lock-in on a suboptimal solution.

During this tender phase, we find that the System Building motor has replaced the Science and Technology Push motor. This new motor draws from the aligned interests of the PBIS' actors. Firstly, the consortia want to make money by increasing their chances of realization of the project or indirectly, through the benefits of exposure. Secondly, the OIVA's organizational structure wants to provide in demand according to the rules and regulation issued by the government. Thirdly, experts and knowledge organizations want to be involved because they get paid for their services and fourthly, interest groups want to be involved and voice their opinion to make sure their needs are satisfied. Hence, all actors benefit from the broad network that constitutes the PBIS and which allows the system to develop as a whole through all types of system functions. This motor is strengthened by the diffusion of knowledge between the different actors in the PBIS. Moreover, market formation is an important driver that stimulates the consortia to develop their technological solutions. Additionally, creation of legitimacy is an important driver, as it prevents the government from avoiding risky but promising innovative solutions. Finally, the selection process that allows these solutions to be explored is successful, but the overall guidance of the search is not, as some technological solutions are misaligned with the government's demands. Therefore, this function is a bottleneck to innovation.

6.2.2.3 Analysis project's planning stage OIVA, decision phase
During the tender contest episode's decision phase, the network of the preceding tender contest is mostly retained, although external knowledge institutes and organizations become involved in the PBIS and strengthen the knowledge infrastructure, see figure 6.5. Moreover, the organizational structure is somewhat regrouped, but as figure 6.5 indicates, their roles remain the same in terms of the system components.

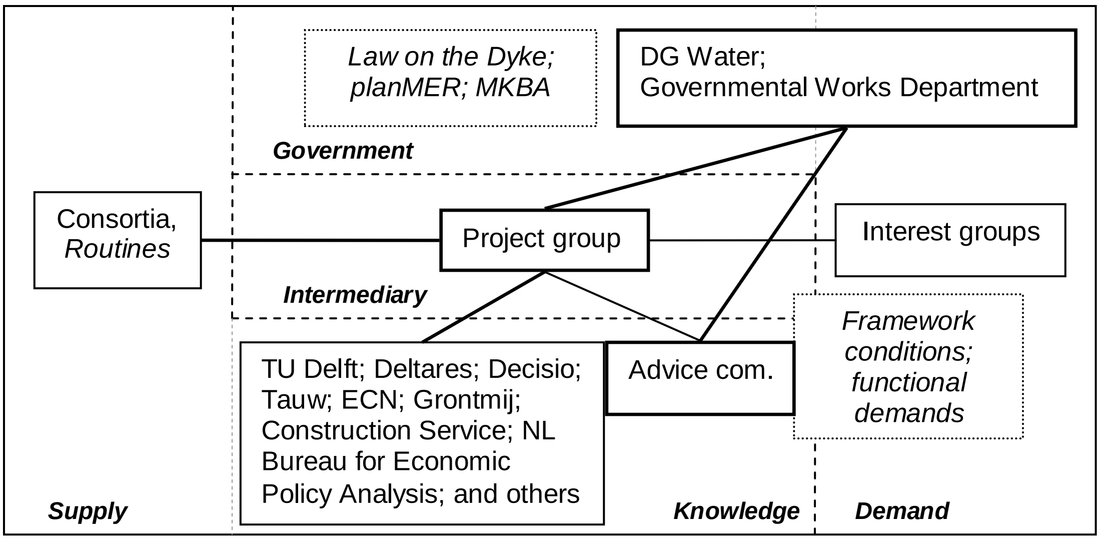


Figure 6.5, System configuration and interactions during the OIVA planning stage's decision phase

We find that the goal of the PBIS in the decision phase is to create knowledge [F2] in order to validate and elaborate the technological solutions of the consortia. Therefore, knowledge creation is an important driver to system growth during this phase and this function is supported by the vast representation of knowledge institutes in the PBIS. In order to perform these studies, knowledge that underlies the technological solutions has to be diffused [F3]. Moreover, these extensive studies by the consortia and the knowledge infrastructure are funded by a significant amount of resources allocated by the government [F6]. Hence, knowledge diffusion and resources allocation are also drivers to innovation, as they allow the system to develop as a whole and thereby strengthen the System Building motor. Accordingly, market formation has lost its function as a driver to innovation, as the consortia's main incentive to develop technological solutions is now because this process is governmentally funded. Moreover, the creation of knowledge is strongly guided [F4] by the project's organizational structure. However, this guidance of the search is perceived as a bottleneck to innovation, as it does not allow the technological solutions to be optimized before selection of the final solution takes place.

6.2.2.4 General findings tender contest episode

Firstly, we find that during this tender contest episode the enactor/selector roles change. Firstly, the governmental project-enactors also become technology-selectors during the tender contest and stay so during the decision phase. Secondly, the consortia are first project-selector when they decide whether to join a tender contest or not, then a technology-selector when they explore the various technological opportunities and when they select one and become fundamentally dependent on its success, they become technology-enactors. The consortia stay technology enactors throughout the tender contest and the decision phase.

Secondly, we find that during the initiation phase, a System Building motor starts replacing the incumbent Science and Technology Push motor, as a network was set up with the intention of developing the PBIS as a whole. This System Building motor was reinforced during the tender contest phase with the inclusion of the consortia that, triggered by the driver market formation, supported the PBIS' supply side by developing technological solutions. Moreover, the System Building motor draws from the aligned interests of the PBIS' actors that allows for the diffusion of knowledge through the system; enables the system to develop in sync. At this phase, all system functions are being fulfilled. Moreover, during the decision phase, more actors supplemented the PBIS' knowledge infrastructure to facilitate system development with the verification and diffusion of knowledge [F2, F3]. Hence, the System Building motor becomes increasingly stronger during this episode. Moreover, in the decision phase this motor in supported by resources allocation. Accordingly, resources allocation takes over the role of market formation in supporting the System Building motor, namely as a driver for the consortia to develop their technological solutions.

Thirdly, creation of legitimacy is an important driver, as it prevents the government from avoiding risky but promising innovative solutions. Moreover, this positively influences the selection process, allowing promising opportunities for innovations to be explorated. However, the overall guidance of the search is the only bottleneck to innovation, as some technological solutions are misaligned with the government's demands.

Fourthly, we find that new knowledge creation [F2] becomes an increasingly more important source of innovation than the new recombination of existing knowledge [F3]. Accordingly, knowledge creation becomes the primary system goal during the decision phase and is an important driver to innovation.

6.2.3 Summary of the PBIS development

This case has provided us with insights on how the PBIS of a multifunctional renewal of the Afsluitdijk emerged because a series of safety test on the Afsluitdijk indicates its incapacity to provide water safety. We find that a Science and Technology Push motor as well as an increasingly formal governmental institution guides this demand for water safety towards a demand for a multifunctional dam. Consequently, a demand for a multifunctional Afsluitdijk emerged, although previous attempts to make the Afsluitdijk multifunctional failed due to regulations and lobby activities by protest groups. This demand resulted in the initiation of the OIVA project (Research Integral Improvement Afsluitdijk) with the goal to study and potentially realize a multifunctional Afsluitdijk.

Subsequently, project-enactors lobby towards different levels of government and institutes to attain support for the project and develop its organizational structure. Subsequently, they plan and prepare a tender contest in the project's planning stage with the goal to explore the possibilities for a multifunctional Afsluitdijk. They trigger market parties (project-selectors) through market formation to join the tender contest and support the PBIS by developing technological solutions. Accordingly, a network of actors that comprises all system components is set up and whose interests are aligned to allow the PBIS to develop as a whole. This force drives the System Building motor that replaces the incumbent Science and Technology Push motor and that fulfils all system functions. The consortia search for (technology-selectors) and subsequently develop technological solutions (technology-enactors). Knowledge diffusion is an important driver that allows the consortia to develop their technological solutions in cooperation with other actors in the PBIS. However, despite the fact that guidance of the search by the project's organizational structure allows for a well structured selection process that enables the optimal exploration of risky but promising solutions, this functions forms a bottleneck to innovation as it is fulfilled too weakly, resulting in solutions that are misaligned with the demand.

In the planning stage's decision phase that follows the tender contest, we find that the network remains intact, although the system is somewhat restructured. Therefore, the System Building motor to innovation continues running during this phase. The most important drivers during this phase are firstly, knowledge creation [F2], since numerous studies are done to elaborate and verify the technological solutions. Secondly, allocation of resources [F6], since the government's resources are what keeps the system together. The bottleneck during this stage is again guidance of the search [F4], as it does not allow the technological solutions to be optimized before selection of the final solution takes place. So far, the output of the PBIS is perceived as a success.

With respect to the system functions, we integrate all data points relevant to the PBIS of the multifunctional Afsluitdijk renewal into figure 6.6 below. By using monthly data points we attempt to give an indication of the system's development from system emergence to system formation and development.

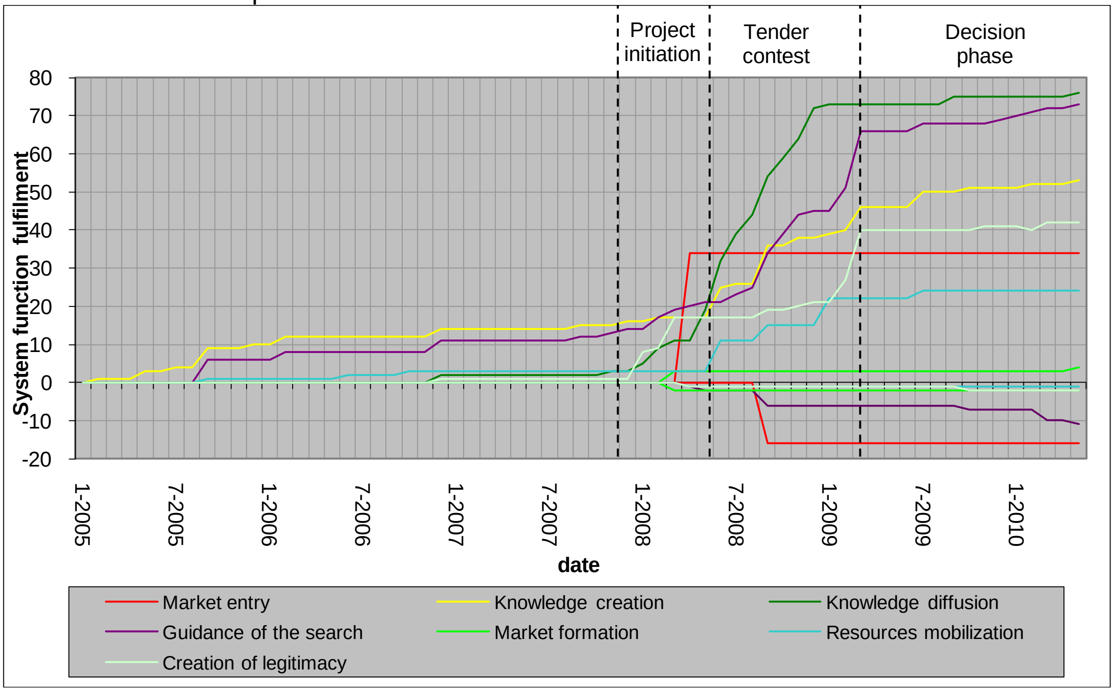


Figure 6.6, The development of System Functions over time

The figure underlines the importance of the Science and Technology push motor, that runs before project initiation. As the data show, this motor runs primarily on the functions knowledge creation, guidance of the search and resources mobilization.

As the OIVA project is initiated in November 2007, the emergence of the System Building motor is characterised by a strong increase in all system functions. Accordingly, the functions knowledge diffusion, market entry[2] and creation of legitimacy become increasingly important. The number of market entrants increased due to the driver market formation, declines as consortia are excluded from the OIVA.

Although the qualitative analysis indicates that market formation is a driver to innovation, this cannot easily be distracted from figure 6.6 (although the almost simultaneous increase in market entry provides a hint) that depicts this function as infrequent. Moreover, the qualitative

[2] We have labeled this function market entry as this is the only indicator of the system function entrepreneurial activities that is fulfilled.

analysis indicates that guidance of the search is a bottleneck, but this cannot be derived from figure 6.6, as this function is fulfilled numerously. Hence, the development of a PBIS according to system functions cannot only be studied with a quantitative analysis, but requires a qualitative explanation as well. The same goes for the function allocation of resources that drives innovation in the decision phase, but which cannot be deduced from figure 6.6 because a quantitative data point does not distinct between the amounts of resources mobilized.

6.3 Case specific conclusions: the Afsluitdijk renewal case

In this section, we will first discuss the changes brought about by the application of the innovation systems' structural components, system functions approach and motors of innovation to the delineation of a PBIS by validating or falsifying our previously formulated hypotheses. Subsequently, we will conclude whether this application is justified. The actual answer to our research question is provided in section eight, after comparing the findings of the two case studies in our case comparison section.

6.3.1 Conclusions regarding the structural and system components

We will first reflect on the changes the structural components went through as the PBIS developed and relate these changes to our first hypothesis, which states that *"If we apply the structural components of the innovation systems perspective to the new system delineation of a PBIS, than we expect changes in the enactor/selector notion, in the technology component and in the content of the system configuration"*. An overview of the structural components of the developing PBIS of the Maeslantkering is depicted in table 6.1 below.

As the table shows, we find that roles of project-enactor and -selector and technology-enactor and –selector have changed in the same way as they did in the Maeslantkering case. Hence, we find again and in accordance with our theoretical deduction that within the tender episode of the planning stage, governmental agents are again both project-enactors and technology-selectors at the same time, but that consortia are successive project-selectors, technology-selectors and technology-enactors. Hence, the latter we did not expect to find, but the consortia clearly indicated that they first explore and develop different technological solutions before they choose one and become its respective technology-enactor. In conclusion, the enactor/selector notion has changed significantly and in the same way in both cases when applied to the PBIS delineation, but its application is justified as we have clearly described the consequences of this change.

We also conclude that, in compliance with our theoretical deductions, there is indeed an institutional tendency towards search heuristics during the tender contest episode, but that there are no further changes when applied to the context of a PBIS. Moreover, the network component also shows no significant changes.

However, the technology component does significantly change when applied to a PBIS, especially that of a multifunctional project. We have found that within the technological solutions for a multifunctional PBIS, various technologies are integrated that support each other's performance. Moreover, these competing technological solutions might use comparable technologies, so that a complex interaction of technology takes place in the PBIS. To retain as many of the underlying technologies as possible, the project's organizational structure selected the most diverging solutions to progress to the second round of competition and the decision phase; hence this component's interrelatedness with guidance of the search. In conclusion, the technological component has changed significantly when applied to a PBIS, but again its application is justified since we have clearly described and brought insights in the consequences that underlie this change.

With respect to the configuration of the structural components, the figures 6.3, 6.4 and 6.5 in our analysis section show that as expected, the government has a powerful role in the PBIS and occupies all system components but the supply side. However, in comparison to the Maeslantkering case, the government has a much weaker position on the knowledge infrastructure of the PBIS for the multifunctional Afsluitdijk renewal. Hence, no unexpected changed are identified that regard the PBIS' system configuration.

In conclusion, we may verify our first hypothesis and conclude that application of the innovation systems perspective's structural components and system configuration is justified to the new delineation of a PBIS and provides valuable, but static insights on the development of such a system.

		Episode 1, emerging demand	Episode 2, tender contest
Project stage		Pre-project	Initiative and planning stage
Actor	Gov.	project-enactor	Project-enactor and technology-selector
	Market	Some individual technology-enactors	Project-selector → organized technology-selector → organized technology enactor
Institution		Gov. informal institution towards multifunctional projects; formal regulations like law on the Dyke	Search & select new techn. solutions; predominated selection by organizational structure; guidance by formal regulations
Network		None	Broad network; converging interests
Technology		A few ideas for technological solutions; wind turbines	Eight competing technological solutions that integrate various complementing technologies

Table 6.1, Changes in terms of system components over time in the renewal of the Afsluitdijk case

6.3.2 Conclusions regarding the drivers and bottlenecks to innovation

We now reflect on the changes in system functions brought about by the application of the System Functions approach of Hekkert et al. (2007) to the new system delineation of a PBIS. Therefore, we test our second hypothesis: *"If we apply the System Functions approach to the new system delineation of a PBIS, than we expect the functions entrepreneurial activities to be insignificant in terms of pilot projects; knowledge diffusion, guidance of the search and market formation to be crucially important to PBIS success; knowledge creation, resources mobilization and creation of legitimacy to be important".* An overview of the drivers and bottlenecks, which give an indication of the importance of the system functions that emerged during the Multifunctional Afsluitdijk renewal is provided in table 6.2; their respective project stages are included to enhance comparability with the case of the differently structured Afsluitdijk renewal.

	Episode 1, emerging demand	Episode 2, tender contest		
Project stage	Pre-project	Initiative stage	Planning stage, tender phase	Planning stage, decision phase
Driver	F4, F5	F7, F5	F3; F5; F7	F2; F3; F6; F7
Barrier			F4	F4
Motor	STP motor	System Building motor	System Building motor	System Building motor

Table 6.2, Drivers, bottlenecks and motors to innovation of the renewal of the Afsluitdijk case

Based on this table and accordingly, our analysis, we conclude that the functions that are crucially important to the PBIS for the multifunctional Afsluitdijk renewal are market formation, guidance of the search, creation of legitimacy and knowledge diffusion. Hence, these functions should be managed especially when to support the innovative success of infra projects in the DWCS. Moreover, the important functions are knowledge creation and resources mobilization, especially in the decision phase. Finally, we find no pilot projects in this case, making entrepreneurial activities an insignificant system function with respect to this indicator. These conclusions comply precisely with the expectations formulated in our hypothesis and despite the absence of pilot projects, allow us to justify our application of the System Functions approach by Hekkert et al. (2007) to the PBIS delineation.

6.3.3 Conclusions regarding the motors of innovation

In reflection on what motors of innovation (Suurs, 2009) to expect when applying this concept to PBIS, we test our third hypothesis: *"If we apply the motors of innovation concept to the new system delineation of a PBIS, than we expect the Science and Technology Push and the*

System Building motors to be present, but not the Entrepreneurial and the Market motors". The overview of the motors of innovation that were present during the development of the PBIS is given in table 6.2 and allows us to confirm this third hypothesis. In compliance with our expectations, the absence of the Entrepreneurial motor is explained by a lack of entrepreneurial activities' pilot projects. In addition, the lack of a mass market explains the absence of a Market motor in this PBIS. In conclusion, although two motors of innovation are not found in the development of a PBIS, application of the motors of innovation system concept by Suurs (2009) is still justified and has proven insightful.

6.3.4 General conclusions

The above indicates that the application of the innovation system perspective and its approaches to the PBIS delineation has successfully provided insights on the dynamics by which a PBIS develops. However, in order to determine which functions are characteristically important to the successful development of a PBIS and how to manage these functions, we compare the findings for each case in the subsequent case comparison section so that our research question can be answered.

7. Cross case comparison

Because system functions are the properties that need to be intervened for policy makers to boost innovative performance (Bergek et al., 2008), in this section, we attempt to deduce which properties are crucially important to the successful innovation process that underlies PBIS. Hence, on these properties should be intervened in the DWCS to boost the innovative performance of infra projects. To identify these properties, we compare the drivers, bottlenecks and motors to innovation that are identified as of crucial importance to the success of the PBIS in both cases. Recommendations on how to manage these properties are provided in our conclusions section.

An overview of the drivers, bottlenecks and motors of innovation of each case is provided in the case specific conclusions sections, in tables 5.2 and 6.2. We compare the drivers and bottlenecks of these tables to identify which functions are generally of crucial importance to the development of a PBIS. The same is done for the motors to innovation, resulting in table 7.1 below. Below, we elaborate on how this table is developed.

	Episode 1, emerging demand	Episode 2, tender contest	Episode 3, up-scaling	Episode 4, construction
Project stage	Pre-project	Initiative, planning and design stage	Design stage	Construction stage
Crucially important functions	F5	F3; F4; F5; F7	F3; F5	F3; F5
Motor	Science&Technology Push motor	System Building motor	System Building motor	System Building motor

Table 7.1, The drivers, bottlenecks and motors to innovation that are characteristic to Project-Based Innovation Systems of complex infrastructural projects

With respect to the first episode, we find that in both cases the PBIS' underlying demand developed from an external event. In the Maeslantkering case this was the storm surge of 1953; in the Afsluitdijk renewal case this was the safety tests of 2005, showing the unsatisfying water safety performance of the Afsluitdijk. Not surprisingly, market formation – the function that should incorporate this demand, is an important and characteristic driver to the emergence of a PBIS that drives the fulfilment of other functions. The bottlenecks of creation of legitimacy and knowledge creation in the Maeslantkering case are also case specific and caused by the lack of support and 'learning by doing' for the emerging technological solution of a Navigable Storm Surge Barrier that do not necessarily hamper innovation in other PBIS. The same goes for the guidance of the search by governmental institutions in the Afsluitdijk case: such institutions are not crucially important to any PBIS, as the PBIS for the Maeslantkering emerged without this driver. Furthermore, we find that in both cases, the Science and Technology Push motor (STP) drives the emergence of a PBIS; see table 7.1. This motor provides the knowledge and expectations that are generally required to support the emergence of a PBIS and the initiation of a complex infra project in the DWCS.

With respect to the second episode, we find that all influential functions of the Maeslantkering case are also influential in the Afsluitdijk renewal case. Knowledge diffusion [F3], market formation [F5] and creation of legitimacy [F7] are important and serve as drivers in both cases. Knowledge diffusion is important since it allows for the structured development of the PBIS; without the diffusion of knowledge, the 'wheel might be invented more than once' and the various groups would not be able to complement each other. Market formation is in both cases seen as the most important function as it drives the market parties to procure their innovative capacity to support the development of the PBIS. Moreover, creation of legitimacy is an important function in the setting up of the tender contest as well as to maintain the support for the tender contest. Hence, these three functions (F3, F5 and F7) are all important and each serves as a driver to PBIS development during the tender contest episode.

However, guidance of the search is a bottleneck in the Maeslantkering case and a driver in the Afsluitdijk case. This finding implies that also guidance of the search is crucially important to the success of the PBIS, but that whether its effect will be to drive or hamper innovation is determined by the way this function is managed. Consequently, we find that in the

Maeslantkering case, this system function is managed really well and therefore it drives innovation. In addition, in the Afsluitdijk case this system function is managed in a suboptimal way and therefore hampers innovation. This may imply that the previous three characteristically important functions also only serve as drivers due to their successful management and that they will function as bottlenecks to the development of a PBIS, if not managed optimally.

Hence, we conclude that the success of a tender contest is critically depended on the functions knowledge diffusion, guidance of the search, market formation and creation of legitimacy are all functions. Consequently, it is crucial to the success of the whole PBIS, since the tender contest forms the most important episode in the PBIS development (see figures 5.6 and 6.6). Accordingly, these system functions will occupy the role of either a driver or a bottleneck, depending on the way they are managed. It is therefore important that these functions are managed correctly by the organizational structure; we give practical recommendations on how these functions can be managed in our conclusions section.

The Afsluitdijk renewal's decision phase is peculiar with respect to the build up of PBIS, since two drivers present themselves that are not found in any of the other phases or episodes of the cases. The function resources allocation seems to take over the role of market formation in driving the market parties to support the PBIS' development. Moreover, knowledge creation seems to be the primary function of the system. This incidence can be explained by on the one hand, the need for more knowledge that is required to make an important decision in the project's planning stage and on the other hand, by the lack of commitment to market formation at this stage, so that resources have to compensate to trigger market parties.

We conclude that the successful development of a PBIS during its tender contest episode, is characterized by a quick emergence of a strong System Building motor. In both cases, we find that this motor draws from a network comprised of actors and institutions and causes the fulfilment of all system functions. We will elaborate on this motor in the theoretical contribution-subsection.

With regard to the remainder of the PBIS' episodes, the Maeslantkering case shows that the functions knowledge diffusion, market formation and creation of legitimacy fulfil an important role throughout the entire project. We discuss the underlying cause of the importance of these functions to hypothesize whether this can be attributed to the nature of complex infrastructural projects in general, or to case specific occurrences, see figure 7.1.

The importance of the function market formation draws directly from the reason for the existence of the PBIS and is therefore expected to be a characteristically crucially important function to drive system development. The same goes for knowledge diffusion [F3]: as long as more than one actor is responsible for the further development of the winning technological solution, the knowledge diffusion between these actors is of crucial importance. Therefore, this function is either a bottleneck in case of hampered cooperation (during the up-scaling episode of the Maeslantkering case) or a driver in case of good cooperation (during the construction episode of the Maeslantkering case).

Creation of legitimacy [F7] is a bottleneck during the up-scaling episode because the clashing interests between the Construction Service and BMK consortium caused a lacking knowledge diffusion and guidance of the search. Moreover, creation of legitimacy is seen as a driver in the subsequent construction episode, since it allows the BMK to revise their contract, thereby alleviating the bottlenecks of guidance of the search and knowledge diffusion. However, the importance of this function is in this case caused by the opposition between two important actors and is thus specific to the Maeslantkering case. Therefore, this function is not perceived as important to PBIS in general. The same goes for the bottlenecks of guidance of the search and resources mobilization, caused by the same opposing actors and the wrong decision of the minister. In contrast to knowledge diffusion, guidance of the search no longer has the same important role as during the tender contest, namely selection of the technological solutions.

8. Conclusions and discussion

In this section we distinguish between the main conclusions, i.e. the answer to our research question, the theoretical contribution, the reflection on the method and recommendations for further research.

8.1 Research questions answered

The goal of this research is to identify the properties on which policy makers can intervene to stimulate the innovative performance of infra projects in the Dutch water construction sector. These properties are the functions and motors that are of crucial importance to the success of innovation in complex infra projects in the DWCS, that is, crucial to PBIS development. Therefore, we have researched and compared the cases of the Maeslantkering and the multifunctional Afsluitdijk renewal. As a result, we are now able to answer our research question *"What properties are crucial to the success of innovation systems of complex infra projects in the Dutch water construction sector as they develop over time and how should these properties be managed to increase the innovative capacity of this sector?".*

Because distinctive episodes can be identified in the development of a PBIS, the answer to this research question is that different functions should be managed and different motors should be supported during the successive episodes of a PBIS. Therefore the first part of our research question *"What properties are crucial to the success of innovation systems of complex infra projects in the Dutch water construction sector as they develop over time …"* can be answered by the following description of how a successful PBIS should develop over time.

During the first episode, a PBIS' underlying demand forms a market. This market formation drives PBIS development during this episode by stimulating the emergence of a Science and Technology Push motor to innovation. Through this motor's virtuous cycles, the PBIS is developed to such an extent that an infra project is commenced.

During the second episode, creation of legitimacy drives innovation by developing the PBIS' structural components, the organizational structure. Accordingly, market formation continues to drive innovation as it triggers market parties to support the PBIS. These functions incite a System Building motor to replace the weaker Science and Technology Push motor. Accordingly, knowledge diffusion and guidance of the search drive innovation by supporting the performance of this motor.

During the third and fourth episode, the System Building motor continuous to run and is supported by the functions knowledge diffusion and market formation.

In conclusion, the following functions are of crucial importance to the success of PBIS: knowledge diffusion, guidance of the search, market formation and creation of legitimacy, see also table 7.1, and should therefore be managed well – at the appropriate time – to boost the innovative performance of infra projects in the DWCS. In addition, the Science and Technology Push motor and the System Building motor should also be supported – by managing the previous system functions – to boost these projects' innovative performance.

By qualitatively analysing these crucially important system functions and motors to innovation in our cases of successfully innovative complex infra projects, we subtract the following lessons that can be used to boost the innovative performance of infra projects in the DWCS. Accordingly, these lessons form the answer to the second part of our research question *"... and how should these properties be managed to increase the innovative capacity of this sector?".*

Firstly, to ensure that a tender contest operates as a coordinated innovation system, which is required to generate innovations successfully, knowledge diffusion is pivotal. A organizational structure needs to make room for this system function, by creating a network and an environment in which actors are stimulated to share each other's work, so that these actors can complement each other and work as a system. As both our cases show, this function remains important to the successfulness of the innovation process for as long as multiple actors have to cooperate to develop the PBIS.

Knowledge diffusion is dependent of the function market formation, since on the one hand, actors will only share their knowledge if they are able to protect it well enough, for example through Intellectual Property Rights. On the other hand, actors must have an incentive to share knowledge; for a consortium this could be to increase its chances at winning a contract that is put out to tender. Note that Intellectual Property Rights arrangements and a contract are both indicators of market formation and that therefore market formation determines the extent of knowledge that is shared in the PBIS.

Because market formation also proves pivotal to the success of a tender contest as well as to the entire project, it is especially important to manage this function well. On the one hand, this can be done by improving policy regarding Intellectual Property Rights, so that market parties are enticed to create and share their knowledge in codified form, i.e. in the shape of a technological solution. These rights should encompass not only knowledge that is entirely new, but also new combinations of existing knowledge. The organizational structure of the Afsluitdijk renewal project indicates that currently, such developments are underway, as a new Intellectual Property Rights scheme is being explored.

Besides such rights, the incentive for market parties to win the tender contest should also be maintained. This can be done in two ways. One is to trigger consultancy-based consortia by providing them with opportunities for exposure. To stimulate this incentive, organizational structure should lobby extensively towards different levels of government and media to promote the infra project. Accordingly, the project will provide the winning consortium with the exposure it wants. The other way is to trigger construction-based consortia by providing them with a chance of winning a Design-Construct (-Maintain) contract for a large infra project. Accordingly, these consortia should be triggered by a level of certainty that such a contract will indeed follow, a reservation of funds by the government might suffice. With this idea, project-enactor Leendertse lobbied the government to reserve 750 million euros for the renewal of the Afsluitdijk, which proved a trigger for many construction-based consortia to compete already in the planning stage. Moreover, in the Maeslantkering case it provided the incentive for the BMK consortium throughout the entire project.

Hence, the function lobby activities can be used to supports market formation. In addition, this function is on itself also crucial to the successful development of a PBIS during the tender contest episode, and as the Maeslantkering case indicates, also during the remainder of a PBIS. Lobby activities are important to acquire sufficient support for the project and to involve actors to develop the PBIS. Both cases have indicated that various levels of government, market parties, knowledge institutes and interest groups need to be involved for a project to become legitimate and to form the PBIS' organizational structure. The cases also indicate that this support should be acquired by strategically lobbying towards key-actors within a project-enactor's personal network that are able to support the PBIS by lobbying among the necessary levels of government and institutes. If through creation of legitimacy the interests of the actors are not aligned, bottlenecks are likely to occur. The Maeslantkering case shows that in consequence of the clashing interests between the Construction Service and BMK consortium, knowledge diffusion and guidance of the search were lacking in the episodes after the tender contest. Therefore, the importance of this function is, like the previous two functions, not restricted to the tender contest episode, but affects the entire project's duration.

Finally, the organizational structure needs to manage the function guidance the search. Therefore, they need to align this guidance of search with their intentions, which is mostly an initial broad orientation on solutions that is subsequently narrowed down. Initially, often a broad range of technological solutions is demanded, therefore, a broad guidance of search is required in the form of lose framework conditions. As a result, the consortia will develop multiple diverging technological solutions. However, this approach will only work if enough room for innovation is provided, i.e. if there is room for own interpretation of demand and institutions and if there are different points of departure like specific capabilities and interests. However, guidance should not be so broad that consortia do not understand the demand, as happened in the Afsluitdijk case: the basis of the demand should be clear. Subsequently, a selection needs to be made in which quality is maintained, therefore, a subsequent development phase can be induced in which the market parties' technological solutions need to comply with increasingly narrow guidance of the search, i.e. more specific functional demands. This process continues until the best technological solution is maintained. Hence, guidance of the search is especially important during tender contests' search for and selection of technological solutions. Hence, management of this function is of less importance during the later stages of a project in which only development takes place.

In conclusion, because these important functions are so interdependent management of one function is likely to influence the others. For example, good management of creation of legitimacy, might result in better market formation that consequently affects the degree to which knowledge is shared within the system. Maybe this interdependency explains why all these three important functions all serve as drivers, while the guidance of the search that has no such direct interdependency serves as a bottleneck in one case and as driver in the other.

8.2 Theoretical contribution

By performing this research, we have contributed to the innovation systems theory in various ways. Firstly, we have applied the innovation systems theory to the Dutch Water Construction Sector (DWCS) and found that in this sector it is more interesting to research infra projects instead of the development of technologies. Secondly, we have introduced a new innovation systems delineation, the Project-Based Innovation System (PBIS), that allows scholars to research the dynamics of these infra projects.

With respect to the innovation systems perspective's structural components, this research also contributes to the actor concept based on Garud and Ahlstrom (1997) and elaborated by Suurs (2009). In compliance with the work of Suurs (2009), we acknowledge the importance of the role of system-enactors in the development of an innovation system, but find that two types of enactors should be distinguishes on the basis of their purpose. On the one hand, a technology-enactor enacts technology by ensuring its development and establishing marketing possibilities. Hence, the enactor maintains a technology-push perspective. On the other hand, a project-enactor enacts a project by formulating a demand and ensuring the involvement of other actors to provide in this demand. Hence, the enactor maintains a demand-pull perspective. Related to the work of Dosi (1982), technology-push and demand-pull enactors can be distinguished; presumably, a compromising enactor might be the most effective.

This research contributes to the System Functions approach by Hekkert et al. (2007) and Suurs' (2009) concept of motors of innovation, since we have indicated how system functions bridge the changes in the structural components of the PBIS and hence, how these systems develop. Consequently, we have shown that this approach and concept is applicable to more system delineations than the Technological Innovation System, namely also to the PBIS delineation.

However, we do find some differences with these literatures that research Technological Innovation Systems in the energy sector. Suurs (2009) describes the emergence of four successive motors of innovation, the Science and Technology Push motor, the Entrepreneurial motor, the System Building motor and finally, the Market motor. However, in our research we have identified only the Science and Technology Push motor before project initiation and the System Building motor as an infra project commences. The absence of the Entrepreneurial motor is explained by the fact that the characteristic event of this motor, experimentation, does not take place in PBIS. Moreover, due to the specificity of demand that underlies a PBIS, no mass market is formed either. Therefore, no Market motor of innovation will emerge. Hence, we conclude that the type of innovation system under research determines the occurrence of motors of innovation.

Moreover, the application of the motors of innovation concept by Suurs (2009) to the PBIS also results in some changes in the interactions that underlie the motors of innovation, especially those of the System Building motor, see figure 8.1. We give a short description of this motor and the changes that can be found in comparison to Suurs´ (2009) System Building motor identified in a TIS.

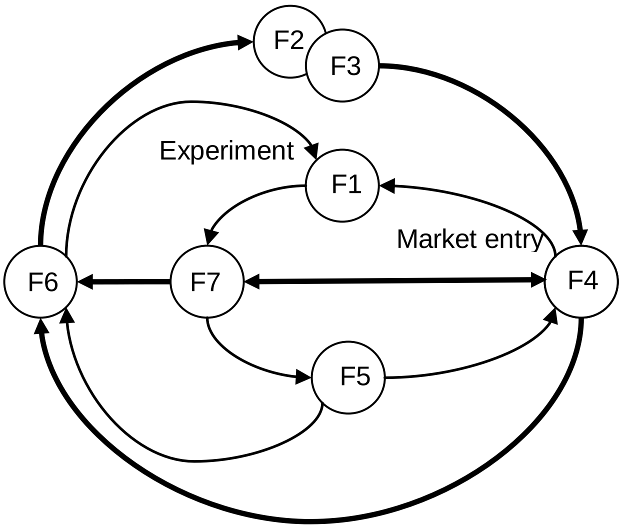


Figure 8.1, The System Building motor in Project-Based Innovation Systems

This motor emerges during the build up of a PBIS at the initiative stage of a PBIS, when extensive lobby activities [F7] of governmental project-enactors are directed towards different levels of government to acquire support for the project (and approach) they want to initiate. If successful, these lobby activities are followed by market formation [F5] and the allocation of resources [F6] (see figure 8.1). Market formation generates expectations among market parties in- and outside the DWCS. Based on these expectations [F4], they decide to enter the PBIS [F1] and lobby among other market parties to form networks, i.e. consortia [F7]. Subsequently, they allocate resources [F6] to develop and diffuse knowledge [F2, F3] to search for and develop technological solutions, guided [F4] by the organizational structure's demands. When expectations [F4] demand more knowledge [F2, F3], additional resources might be allocated [F6]. Moreover, because of expectations [F4], interest groups, decide to support [F7] the PBIS and some technological solutions rather than others.

In parallel, the organizational structure selects [F4] between the technological solutions of the consortia, causing some of them to be excluded [-F1]. This selection needs to be supported by higher levels of government as well [F7]. After selection, a new round of competition is started, during which the consortia further develop their technological solutions. Note the virtuous cycle that sets in, as consortia again triggered by market formation [F5], allocate resources [F6] to create- and develop knowledge [F2, F3] guided [F4] by the organizational structure's demands. Additionally, market parties might also lobby towards government F7] to promote their solutions [F4].

As the system develops this way, project-enactors lobby the government to reinforce market formation based on the positive expectations generated within the PBIS. In other words, they lobby towards government to make sure that the winning technological solution will indeed be implemented. Consequently, the PBIS arrives at a stage during which the technological solution needs to be constructed. At this stage, all functions are still fulfilled, and even some tests [F1] with the technological solution are attempted (at least in the case of the Maeslantkering).

In conclusion, the PBIS develops through all system functions, virtuous cycles are identified and the actors in the PBIS cooperate to work as a system: all characteristics of the System Building motor described by Suurs (2009). However, we find important differences with the System Building motor described by Suurs (2009).

Most importantly, our description of the System Building motor in a PBIS implies that this motor starts with the formation of a market, with the goal to develop technological solutions. Suurs (2009) on the other hand, describes the start of the System Building motor in a

Technological Innovation System as the development of technology with the goal to form a (mass) market. Hence, we describe the same phenomenon from opposite perspectives. In terms of Dosi (1982), we might state that the focus on PBIS resembles more to a demand-pull for innovation because we focus on an emerging demand that results in the search for, selection, development and realization of technological solutions, whereas the focus on TIS resembles more to a technology-push for innovation because the focus is on emerging technologies that results in the search for and development of a (mass) market. In conclusion, because the PBIS and TIS delineations focus on two different units, they are driven by two opposite forces, i.e. a demand-pull and technology-push respectively, and therefore the goal of the System Building motor, i.e. to create technology or a market, is also completely opposite.

We also find some minor differences between the interdependencies of the System Building motor we describe and that of Suurs (2009). Firstly, we find no mutual relation between entrepreneurial activities [F1] and knowledge diffusion [F3]. This is caused by the fact that the function entrepreneurial activities in the TIS take shape in extensive pilot projects, whereas they do not in PBIS, because it would be too expensive and inefficient for a single project's demand. Hence, entrepreneurs in PBIS focus on other system functions to develop their technological solutions. In conclusion, this difference is also caused by applying the motors of innovation concept to the PBIS delineation.

Moreover, Suurs (2009) describes how lobby activities [F7] by private technology-enactors towards the government are always the result of entrepreneurial activities [F1], i.e. new entrants or pilot projects. However, we find that lobby activities might also result from expectations. This finding might be explained by the fact that in projects there is no continuous stream of new entrants and there are not many pilot projects [F1]; therefore, lobby activities might occur from other system functions, like, as the Maeslantkering case shows, negative expectations due to a lack of knowledge diffusion and resources mobilization. Moreover, lobby activities might also result from positive expectations, for example, those of interest groups that regard a certain technological solution; these groups might lobby the organizational structure to support the selection of this solution. In conclusion, we find that expectations (indicator for the function guidance of the search), instead of entrepreneurial activities are the primary cause of lobby activities, presumable because a PBIS does.

8.3 Reflection on the method

In this section we discuss the usefulness of the method of even history analysis and the application of the operationalization scheme that we adopted from prominent innovation systems literature. Hereby we discuss the internal validity of our research, referring to the meaningfulness of the concepts used and the quality of the inferences through which we identified the causal relationships between the concepts. Moreover, we discuss the external validity that refers to the applicability of our findings in other cases and contexts.

8.3.1 Internal validity of the method

Our research has pointed out that event history analysis is a powerful tool to evaluate and compare the build up of PBIS. Moreover, as Hekkert et al. (2007) and Suurs (2009) state, this type of analysis continuously checks whether the system functions and their indicators match with the raw empirical data. Because all system functions match with our raw data, we conclude that the internal validity of our research is high. However, we do find some implications in the indicators that underlie the system functions and also find that one indicator should support the system function resources mobilization.

Because of the shorter time frame of our cases compared to the time frames used in TIS studies (Suurs, 2009; Simona, 2007), it became apparent that system functions could not always be fulfilled as extensively as intended, due to a lack of time. Consequently, the study by Lenferink et al. (2009) indicates that because market parties did not have enough time to allocate sufficient personnel, they did not participate in the tender contest of the Afsluitdijk renewal. Hence, the bottleneck to innovation is in this case is the lack of time for preparation and not the lack of personnel, since the personnel was available, only not on such a short time scale. Moreover, some of the consortia respondents indicate that a lack of time during the tender contest phases hampered the further development of their technological solution. Consequently, we conclude that by correctly managing the resource time, the innovation process might be improved. It is possible that because time was of lesser importance in the long timeframe with which a Technological Innovation System is studied, time has not been identified as an indicator to resources mobilization. Therefore, the allocation of time might be a useful additional indicator for the system function allocation of resources.

We identify an implication in the indicators for the system function entrepreneurial activities, when applying this function to PBIS. New entrants is an indicator often found in our raw data, but pilot projects are not. Moreover, on the one hand are pilot projects only identified in the very last stage of the PBIS and therefore characterise the ending of such system. New entrants on the other hand, are found numerously at the beginning of a project and characterise the beginning of a tender contest. Hence, the two indicators carry completely different meanings when applied to a PBIS. Therefore, these indicators might best be attributed to two different system functions, e.g. entrepreneurial activities becomes the function for market entry and experimenting becomes the function for pilot projects.

We also find that the indicators for market formation carry a different meaning with regard to the PBIS delineation. In the context of a PBIS, this function is only fulfilled with respect to the demand that underlies the complex infrastructural project, since the innovation system is per definition delineated to this realm. Accordingly, the emergence of other markets – let alone a mass market – like in the studies on TIS, will never be monitored within a PBIS. Moreover, it is doubtful if ever such a mass market will emerge, because since the initiation of the Maeslantkering project in 1987, still no concrete plans exist for the construction of a second such barrier.

The above two indicator-implications have significant effects on the motors of innovation concept, as they explain why the Entrepreneurial motor and the Market motor do not emergence in a PBIS. This is because the indicators that these motors rely on, that is pilot projects and the number of markets, are not identified in the raw data on PBIS.

This research's validity is not only influenced by implications that regard the indicators, but also by our data collection. In the Maeslantkering case, documentation was not extensively available; therefore we had to rely extensively on interviews. To account for the problem of bias in interviewees' perceptions and memory, the data were cross-referenced so subtract the underlying events. Moreover, to prevent a one-sided image, our interviewees include representatives of all actor groups relevant to the PBIS. Furthermore, we let these interviewees validate the database presented in this thesis' Appendices. However, inevitably, the data attained through interviews are not as time-specific as documentation is. Although this problem did not affect the causality of the system functions' relationships, the data overview was less time-specific as a result. We accounted for this problem by dividing the system function fulfilment for each episode. Hence, the database of the Afsluitdijk renewal case is more time-specific, as it relies more on documentation. Nevertheless, we were able to compare the cases in terms of drivers, bottlenecks and motors to innovation successfully and conclude that because no events go unexplained in the development of the PBIS, all important data are incorporated in our research.

A problem on data interpretation is caused by the small time frame of our cases. The time frame of the projects in our research, ranging from three years to eleven, are relatively short compared to the time frame maintained in studies on the Technological Innovation Systems in the energy sector that use time frames that range from 18 to 38 years (Suurs, 2009; Negro, 2007; Suurs et al, 2009). As a result, system functions seem to be fulfilled more intensively, hampering the identification of causal relationships between system functions. However, we divided the time frame of each case into various episodes and even phases, as other event mapping analyses do that use the System Functions approach, e.g. Negro (2007) and Suurs (2009); this helped us to structure our data and attain the causality between related system functions.

In reflection on the combination of the System Functions approach with the concept of structural components that is characteristic to innovation systems theory, we conclude that it has proven useful in this research. The combination allows us to derive the interplay of system functions and crucial structural components.

In order to form policy recommendations on the basis of these system functions we find that it is important that the indicators are not translated into system functions without further notice, as a lot of information is lost in the transition of indicators to system functions. For example, when a policy maker attempts to stimulate the amount of new entrants [F1] to a tender contest, a quick look at the analysis indicates that this can be done by stimulating market formation. However, a more thorough look shows that market entry is only directly and strongly influenced by market formation's indicator formation of demand and but not so much by market formation's indicator of subsidy scheme's that should actually promote market entry. Hence, the abstract conclusions that might be drawn from system functions' relationships might be easily misinterpreted; therefore, it is important not to lose sight of the system function's underlying indicators when formulating specific policy measures.

However, as the descriptive research by Suurs (2009) indicates, the formulation of such specific policy measures is not the ultimate goal of System Functions analysis. Accordingly, the system functions approach coupled to the static changes in structural components, has proven especially useful in describing the development of a PBIS and in identifying the most important functions and sequences of functions that determine this development.

8.3.2 External validity

To identify the characteristic system functions and motors of innovation that determine the successfulness of the innovation process of complex infrastructural projects, we have researched two cases in the DWCS, of which one case is completely finished. Accordingly, although our qualitative analysis indicates that we have identified the system functions and motors of innovation that are characteristically decisive for the innovative success of an infra project, we have only found cross case support for the functions and motors during the first two episodes – emerging demand and tender contest – of a developing PBIS. Therefore, our findings regarding the up-scaling and construction episode should be tested in further research, i.e. are the functions market formation and knowledge diffusion and is the System Building motor crucially important to the success of these episodes in the development of a PBIS? This way, more empirical support can be attained by analysing and comparing more successful cases of infra projects in the DWCS.

Moreover, in our study we only include successfully innovative projects. However, it is important to also research a series of unsuccessful projects to validate our assumption that the system functions knowledge sharing, guidance of the search, market formation and creation of legitimacy are (at least during the tender contest episode) critically important to innovation. Only when a series of non-innovative projects are researched and these cases support our findings, is generalization of our findings to any infra project in the DWCS justified.

Because our cases only involved projects in the DWCS, we should not generalize our findings to other governmentally dominated sectors, whether they are completely different sectors like the road sector, or the same sector in different countries. Hence, to pursue the purpose of formulating uniform policy guidelines for tender projects that are indiscriminative of sector (like done by the advice commission Elverding, see Sneller en Beter, 2009) and country, more studies need to be administered in different contexts.

8.4 Further research

Based on the issues discussed above, we formulate a number of suggestions for further research.

8.4.1 Further theory building through replication

Replication of our research allows for an enhanced external validity of our findings as well as for a wider area of application of the PBIS. To enhance the assessment of other PBIS, it would be useful to develop a more systemic approach. For example, a clear set of timeframes could be formulated on the basis of respective process goals, like the episodes we divided our research in. Such a systemic approach would enhance the comparability of different cases.

We recommend that further research is done on comparable cases of successfully innovative infra projects in the DWCS, like the ´Tweede Maasvlakte´, the ´Hollandsche IJssel´ and the ´Oosterschelde kering´. Such studies allows us to increase the external validity of our findings.

Moreover, we recommend that a series of non-innovative infra projects are also studied, so that characteristic bottlenecks to innovation in these projects might be identified. Moreover, within these cases of non-innovative projects, it is also interesting to research the occurrence of vicious cycles. Literature on these vicious cycles is few (Suurs, 2009) and insights in these cycles would be useful in identifying bottlenecks to innovation in such unsuccessful projects. If, according to our expectations, these bottlenecks characteristic to non-innovative projects comply with the functions that we have shown to be characteristically important to the innovative success of an infra project, generalizations of our findings to the level of all infra projects in the DWCS are justified.

Moreover, we recommend that further research is done on both innovative and non/innovative projects in other governmentally or buyer dominated sectors, like the road sector and the railroad sector. An example of a successful innovative project in the road sector would be the ‘Tweede Coentunnel’; an example of a less successful and contemporary case might be construction of the ‘Noord/Zuidlijn’ in the railroad sector. By studying these sectors, the applicability of the PBIS demarcation is increased and our findings can, if in compliance, be generalized to other sectors as well; thereby stimulating the possibility to develop uniform policy recommendations for PBIS.

Finally, we recommend that research to infrastructural projects in foreign water construction sectors are also done. Interesting cases would be Indonesia, Dubai and Japan due to their extensive activities in this sector. By studying foreign cases, lessons can be learned from abroad and findings might be generalized to the international level of water construction.

In this research we have proven that the successful application of the System Functions approach is not only restricted to the demarcation of a Technological Innovation System, but that it also applies to Project-Based Innovation Systems. Therefore, we recommend that further research explores the boundaries of application of the System Functions approach, by applying this approach to other demarcations of innovation systems as well.

Furthermore, it would be interesting to research how in some cases of Technological Innovation Systems in the DWCS, several PBIS might be involved, i.e. how some technologies participate in various tender contests for implementation. Such cases can be identified in the more conventional infra projects, like dyke reinforcement, in which a technology is applied in a broad range of projects. This would make it possible to monitor if development of the technology during such PBIS is supported by the same system functions and motors of innovation and also if the technology is developed in between projects, i.e. when not part of a PBIS. On the one hand, the technology might also not be developed at all during multiple PBIS, since it is in a mature stage already. On the other hand, the technology might be developed – custom made – to fit the specific demands of the infra project.

8.4.2 Policy

Our analysis reveals only the innovative capacity of some infra projects in the DWCS. However, it would be interesting to apply a thorough analysis on the innovative capacity of the sector as a whole and how this capacity is coupled to the sector’s sources of innovation, like the infra projects that we studied. Such analysis would help place our research into context. Besides settling the debate on the DWCS´s innovativeness that takes place in practice, it is important to identify exactly what the sources of innovation in this sector are, how much they contribute to the innovativeness of the sector and in what areas innovation is required. Then can our findings be translated into effective policy measures and be used to boost the innovative performance of this sector.

The further research recommended in our previous subsection should also provide input to fine-tune the policy measures to boost the DWCS's innovativeness; not only can the combination of PBIS with the System Functions approach be used to formulate policy, it can also be used as an evaluative tool for assessing project-based policy. Simply measuring the output of a project does not suffice to evaluate policy because, as our research shows, to many factors influence the outcome. These factors should be accounted for in a dynamic tool like the PBIS in combination with the System Functions appraoch. Accordingly, by combining both the ability to formulate policy and to test policy, the PBIS can be used to formulate and incrementally improve policy measures to a policy maker's goal.

Although we have identified the system functions that are characteristic to the success of infra projects in generating innovation, it would be useful to acquire more specific policy recommendations on how to precisely manage the system functions.

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Appendix I: Technical description of the Maeslantkering case

The Delta law that resulted from the 1953 storm surge, states that the waters of the 'lower rivers area' that are connected to the New Waterway, should be protected from storm surges. The two solutions are researched by the 'Commission study Storm surge barrier New Waterway' (CSW), reinforcing all the dykes along these waters, or installing a navigable storm surge barrier (NSSB) and complementing works that include minor dyke reinforcement and an additional NSSB in the Hartelkanaal. Although both technologies compete for this demand, we focus in this case only on the latter, and delineate this technological solution to the installation of a NSSB in the New Waterway. The technology of navigable storm surge barriers, in this context, differs from other barrier technologies in the sense that it protects against flooding due to storm surges from sea and that the barrier allows shipping to pass through when the barrier is not activated. Hence, we do not classify navigable flood barriers like the Princes Marijkesluis as a NSSB technology, since they protect only from flooding due to high river throughput. Accordingly, hydrological properties, e.g. seiches, have different effects on the respective barriers, resulting in different technologies (Vrijling, 2010). Due to the importance of shipping activities, predefined framework conditions had to be met by the NSSB designs in the first round of the tender contest (CSW, 1987):

- A reduction of the normative high water levels of 1.6m by Rotterdam and 0.4 to 0.6m by Dordrecht.
- All designs must apply to the indicated region between Maassluis and Hoek van Holland (km 1022 to 1028).
- A passage breadth of 360m.
- A unlimited passage height.
- A threshold depth of -17.0m below sea level [N.A.P.]

These framework conditions constituted an advanced demand in NSSB that had never been formulated before, i.e. never had a width this large been crossed without hampering shipping activities. These circumstances rendered existing NSSB designs like the 'Hollandsche IJsselkering' and the Thames Barrier obsolete (Arcadis, 2006; Environment Agency, 2009). Accordingly, this NSSB demanded an advanced design and we can speak of what Dosi (1982) defines as a demand-pull for radical innovations.

According to the framework conditions six designs were developed and handed in by five consortia during the first competition phase (see figure A1.1). The BMK and NIWAS consortia, both Dutch, were the most experienced participants, as most of their member organizations had also worked on the construction of the 'Oosterschelde kering' barrier. Both consortia are comprised of a small number of relatively large organizations. The CSNW was comprised of the largest number of member organizations and included both French, international and Dutch members. Storcom was also comprised of a large number of organizations, Dutch and German in this case, whereas the CHNW was comprised of a small number of Dutch and German firms.

With regard to the consortia's designs we cannot speak of radical innovations during the tender episode, because no successful implementation has taken place yet, it is possible to speak of radical inventions, of which each represents its own potential technology. As this section will show, radical invention or technological solution constitutes a complex and unique operational mechanism that represents a distinctive technology in the making. The initial number of these technological solutions or designs was larger than six, as not all designs were handed in. The BMK for example, also worked on a parachute design, which was not handed in, as it lacked robustness and provability of its functioning (Nederend, 2010). However, the idea of the flap gates and slide gates designs were not very new, but built on some of the designs made by Jitta in 1970 (Jitta, 1970). The boat door design was relatively new, but proved ineffective (CSW, 1987). The originality of the sector gates designs is often disputed, as in the same period such a design replaced the initial straight sliding gates design for the St. Petersburg barrier (Visser and Huis in 't Veld, 2010; Nederend and Koopmans, 2010; Alkhimenko, 1999). No empirical sources point out unequivocally how these designs relate to each other. However, our interviewees, as well as other informants involved in the design process (e.g. Prof. MSc. Jacques Berenbak), stress that these sector gates are designed independently from each other.

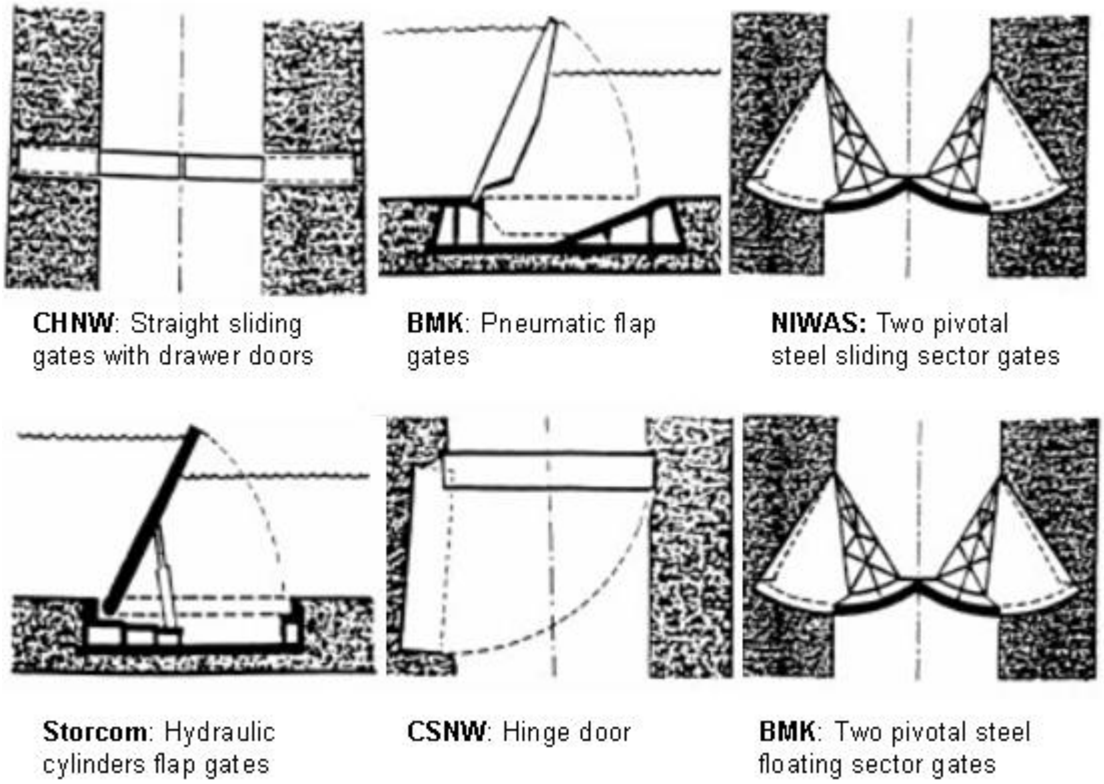


Figure A1.1, the six designs by the five consortia in competition, Source: CSW, 1987

The CHNW design is comprised of two long steel doors each more than 200 metres in length, which rest in on-shore docks during inactivity. During closing, these doors are slided inward over a threshold on the bottom of the New Waterway (CSW, 1987). Advantages of this barrier are that it lies within the experience of the governments Construction Service; the doors are well protected and easily accessible for inspection and maintenance during inactivity (Keringshuis, 2010). However, the main disadvantages are the high costs, the hampering of shipping activities and that the design is overdimensionalized (CSW and RWS, 1988).

The BMK's pneumatic flap gates design is comprised of 14 hollow steel flap gates, each 25 metres in breadth, that are connected by hinges to caissons on the bottom of the New Waterway (CSW, 1987). When the barrier closes, the initially lowered flap gates are compressed with air to make them float upwards to the surface and form a closed barrier. Advantages are its simplicity and reliability. The main disadvantages are sedimentation, inaccessibility of the gates for maintenance and inspection and its susceptibility for the accumulation of river throughput behind the barrier (Keringhuis, 2010).

The NIWAS design encompasses two sector gates, connected by steel frames to horizontally rotating hinges (CSW, 1987). During closing, the gates that are initially resting on-shore in docks, are driven inwards on a rail. Advantages of this barrier are that it can be closed under the most extreme storm surges; it has an simple and proven construction system. Disadvantages are sedimentation, inaccessibility of the gates, vulnerable to collision with ships and the hampering effects on shipping activities during construction (Keringhuis, 2010).
The Storcom design contains 24 steel flap gates, each 15 metres in breadth, that are connected by hinges to caissons on the bottom of the New Waterway. These flap gates are moved upwards by hydraulical cylinders to close the barrier. Advantages of this design are its low chance of failure, minimal occupation of space and relative inexpensiveness (Storcom, 1987). Disadvantages are that the design is overdimensionalized, uncertainties regarding the feasibility and sedimentation (Keringshuis, 1987).

The CSNW design resembles a 400 metres long pontoon. This pontoon is sunk in parallel to the New Waterway during inactivity, and is turned on a hinge at right angles to the waterway during closing. Subsequently, the pontoon is sunk again (CSW, 1987). Advantages of this barrier are that it is not susceptible to sedimentation and that it has no moving parts underwater, increasing accessibility and reliability. Disadvantages are a less controllable closing system and an uncertain barrier load (Keringhuis, 2010).

Finally, the winning BMK's floating sector gates design comprises two hollow sector gates that are connected by steel frames to two (vertically as well as horizontally rotating) ball-joints. During closing, the sector gates that rest in on-shore docks are floated upwards, then turned inwards and subsequently sunk down by filling them with water (Van Oorschot, 2001). Advantages of this barrier are that the gates are well protected and accessible during inactivity, its insusceptibility regarding sedimentation and the low strain on shipping activities (CSW, 1988). Disadvantages are that the ball-joint carries the entire barrier load and thus represents a weaker point of the barrier (Keringhuis, 2010). Based on the technical advantages and the estimated price of the barrier, this design won the Design and Construct tender contest (Van Oorschot and Pruijssers, 1995; Smit-Kroes, 1989). Although this design is comprised of many innovations, the ball-joint was the most pivotal one (Van Oorschot and Pruijssers, 1995; Van Oorschot, 2001; Nederend and Koopmans, 2010).

The seventh design included in the CSW study is made the Governmental Works Deparment's Construction Service, i.e. the 'shadow design'. This design resembles the straight sliding gates design of CHNW. Moreover, various actors closely involved in the study on the NSSB in the New Waterway acknowledge that this relatively conservative Service would never have produced designs as uncertain as the sector gates or the flap gates, but would rather rely on their experience with slide gates (Hoogland, 2010; Vrijling, 2010; Visser and Huis in't Veld, 2010). Accordingly, their shadow design was more costly than the designs by the consortia (about 1.5-2 times that of most consortia's) (Visser and Huis in 't Veld, 2010; *SOURCE*) while not being superior in quality (Hoogland, 2010).

The implementation of the winning BMK design, the Maeslantkering, resulted in a barrier that contains two retaining walls of 22 metres in height and 210 metres in width that have to withstand a waterpressure of 35.00 tonnes (Keringshuis, 2010; De Groot, 1995). These walls are connected by arms, comparable in length too the Eiffel Tower, to 680-tonne steel ball joints, resting on a 52,000 tonne concrete foundation (Keringshuis, 2010; De Groot, 1995).

Appendix II: Results of the Maeslantkering case

Results Episode 1: the emergence of a PBIS for a NSSB in the New Waterway (1953-1987)

Although the Maeslantkering is officially no part of the Delta works, the reasons for its construction date back to the storm surge of 1953, in which nearly 2000 people drowned. This storm surge forced the Dutch government to strengthen the sea defence works, and can be interpreted as an external factor stimulating the search **[+F4]** for an adequate solution in (among others) the New Waterway area (Schot et al., 1998). The Delta Act, which passed parliament as a law in 1958 **[+F4]**, dictated that dykes along the Rotterdam Waterway and connected waters should be heightened, but that the possibility for a Navigable Storm Surge Barrier (NSSB) should remain open (De Groot, 1995).

Accordingly, from 1954 to 1957, the first governmentally funded **[+F6]** feasibility study **[+F2]** was administered to research the possibilities of building, a navigable storm surge barrier in the New Waterway. However, construction was not recommended to the minister **[+F3]**, as such a project was considered to be technically too advanced at the time **[-F4]** (CSW, 1987; Van Oorschot and Pruijssers, 1995). The study did prove that the costs for inland dyke reinforcement could be significantly reduced by the construction of a barrier in the New Waterway **[+F4]** (SNW, 1987). Moreover, in the 1950s the Rotterdam harbour develops its Euro-port vision, which requires it to remain fully accessible to all shipping activities, including the new mammoth tankers (Toussaint, 2010). Hence, the Rotterdam municipality was strongly against a barrier **[-F7]**, which would inhibit shipping activities during its construction and operation (SNW, 1987). Experience on navigable storm surge barriers did increase, as in the years 1954 to 1958, the installation of such a barrier in the Hollandsche IJsselkering took place **[+F1]** (Ligtermoet and de Visch Eyberg, 1990).

A second governmentally funded **[+F6]** study **[+F2]** was administered in the years 1965-1969. Its publication **[+F3]** in 1969 proves that the construction of a navigable barrier is technically feasible **[+F4]** and that a western location proves the most effective **[+F4]** (SNW, 1987). However, this study had to be stopped prematurely, as construction in the New Waterway made a required study of the nautical behaviour impossible (SNW, 1987). The next year, several barrier designs were made **[+F2]** by the Governmental Works Department. Some of these designs resemble the slide gate designs and some resemble the flap gates design handed in during the tender contest in 1987 **[+F4]**. The latter were estimated to cost 250 million guilders, which would turn out to be much cheaper than the additional dyke reinforcement required in subsequent years **[+F4]** (Jitta, 1970).

In the 1970s and -eighties the dyke reinforcement programme, which started soon after the 1953 storm surge, was meeting difficulties. Starting in 1975, when in the village of Brakel cultural heritage had to be destroyed due to reinforcement operations **[-F4 dyke reinforcement TIS]** (Toussaint, 2010). This led to the involvement of various protest groups as well as negative media attention **[-F7 dyke reinforcement TIS]** (VenW and BMK, 1995). Moreover, studies on climate change **[+F2]** predicted a more rapid rise of sea level than initially expected **[+F4]**. This resulted in a re-examination of the design water levels **[+F2]**, which led to the conclusion that the dyke reinforcement programme was not sufficient and that dykes should be heightened even more **[+F4]** (Van Oorschot and Pruijssers, 1995). This finding implied that large industrial areas, densely populated areas and cultural heritage would be damaged even more **[-F4 dyke reinforcement TIS]** (VenW and BMK, 1995). It even required the heightening of the Meuse-boulevard, on which a large part of the Rotterdam city centre is build **[-F4 dyke reinforcement TIS]**. Additionally, these works would not be finished until 2020 and would cost approximately 1 billion guilders more than initially accounted for **[-F4 dyke reinforcement TIS]**. This led to resistance from nature groups and local citizens, and more importantly municipalities, as it would damage their economic growth **[-F7 dyke reinforcement TIS]** (Toussaint, 2010; SNW, 1987). Accordingly, the minister of the Governmental Works Department did not perceive it as an acceptable option (Smit-Kroes, 1985).

In 1985, Hoogland enacted governmental funds **[+F6]** and scientists **[+F7]** to enact a study **[+F2]** was administered to research the cost of constructing a navigable storm surge barrier **[+F4]** (NSSB) in the New Waterway, so that the increased dyke reinforcement could be prevented (Hoogland, 2010; Visser and Huis in 't Veld, 2010). This study indicated that a NSSB would cost 600-700 million guilders **[+F4]**. Moreover, technical and process knowledge on how to construct movable storm surge barriers increased as the 'Oosterschelde kering' barrier was finished in 1986 **[+F1]** (Vrijling, 2010; Van Oorschot, 2010) and generated optimistic expectations regarding a NSSB in the New Waterway **[+F4]** (Nederend and Koopmans, 2010). However, minister Smit-Kroes of the Governmental Works Department did not want to start a project like the 'Oosterschelde kering' barrier **[bottleneck F4]**, which she believed had cost much more than anticipated **[-F4]**, if the latter was still being constructed (Hoogland, 2010). Late 1986 the 'Oosterschelde kering' was finished and human and financial resources became available **[+F6]** (Olierook, 2010; Hoogland, 2010). Accordingly, the minister reconsidered in April 1987 **[+F4]** due to the persistent advice of Hoogland **[+F7]**, and appointed Ab Schreuders with the task to find the cheapest way of building a NSSB in the New Waterway (CSW, 1987). The reason for the approval of this study are the promising technical features of a NSSB, i.e. cost reduction, quicker meeting of safety standards and a better perspective regarding future sea level rising (Smit-Kroes, 1988). Moreover, this decision was supported by a vast amount of interest groups, municipalities, local residents and nature and cultural groups, that were exerting strong resistance against dyke reinforcement **[+F7]** (Raad van de Waterstaat, 1987; Hoogland, 2010; Toussaint, 2010).

Schreuders proposed a Design and Construct[3] contract to be put out to tender using a tender contest in which market parties would compete for implementation of the barrier based on their designs (CSW, 1987). This type of tender fitted in well with the developments regarding the decreasing role of government in the DWCS. In April 1987, the minister of Public Transport, Public Works and Water Management ordered a third governmentally funded **[+F6]** study **[+F2]** for the installation of storm surge barrier. Accordingly, the 'Commission Study Storm Surge Barrier New Waterway' (CSW) was established **[+F7]** with the goal to study **[+F2]** the costs and effects of continuing the increase of inland levees' height and strength, compared to costs and effects of installing a storm surge barrier and a resulting lower strengthening and heightening of the inland levees **[+F4]**. The CSW included Schreuder's proposed process of a tender contest in this study, in order to identify the best applicable NSSB design by involving the market **[+F4]**. The decision to tender the design received great resistance from the government's Construction Service (a directive of the Governmental Works Department) **[-F7]** [Bouwdienst], which used to be responsible for the design up to then (Olierook, 2010).

Results Episode 2: the tender contest (1987-1989)

Initiation stage: Formulation of the Design and Construct tender contest and pre-qualification (4/1987 - 7/1987)

After the CSW's instatement in April 1987, project-enactor Schreuders initiated the regime-breaking project approach of the Design and Construct tender. He was supported by the minister of Ministry of Public Transport, Public Works and Water Management, a colleague and personal friend whose support lasted even through strong opposition from the exiting regime **[+F7]** (Schreuders, 2010). Moreover, additional key-enactors, like Huis in 't Veld helped Schreuders to lobby towards other governmental agents – especially the Construction Service – that opposed the innovative approach of the Design and Construct tender **[+F7]** (Schreuders, 2010; Van Oorschot, 2001). The reason for the Construction Service's malcontent was that they had always successfully designed the technological solutions to large infrastructural projects and believed they were better appointed with that task than the market parties would be (Visser and Huis in 't Veld, 2010; Schreuders, 2010). However, Schreuders lobbied towards the head of the Construction Service, who agreed that the Service should fulfil the important role in the testing and selecting the technological solutions

[3] Although people commonly referred to this contract as a Design and Construct contract, the contract that was signed also involved five years of maintaining the barrier. Therefore, the contract will later be referred to as a Design-Construct-Maintain contract.

that would be created by the market parties **[+F7]**. Moreover, would the market parties fail, the government could fall back on the Construction Service's 'shadow design'. The head of the Construction Service (at that moment still split up in sub-Services), Visser, convinced the rest of the board to support Schreuders' commission **[+F7]** (Visser and Huis in 't Veld, 2010). Eventually, the approached Services agreed to create a supporting organisational structure, comprised of several research groups **[+F6]** (see Appendix figure A2.1 and textbox A2.1 for information on this support structure). The main goal of the CSW supporting groups is to test the validity of the consortia's designs **[+F4]** and to provide the legal support for installing a NSSB in the New Waterway **[+F7]** (CSW, 1987). Instating such a test group can also be seen as a preventive measure, as it shifts the competitive focus between the consortia from competition on price to more on quality **[+F4]** (Visser and Huis in 't Veld, 2010). Furthermore, the CSW informed various interest groups, like municipalities and local industrial organizations of the progress of their study, to maintain their support **[+F7]** (CSW, 1987). Moreover, the Counsel of Water State [Raad van de Waterstaat] is responsible for the advice regarding the compulsory Environmental-Effect Report [*Dutch: Milieu-Effecten Rapportage*], as is dictated in the 1986 law 'common determination of environmental hygiene' **[+F7]** (Raad van de Waterstaat, 1987). The guidelines for the report's content are discussed publicly to maintain legitimacy **[+F7]** and coordinated by the commission for environmental-effect reporting **[+F7]** (Cohen, 1987). This report does not influence the choice of barrier design, but only the choice to adopt a NSSB or continue dyke reinforcement (Hoogland, 2010). The final report of the CSW study was due by 16/11/1987, to enable swift parliamentary decision **[+F7]** making regarding the continuation of the dyke reinforcement program.

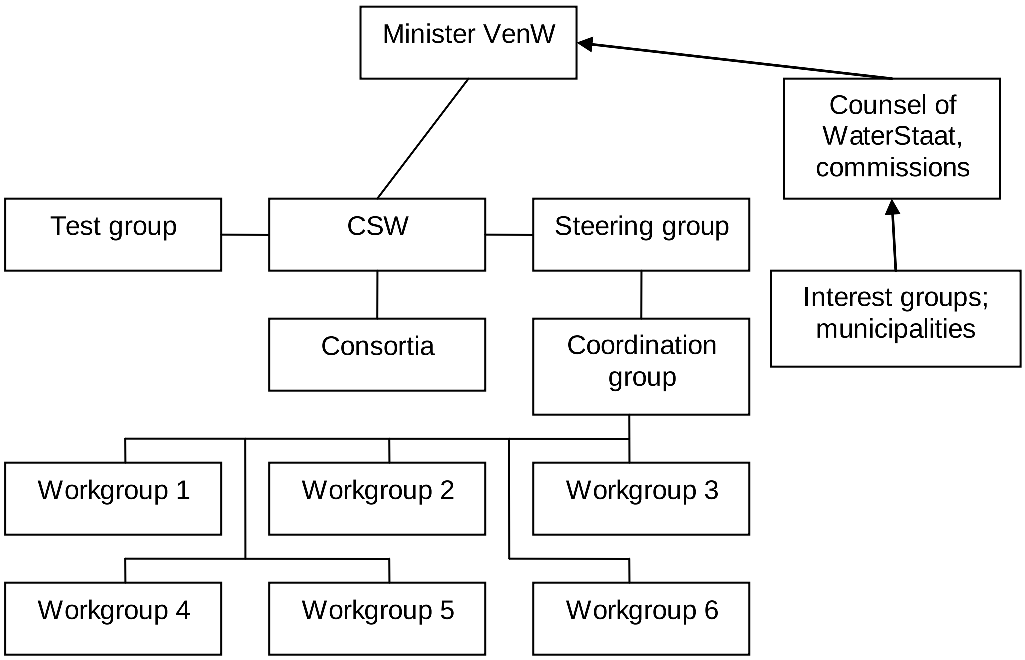


Figure A2.1, Organization of the study requested by the minister of Public Transport, Public Works and Water Management in 1987, Sources: CSW, 1987; CSW and RWS, 1987

Textbox A2.1: CSW configuration

The CSW commission is comprised of independent experts; represents the pivotal point of the study and tender process (see A2.1). On the one hand, the CSW is provided with information by the various 'groups'. The steering group is responsible for the information flow to the CSW and stimulates the coordination group to coordinate the study (CSW, 1987). Moreover, they take care of permits and legal matters that involves the construction of a NSSB (Hoogland, 2010). The coordination group coordinates the actions of the various work groups that each have their own expertise: hydraulics, technique, Europoort, dike reinforcement, procedures and additional aspects respectively. Together, the groups provide information on the entire breadth of the study. On the other hand, the CSW acquires information from the five consortia that have been triggered through the tender process, to produce navigable storm surge barrier designs; the accompanying time planning; a local environmental effects report and the financial costs. Finally, the test group verifies the information attained by the various actors and reports to the CSW. All groups are composed of agents of the Governmental Works Department, only the test group is partly composed of representatives from the market (CSW, 1987).

With regard to the traditional tender configuration, it is clear that the consortia have the role of contractor. Moreover, the CSW and Counsel of 'WaterStaat' play the role of advisor, led by the information provided by de various groups. Accordingly, the minister is the taskmaster that, in compliance with the Turnkey-model, is very little involved in the tender process: the cabinet merely decides on the basis of the advice and information presented to them.

In May 1987, the advertisement for the tender contest was published in several news papers and some firms were individually approached. This advertisement states that the winner of the tender contest is rewarded with the elaboration of the design and construction of the barrier, if the cabinet decides to choose the construction of a NSSB instead of continuing dyke reinforcement **[+F5]**. This reward generates positive expectations **[+F4]** among new and diversifying organizations, leading them to enter the market **[+F1]** (Nederend and Koopmans, 2010; Van Oorschot, 2010; Den Ouden, 2010). On the other hand, the chance of loosing the tender contest combined with the chance that the NSSB option is not chosen over dyke reinforcement, are relatively high and imply that initial investments cannot be earned back. Competitors did not perceive the advertisement as the opening up of a new market of NSSB, with extensive export potential **[-F5]** (Nederend, 2010; Vrijling, 2010). Although some did expect some future export potential (Nederend, 2010), the main goal was to win the tender contest. Accordingly, this lack of export potential did not influence the rate of investments in the competition rounds, or the incentive to join the tender contest (Nederend and Koopmans, 2010). It turns out that only engineering agencies profited from the knowledge development of the consortia (Nederend and Koopmans, 2010), see for example Arcadis' work in New Orleans that builds on all six designs (Arcadis, 2006). All consortia interviewees indicate that the reason for their lack of export opportunities is protectionism, i.e. foreign countries that stimulate their domestic industries by providing them with public works projects. This form of protectionism is combated in Europe with a law, instated in 1986, that forces public works projects to be put out to tender internationally **[+F5]**. Accordingly, Koopmans and Nederend (2010) state that they were able to use the project management skills, developed through experiences in projects like the Maeslantkering, in infrastructural protects in several EU-member states **[+F6]**. Van Oorschot (2010) agrees that while export opportunities were lacking, a lot of valuable experiences were attained among participating individuals, which proved valuable to their organizations once they returned to them [F2; F3]. Vrijling (2010) points out from experience that non-EU countries often try to import knowledge as cheap as possible, while keeping the actual work inland. Of course, as the water construction sector is a public sector, it is in the interest of the governmental demander to divide the work domestically, in order to maintain employment rate.

The ad put out by the CSW requires that competitors hand in a design, a time scheme and a cost estimate **[+F4]** (SNW, 1987). Moreover, it states that the competitor for the tender contest is required to have knowledge and experience in the various areas of expertise that are important to the construction of a NSSB **[+F4]**. This requirement forces organisations to unite themselves into consortia **[F7]**. Moreover, a financial compensation of 250.00 guilders is offered to competitors for services rendered, which is perceived by all interviewees as 'peanuts' compared to the actual expenses of the consortia **[-F6]**, making it a less interesting market in that perspective **[-F5]** (SNW, 1987). Another disadvantage are the intellectual property rights: consortia have to publically present their solutions, which can afterwards be used by others. Moreover, all intellectual property rights that are used in a project for the Governmental Works Department become property of the government, which is also not supportive to the market being created **[-F5]** (Vrijling, 2010; Visser and Huis in 't Veld, 2010; Toussaint, 2010).

In response to the advertisement, interested organizations began lobbying for other organizations that could complement them in their capabilities **[+F7]**, as they could not comply with the requirements by themselves **[F4]** (Van Oorschot, 2010; Den Ouden, 2010). Six of these 33 entrants **[+F1]** had already worked on the 'Oosterschelde kering' barrier, under extensive cooperation with the Construction Service (Visser, 2010). Organizations that had already worked together – that were already in the same network – **[F7]** were more likely to team up based on mutual trust and transparency of capabilities [F3] (Nederend and Koopmans, 2010; Van Oorschot, 2010). Accordingly, the six entrants that had already worked together during the 'Oosterschelde kering' barrier formed two of the six consortia (Visser, 2010). With these organizations they formed a network in the form of a consortium **[+F7]**. Subsequently, the organizations decide on the percentage in which they take part in the consortium[4] **[+F6]**.

Subsequently, in June the competitors participated in a pre-qualification, based on their financial means, their productive capacity and experience **[+F4]** (Oorschot, 2010). After this pre-qualification, one consortium was excluded **[-F1]**; the five remaining consortia signed the contract for the tender contest **[+F5]** on 1/7/1987, thereby agreeing to hand in their project(s) on 1/10/1987. In this contract, several framework conditions were set up by the Governmental Works Department groups to which their proposals had to comply **[+F4]**, these conditions are discussed in Appendix I and encompass broadly formulated conditions (CSW, 1987).

The lack of public preference regarding the shape location of the barrier, allowed for such broad formulation of framework conditions (Van Oorschot, 2001). Visser and Huis in 't Veld (2010) and Vrijling (2010), state that these conditions were purposefully formulated in the broadest sense so as not to exclude any unconventional solutions and stimulate creativity **[broad F4]**.

Planning/design stage: The first competition round (7/1987 - 2/1988)

All parties signed the contract on 1/7/1987. On this day, several studies commenced in parallel. Firstly, the studies **[+F2]** by the five consortia started, for which they had mobilized resources **[+F6]**. Secondly, the series of studies on the 'shadow concept design' was commenced **[+F2]** by the CSW support-groups. Thirdly, the study for the MER started ***[+F6; +F2]***. Fourthly, a study was initiated by the Governmental Works Department on the complementary works, which were required in the case of a NSSB in the New Waterway ***[+F6; +F2]*** (Visser and Huis in 't Veld, 2010). These complementary works included a storm surge barrier in the Hartelkanaal. However, as our research focuses on the Design and Construct tender contest, we do not elaborate on these latter two studies.

First, we elaborate on the studies by the various consortia. Once the contracts were signed, the consortia started their search for technological solutions and selected the ones they perceive as the best (Den Ouden, 2010; Nederend and Koopmans, 2010) **[+F4]**. Accordingly, they start the development of the chosen technological solution, or in the case of the BMK, the chosen technological solutions. During the three month period the consortia had to develop these technological solutions, no individual communication was allowed between the

[4] For the BMK consortium the following division was made: 50% concrete, of which 50% was provided by Hollandsche Beton Groep and 50% by Van Hattum and Van Blankevoort, and 50% steel, which was provided by HMC (subsidiary of HBG) and Hollandia (Van Oorschot, 2010)

consortia and the CSW or supporting groups **[bottleneck F3]**, as this would hamper the competition by giving one consortium more knowledge than the other. However, two conferences were held in September 1987, where the consortia were collectively allowed to ask some general (mostly contract-related) questions (SNW, 1987; Van Oorschot, 2010). Weekly conferences did take place among the various groups of the CSW support structure **[+F3]** (Visser, 2010). Accordingly, Nederend (2010), Van Oorschot (2010) and Den Ouden (2010) all indicate that in the first months of the competition, the greatest concern of the consortium BMK was how to interpret the relative importance of the criteria in CSW's rating of the designs, e.g. whether shipping would be more important than price. Within the BMK, various brainstorm sessions were held on the importance of the criteria, to make a selection of the possible technological solutions **[+F3].** Due to inconsistencies within the BMK members regarding what criteria to meet, two teams were established that each created their own design **[+F2]**, based on their own set of criteria [F4]. Moreover, Nederend (2010) and Van Oorschot (2010) indicate that the competitive edge **[+F5]** between these two teams was a major success factor. Within the same building, these teams competed intensively with each other; being able to watch their competitor's progress, the teams were stimulated to work even harder **[+F6]**. In the case of the Storcom consortium, the search was guided by the results of a strength-weakness-opportunity-threats analysis **[+F2]** that included both a sector gates and flap gates design. This study was performed by the external engineering agency Witteveen and Bos, enacted by the Storcom consortium **[+F7]** (Den Ouden, 2010). Storcom was unsure in what direction to search, but focussed on flap gates technology as the engineering agency showed the latter to have a lower risk of failing (Den Ouden, 2010). Storcom was one of the few consortia that contacted external organizations in this phase.

Moreover, the financial compensation of 250.000 guilders was perceived by all interviewees as much too small to cover the cost of research in that period, which attributed to more than a million guilders (Nederend and Koopmans, 2010; Van Oorschot, 2010; Den Ouden, 2010). However, these interviewees also state that they attempted to invest as less as possible, while making their chances of winning as high as possible. In these first three months, designers, engineers and people translating the design to financial costs were allocated to work on the consortia's proposals. In the case of BMK and Storcom these people are united in groups of about 20 individuals per design team **[+F6]** (Nederend, 2010; Den Ouden, 2010). In some consortia these groups were more experienced in the area of NSSB than in others. The BMK for example employed individuals with extensive experience in movable storm surge barrier construction **[+F6]**, as BMK member-organizations worked on the 'Oosterschelde kering' barrier. These people were appointed influential positions in the consortium, while the main contractor dominated such positions in the case of NIWAS. Moreover, CHNW had never built a storm surge barrier before **[bottleneck F6]**. Another advantage of BMK was that they possessed a laboratory **[+F6]** in which they tested their sector gates design in an artificial current **[+F2]**, with positive results **[+F4]**.

Under the direction of Huis in 't Veld, the Governmental Works Department attributed about thirty highly educated and experienced scientists **[+F6]** to the study on the concept of the shadow design **[+F2]** (Visser and Huis in 't Veld, 2010). This study was administered to understand what problems would occur in making a NSSB design to close the New Waterway, and to develop functional demands that should determine whether the design would function under circumstances that could not be tested in practise (withstanding a storm surge) (Van Oorschot, 2001). Using a relatively conservative slide doors design, the costs of the concept shadow design was hundreds of millions of guilders higher than those of the consortia while not being superior in quality **[-F4]** (Visser and Huis in 't Veld, 2010;Van Oorschot, 2010). Moreover, the CSW support groups performed a study **[+F2]** on the hydrological and nautical effects of a NSSB, resulting in the formulation of functional framework conditions**[+F4].**

Finally, after three months of study by both the consortia and the governmental groups, the consortia handed-in their proposals **[+F3]** so that a decision could be made regarding the winning design (CSW, 1987). The results of the consortia's studies are perceived as positive **[+F4]**, although the designs show some shortcomings (CSW, 1987; Van Oorschot, 2010; Den Ouden, 2010). Various actors of the different research groups acknowledge that the relatively conservative Governmental Works Department would never have produced radically new designs as the sector gates or the flap gates published in the CSW report, but would rather rely on their experience with slide gates (Hoogland, 2010; Vrijling, 2010; Visser and Huis in't Veld, 2010; Olierook, 2010). A technical elaboration of these designs is given in our case selection section. Due to their creation of the 'concept shadow design' and due to their experience in the 'Oosterschelde kering' barrier, the support groups were able to identify uncertainties that had been neglected in many of the consortia's designs **[+F2]**. General uncertainties **[-F4]** included seiches, lacking application of ground mechanical and hydraulics research in their designs, and no model testing (which had not yet been done by the shadow design either) (Visser and Huis in 't Veld, 2010). Additionally, no extensive price estimates had been given by the consortia **[-F4]**, only the cost of the barriers in terms of the resources required. The consortia, as well as the CSW support structure, attribute these shortcomings to a lack of time. The CSW report published on 10/11/1987 provides information on the strong and weak points of the various designs **[+F3]** and the results of the Environmental Effects Report. This report indicates that a NSSB is favoured over dyke reinforcement **[+F4]**, but does not provide a decision regarding the winning design or the choice to install a NSSB or to continue dyke reinforcement, due to a lack of information **[-F2, -F4]**. The CSW report does state that the design of CSNW, the 'boat door barrier', did not meet the framework conditions and is excluded from competition **[+F4]** (CSW, 1987). The reason for this exclusion is that the CSNW had no experience in building NSSB and had only a clouded idea on what aspects to focus on in its design (Visser and Huis in 't Veld, 2010; Nederend and Koopsmand, 2010). The public [end-user] was allowed no voice in the decision making process, as extensive technical knowledge is required to support such a decision (Hoogland, 2010). In the case of the Europoort barrier, the end-user, industrial firms inhabiting the affected area, were able to voice their opinion regarding the solutions provided by the Governmental Works Department.

Additionally, no decision was made on whether to construct a NSSB in the New Waterway or continue dyke reinforcement **[-F4]** (CSW, 1987). A report by the Counsel of Waterstate, published on 7/12/1987 includes research ***[+F2]*** by the commission for Shipping and the commission for Water maintenance. This report complies with this conclusion of CSW, and favours a NSSB at the cost of dyke reinforcement ***[+F4]***.

Accordingly, based on the CSW's advice provided on 16/11/1987, the minister of the Governmental Works Department could not decide whether to construct a NSSB or continue dyke reinforcement and ordered the CSW and its support structure to continue their study in a more elaborated fashion. From now on, the study was categorized as a 'large public project', which requires more thorough analysis on some aspects **[+F2]** and more extensive communication between the CSW structure and parliament **[+F3]** (Engwirda and Witteveen, 1987)

Planning/design stage: The second competition round (3/1988- 9/1988)

In the letter sent by Schreuders on 29/3/2010, the consortia are asked to develop their designs; time scheme; costs estimations and strength-weakness-opportunity-threats analysis even further, as parliament was not able to make a decision on the basis of the information provided (CSW and RWS, 1988). The deadline for their report is on 25/5/1988 and four weeks later for their oral presentation, after which the consortia are provided with technical and economic feedback **[+F3]** that they can use to improve their proposal **[+F4]**. Furthermore, in April the Governmental Works Department performed a soil analysis **[+F2]**, of which the results were handed over to the consortia **[+F3]** so that it could be used in their design improvement **[+F4]** (CSW and RWS, 1988). Additionally, the CSW and support groups complement the initial framework conditions by more absolute functional specifications attained from the shadow design to provide more guidance for the consortia in improving their designs **[+F4]** (Toussaint, 2010).

During the eight-week period provided by the CSW, the consortia allocated new funds **[+F6]** to enable researching **[+F2]** the possibilities to improve their proposals according to the feedback and information provided by the CSW support structure ***[+F4]***. During this period, no financial compensation was provided by the government for the research activities by the consortia **[-F6]**. In order to comply with the enhanced standards provided by the CSW support structure, the consortia enacted **[+F7]** organizations that possessed the necessary competences **[+F6]** to perform the required research **[+F2]**. After enacting these organizations, their studies were paid **[+F6]** for by the consortium (Nederend and Koopmans, 2010). An example is the BMK-funded **[+F6]** study in the Hydrodynamics Laboratory **[+F2]** that led to the exclusion of the hydrological spring-legs from their design, enabling the BMK to cut down the costs on their design **[+F4]** (Nederend, 2010). Although some studies generated some negative results **[-F4]** (Van Oorschot, 2010), each of the competing designs was handed in. Within this eight-week period, each consortium created significant improvements to their designs **[+F4]** (CSW and RWS, 1988). Accordingly, after the improved designs were handed-in **[+F3]**, a symposium was held, in which all remaining consortia had to elaborate on their design and answer specific questions in front of a critical jury of the CSW support structure**[+F3]** (Van Oorschot, 2001). This symposium was supposed to lead to the final choice of the winning design (CSW and RWS, 1988).

Meanwhile, the study on the financial consequences of installing a NSSB and resuming dyke reinforcement was sent to parliament on 31/8/1988 **[+F3]**. It estimated the costs of constructing a NSSB and supporting works on 1450 million guilders and the costs of resuming dyke reinforcement on 1740 million guilders **[+F4]**, but that acquiring the budget on short term could prove troublesome **[-F4]** (Smit-Kroes, 1988a).

After the symposium, the CSW and support structure decided in September 1988 to exclude the slide gates design by CHNW **[-F1]**, because this design had the same technical standard as the sector gates designs, but was much more expensive **[-F4]** (CSW and RWS, 1988). Since the CHNW design resembled the slide gates of the shadow design, it initially received some of the preferences of the support groups ***[+F7]***, as they knew it would work ***[+F4]***. However, these groups could not express this preference, as societal pressure **[F7]** required them to abandon their conservative attitude and search for a more innovative and cheaper solution **[+F4]** (Olierook, 2010). Moreover, the CSW decided to exclude the flap gates designs **[-F1]**, as these designs were perceived to have a lower technical quality due to the high amount of uncertainties, while not necessarily being cheaper. Although the absolute costs of these designs were lower, the uncertainty margin **[-F2]** on these designs was so high that it could become more costly than the sector gates designs **[-F4]** (Hoogland, 2010; CSW and RWS, 1988). Nederend and Koopmans (2010) state that during this period of selection, the flap gates NSSB design that was to be installed in Venice was being tested in the Dutch Hydrodynamics Laboratory **[+F2]**. The results of this study were negative **[-F4]**, as the design was showing significant instability. These results are expected to be of influence on the risk perception by the CSW support group **[+F4]** (Nederend and Koopmans, 2010). Moreover, the sector gates required less obstruction for shipping activities **[+F4]** (Van Oorschot, 2010; Nederend and Koopmans, 2010). Hence, two sector gates designs remained. Because of lacking information on the specificities of these designs, the CSW decided to recommend further research **[+F4]** (CSW and RWS, 1988). In the letter by Smit-Kroes (1988 b) on 20/9/1988, the minister states that she supports the decision of the CSW support structure **[+F7]** (CSW and RWS, 1988) to resume the study between the proposals of NIWAS and BMK. However, it should be mentioned that swift decision making at that time was not to the minister's avail, as financial means were lacking to support the construction of a NSSB **[-F6]** (Hoogland, 2010; Smit-Kroes, 1988a; Smit-Kroes, 1988b).

Although, the consortium Storcom did not win the tender contest, Van Ouden (2010) indicates that, by working together **[+F2]** and sharing knowledge **[+F3]**, the tender process generated mutual trust between the consortium members and transparency of each other's competences **[+F7]**. From retrospect, Van Ouden (2010) points out that this has led to many more, well functioning collaborations between the member organizations **[+F7]**.

Planning/design stage: the third competition round (9/1988 – 10/1989)

During this phase, NIWAS and BMK were asked to specify their proposal again **[+F4]**. Most actors perceived this as a trap: the consortia's spent investments legitimized further investments, as it would be unreasonable to cut their losses and quit the competition at this phase (Visser and Huis in 't Veld, 2010, Nederend and Koopmans, 2010; Van Oorschot, 2010). Moreover, it was not according to the agreement signed in 1987 (Van Oorschot, 2010). Therefore, the loosing consortium was offered 500.000 guilders as compensation (Visser and Huis in 't Veld, 2010). Another point of debate was that during the symposium in the previous phase, both consortia had acquired extensive knowledge on each other's proposals **[+F3]**.

Various actors perceive this as unfair, and a major flaw of the tender contest process, as the consortia can steal each other's ideas in the subsequent competition phase (Vrijling, 2010), especially since these contractors do not base their designs on intellectual property but on chosen work methods and routines (Van Oorschot, 2001).

At the same time, government was struggling with the problem of allocating sufficient funds **[-F6]** for a NSSB. During this phase, the governmental funds required before the year 2000 for building a NSSB are 456 million guilders higher than the dyke reinforcement **[-F4]** (Smit-Kroes, 1988c, d). Therefore, focus is retained on the dyke reinforcement solution **[-F4]**, which had been perceived as inadequate since the report by the CSW in 1987 (Smit-Kroes, 1988c). However, on 5/10/1988 the Lower House agrees unanimously on the installation of a NSSB **[+F4]**, although the financial scheme of such solution still needs to be completed **[uncertain F6]** (Smit-Kroes, 1988e). Reasons for this decision are firstly to restrict the interventions of dyke reinforcement; prevent entirely the reinforcement of the Rotterdam barrier. Secondly, to enhance a higher water defense quality, i.e. a reduction of the water defense line. Thirdly, to better deal with sea level rising by preventing the reinforcement of kilometers of dykes in municipal areas on the long term (Smit-Kroes, 1988d).

During this third competition phase, the consortia again allocated additional funds **[+F6]** to enable further study **[+F2]**, now partly guided by the information attained from the symposium during the previous contest-phase (Nederend, 2010). Moreover, for the first time during the tender contest there was communication between the CSW support structure and the consortia **[+F3 between consortia and support groups]**, approximately every two weeks, mainly regarding the progress of the designs (Visser and Huis in 't Veld, 2010; Toussaint, 2010; Van Oorschot, 2010). This means that, to keep information from spilling between BMK and NIWAS, the support groups were not allowed to discuss the different design's progress with each other **[-F3]** (Visser and Huis in 't Veld, 2010; Van Oorschot, 2010). Nederend and Koopmans (2010) suggest that BMK's lobbying **[+F7]** for information **[+F3]** from these support groups was a crucial factor. This allowed them to focus on the most important aspects **[+F4]** of their design, which included at this stage the technical and economical feasibility of the design. However, as specific competences were required for these feasibility studies that were not all in the consortium's possession, external organizations were enacted **[+F7]** and their services were paid for **[+F6]** (Nederend and Koopmans, 2010). Examples of such organizations are KEMA and TNO for strength-weakness-opportunity-threats analysis; GeoDelft for ground mechanical research; again the Dutch Hydrodynamics Laboratory for further hydrological studies and model-design testing (Van Oorschot, 2010; Nederend and Koopmans, 2010). More specifically, a governmentally funded **[+F6]** study in the Hydrodynamics Laboratory **[+F2]** led to the exclusion of the hydrological spring-legs from the BMK design, which enabled the BMK to cut down the costs of their design **[+F4]** (Nederend, 2010).

Van Oorschot (2010) indicates that the costs of research over the entire tender contest period by BMK had accumulated to approximately 10 million guilders **[+F6]**. Hence, all interviewees agree that the 250.000 guilders provided by the subsidy scheme so far, for the efforts taken by the consortia, are almost negligible **[-subsidy scheme: F6]**. However, as mentioned, government did pay for the additional research performed by the Hydrodynamics Laboratory at this stage. During this hydrological research, the studies of NIWAS and BMK were kept strictly separate, as to prevent any spilling of information between the two consortia **[-F3 between consortia]** (Visser and Huis in 't Veld, 2010; Van Oorschot, 2010). The BMK consortium enlarged its project team from twenty to forty people, which was justified by the fact that they had two groups of twenty people working on two designs before **[same extent of F6; +F4]** (Van Oorschot, 2010).

During this period, the Governmental Works Department initiated a study on the effects of the various closing- and openings-strategies of both designs on normative high-water levels (VenW, 1990).

In October 1989, after nearly a year of competition between NIWAS and BMK, the CSW and support groups pointed the BMK design out as the winner **[+F4]** (Smit-Kroes, 1989). This decision was based on the minimal obstruction it provided to shipping activities during operation and construction; the easy access for inspection, repair and maintenance in dry conditions; well coping with the sedimentation problem **[+F4]** (Van Oorschot and Pruijssers, 1995). Moreover, the BMK design was cheaper than that of NIWAS **[+F4]** (Smit-Kroes, 1989). The largest disadvantage of the NIWAS design was the sedimentation problem. Sediment accumulated on the gates' railway, which caused problems during the closing of the gates **[-F4]** (Visser and Huis in 't Veld, 2010). Late October 1989, minister Smit-Kroes officially supports the decision of the CSW **[+F7]** (Smit-Kroes, 1989). Due to the exclusion of NIWAS **[-F1]**, the BMK was offered the Design and Construct contract **[+F4]**. However, the BMK design was still perceived as too expensive by the CSW since it did not fit the budget of 840 million guilders set aside by minister Smit-Kroes (Visser and Huis in 't Veld, 2010; Smit-Kroes, 1988e). Consequently, before signing the contract, BMK and the Governmental Works Department had to discuss the financial specificities (Visser and Huis in 't Veld, 2010).

Results Episode 3: Scaling up the design (contract agreement 1989 – start construction 1991)

The contract that was to be signed stated that the BMK would construct the NSSB and maintain it for five subsequent years on their own costs (Smit-Kroes, 1989). This combination stimulates the BMK to find an overall economical solution, regarding both construction and maintenance costs. Hence, it stimulates the consortium to find sound solutions to technical problems, in order to reduce maintenance costs **[+F4]** (Van Oorschot and Pruijssers, 1995). However, there was still heavy debate **[+F3]** regarding the price of the barrier, which according to the Governmental Works Department had to be reduced 'at all cost' (Visser and Huis in 't Veld, 2010). Accordingly, technical feasibility and economical feasibility were weighted against each other and the decision was made to exclude the vertical valves - that spouted water when the internal water level was higher than the external water level - so that the barrier price could be reduced by 30 million guilders **[+F4]** (Van Oorschot, 2010; Nederend, 2010). However, this decision was made hastily, without researching the consequences of such actions **[-F2]**, because the end of minister Smit-Kroes' office term was nearing and she wanted the contract to be signed before the switch of government **[+F7]** (Visser and Huis in 't Veld, 2010). Therefore, it did not become apparent that the vertical valves also had a stabilizing effect on the water flow below the barrier (Nederend, 2010). Consequently, because of the lack of evidence indicating that this barrier part could be missed, BMK insisted that if problems would occur due to the exclusion of this part, government would cover the costs (Van Oorschot, 2010; Visser and Huis in 't Veld, 2010). The minister agreed, but insisted that BMK would be responsible for the remaining exceeding of costs, which was perceived by government as the main advantage of a Design-Construction-Maintenain contract over the traditional way of out-sourcing (Smit-Kroes, 1989). However, BMK could not remain responsible if the barrier failed, e.g. if due to malfunctions a storm surge would cause regions to be flooded, because the BMK cannot compensate for such damage (Vrijling, 2010). Therefore, government would assume responsibility of the detailed design once it was accepted; only then construction could commence (Van Oorschot, 2001). Accordingly, to enhance the quality of the design and reduce the chance of failure **[+F4]**, BMK has to deliver various documents regarding the elaboration of the design that have to be accepted by a group of experts from the Construction Service for a duration of at least two years **[+F6]** (Van Oorschot and Pruijssers, 1995). Hence, it is important that the government employ these types of experts, in order to oversee the risks involved in the design (Vrijling, 2010; Visser and Huis in 't Veld, 2010). Moreover, these documents have to comply with the total Quality Assurance/Quality Control scheme that was set up according to the ISO (International Organization for Standardization)-9000 standards **[+F4]** (Van Oorschot and Pruijssers, 1995). Under these conditions, and when the government's financial scheme was finally completed, the Design and Construct contract was signed **[+F5]** on 27/10/1989 for an amount of 840 million guilders **[+F6]** (Maij-Weggen, 1990a; VenV, 1990). However, it should be noted that a contract price is not the actual price, but an indication. Normally a 10% margin is held for unforeseen costs (Visser and Huis in 't Veld, 2010).

Early January 1990, BMK started working out their design into a comprehensive base design and subsequently, a detailed work-design **[+F2]** (VenW, 1990). At this stage, the number of human resources employed by the BMK and attributed to working out the design increased from 40 people to 100-150 people **[+F6]** (Nederend and Koopmans, 2010). Moreover, these people included individuals whom had experience with Design and Construct contracts through their mother companies' activities in other sectors **[+F6]** (Vrijling, 2010). The BMK initially invested **[+F6]** in a series of model-studies **[+F2]** at the Hydrological Laboratory to test the barrier's functionality without the presence of the vertical valves (VenW, 1990; Nederend and Koopmans, 2010; Van Oorschot, 2010). However, these studies indicated that due to the absence of the valves, the necessary stabilizing current was removed, creating a dynamical instable structure **[-F4]** (Van Oorschot, 2010). This means that every small vertical movement of the barrier gates caused a fluctuation leading to increasingly larger vertical movements, a phenomenon the researchers named 'the dancing doors' (Nederend and Koopmans, 2010; Hoogland, 2010). These unexpected results triggered numerous additional studies **[+F2]** to focus on a new, stable gate design **[+F4]** (Van Oorschot and Pruijssers, 1995). Consequently, the first Governmental Works Department progress report pertains to the period 1/1/1990 to 1/7/1990 **[+F2]** and was sent on 29/10/1990 to the Lower House **[+F3]** (Maij-Weggen, 1990b). This report points out that the time scheme is already delayed by twelve weeks **[-F4]**. Other studies performed at that stage are wind tunnel-research **[+F2]**, to study the wind-forces acting on the barrier **[+F4]**; complementing soil research **[+F2]** regarding the foundation of the barrier **[+F4]**; ground-protection research **[+F2; +F4]** and filter research **[+F2; +F4]** (VenW, 1990). These studies were performed mostly by enacting external organizations **[+F7]**, like GeoDelft, the Hydrological Laboratory and the IV Engineering group. Soil research indicated the presence of soil pollution at the position of the northern barrier hinge **[-F4]**, leading to a subsequent study on the gravity of this pollution and potential solutions **[+F4]** (VenW, 1990). Moreover, the Governmental Works Department's study on closing- and opening-strategies is shared with the BMK **[+F3]**, so that the BMK could use the study's results **[+F4]** in their compulsory feasibility studies **[+F2]** (VenW, 1990). Furthermore, the Governmental Works Department lobbies for the necessary legislative permits **[+F7]** (VenW, 1990). Additionally, expectations regarding the Governmental Works Department's financial feasibility study are still positive **[+F4]**, since unforeseen costs were not accounted for (VenW, 1990).

The second progress report pertains to the period 1/7/1990-1/1/1991 and was sent by the minister to the Lower House **[+F3]** on 17/4/1991 (Maij-Weggen, 1991). The report indicates that during the second half of 1990, the BMK delivered their base design, including the necessary documents to the Construction Service's expert group for acceptation **[+F3]**. However, these experts conclude that the documents do not comply with the pre-defined conditions **[-F7]** and demand a more elaborate version **[+F4]** (VenW, 1991a).

Van Oorschot (2010) and Olierook (2010) indicate that the Governmental Works Department felt circumvented by minister Smit-Kroes' decision to put the design of the NSSB out to tender instead of letting the Construction Service design it. Therefore, the Construction Service's experts would rather prove that they were indispensable by not accepting the base design **[-F7]**. This was possible as the translation from functional demands to a constructive form leaves space for subjective choice (Van Oorschot, 2001). The BMK stresses that this has led to a continuous asking for elaboration **[+F4]**, resulting in numerous additional studies and a base design with a level of detail that more closely resembled a detailed work-design **[+F2]** (VenW, 1993). This is inability of both groups to converge is enhanced by the fact that both groups maintained a different hydrological model **[-F4]**, since the Construction Service experts were not convinced **[-F7]** into sharing their model **[-F3]** (Van Oorschot, 2010). This lack of cooperation continues until 1993. Consequently, the lack of cooperation **[F3]** resulted in a delay of the BMK's progress **[-F4]** (VenW, 1993; Van Oorschot, 2010). Furthermore, direct communication between the contractor and employer (without interference of governmental Services) consisted mostly of infrequent requests regarding the form of contract or additional mobilization of resources. On the other hand, government have accepted legal insurances demanded by the BMK **[+F7]**. Moreover, the study on the barrier's dynamic behaviour in the Hydrological Laboratory was finished and resulted in some geometrical adjustments to the barrier's gates and the shape of the hinge-socket **[+F4]** (VenW, 1991a). Furthermore, the study on soil pollution led to the decision to remove the polluted grounds and store it **[+F4]**. Moreover, preparation of the construction site has started since the permit for the construction of a NSSB has been granted **[+F7]** (VenW, 1991a). This required additional investments in terms of financial-, material- and human resources **[+F6]**. The fact that the government arranged all legislative aspects was perceived by the BMK as one of the **drivers** for system development, as this normally involved a lot of time and costs (Van

Oorschot, 2010). Furthermore, the BMK, the Rotterdam municipality and the Governmental Works Department have started their periodical nautical conferences, in order to tune the NSSB construction in with the shipping activities in the New Waterway **[+F3]** (VenW, 1991a).

In the first half of 1991, BMK continued studying the optimal shape of the barrier gates, which continued to sway during closing. Accordingly, extensive adjustments have been made the barriers design in the form of skirts that created a stabilizing current under the gates **[+F4]** (Van Oorschot, 2010; VenW, 1991b). Adjustments in the hinge foundation-design caused a larger part of the polluted soil to be removed, resulting in unforeseen costs of 1.8 million guilders **[-F4]** (VenW, 1991b). The settled commission for the Governmental Works Department debated **[+F3]** on 5/9/1991 on the fact that the costs of the NSSB were increasing more steeply than anticipated **[-F4]**, due to increases in resource prices and wages, causing trouble for the government's financial scheme **[F6]** (Biesheuvel and Teunissen, 1991). The Construction Service's experts accepted **[+F4]** the BMK's base design and respective documentation after intensive testing **[+F2]** that required the inclusion of external specialists **[+F7]** (VenW, 1991b). Accordingly, the base design could now be elaborated into a detailed design and the remaining construction preparations could start. Moreover, the third progress report **[+F2]** sent to the Lower House **[+F3]**, indicates that the delay has now accumulated to one year **[-F4]**.

During the second half of 1991, the BMK initiated several studies **[+F2]** that worked out the various aspects of the detailed design and handed in **[+F3]** the respective documents for acceptation by the Construction Service experts (VenW, 1992a). Moreover, at the end of 1991, preparations for the construction have progressed to the point that construction of the barrier can commence. Accordingly, on 31/10/1991 a modification to the Delta law is accepted that legally enables the construction of the NSSB in the New Waterway **[+F7]** (VenW, 1992b).

Results Episode 4: Construction (1991-1997)

Due the acceptance of the Delta Law modification, construction of the NSSB was able to commence officially on 2/11/1991 (VenW, 1992a). During this stage, elaboration of the detailed design and construction of the barrier take place in sync. Hence, different project groups are assigned **[+F6]** to different studies **[+F2]**, each elaborating a different aspect of the base design. The study **[+F2]** on the detailed design of the gates' parking-docks generates the first completed sub-design **[+F4]** in the first half of 1992 (VenW, 1992b). Studies on the completion of the other detailed sub-designs took place in parallel, figure A2.2 below gives an indication of the interdependent parts of the barrier.

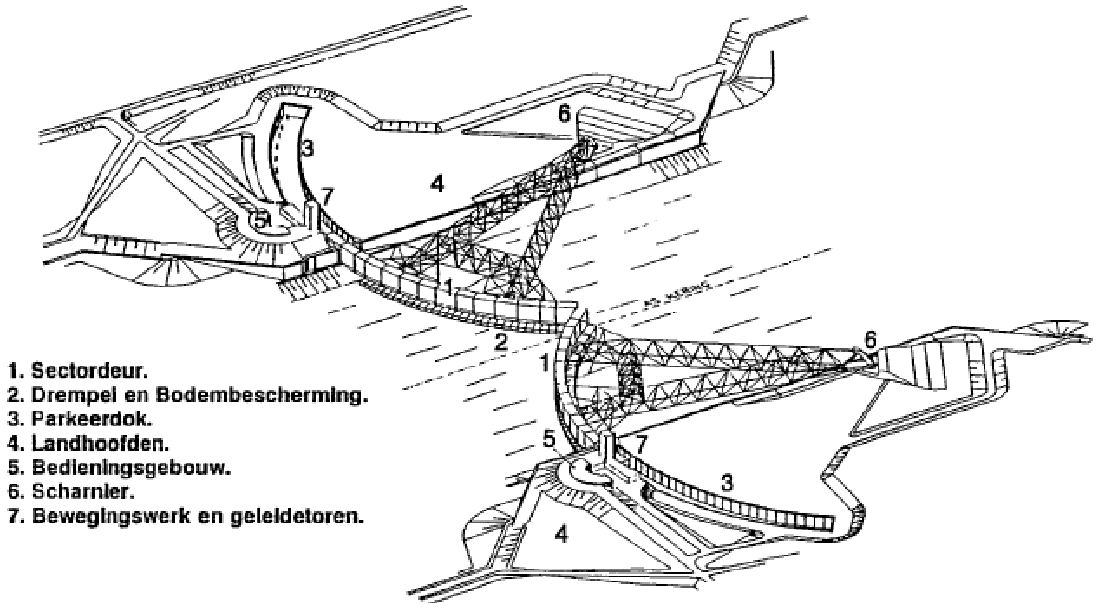
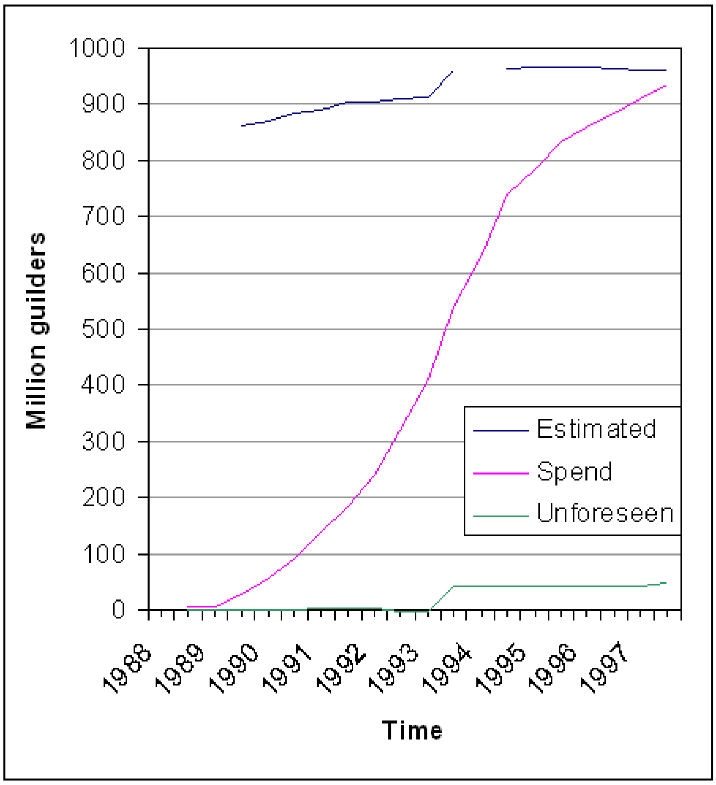


Figure A2.2, The focus of various sub-design studies taking place in sync. Source: VenW, 1992b

The delay of a year, which the BMK appoints to both the government's irresponsible decision regarding the exclusion of valves and the governments' hampering role in the design-acceptation process, turns out to have financial consequences. Moreover, the sub-optimal cooperation regarding design acceptation continues to hamper system development in the construction episode (Van Oorschot, 2010). Because the BMK does not want to be held responsible for these costs, it formally demands additional funds and postponement of the barrier's release date in late 1992, because a one-sided cancellation of contract was estimated to be cheaper than continuing construction (Van Oorschot, 2010; Hoogland, 2010). For the subsequent period of more than a year, the BMK and the Governmental Works Department discussed the terms of a contract revision **[+F7]** (Maij-Weggen, 1993a). Meanwhile, in order to enhance the coordination process between the BMK and the test group, monthly meetings are held **[+F3]** between the directors and representatives of the Construction Service, the BMK and the test group (Olierook, 2010; Maij-Weggen, 1993a). The goal of these meetings was to facilitate the construction and design process **[+F4]**. The contract was revised on 17/12/1993, resulting in an increase of financial funds by 59.1 million guilders **[+F6]** and a postponement on the delivery of the barrier to 1/10/1997 (Maij-Weggen, 1993b). Moreover, this contract revision was accompanied by a change of project leaders on the side of both the BMK and the Governmental Works Department's Construction Service, to facilitate a better cooperation in the future (Van Oorschot, 2010; Olierook, 2010). Moreover, two independent experts were authorized to solve indifferences between these parties **[+F7]** (Van Oorschot, 2001). Accordingly, from contract revision on, the BMK and Construction Service cooperatively looked at design documentation (Van Oorschot, 2010; Van Oorschot, 2001). The periodical meetings continued in a more open manner and resulted in a much better cooperation between the BMK and the Construction Service **[+F3]** (Olierook, 2010; Van Oorschot, 2010; VenW, 1993b; 1996b). Hence, it can be said that the Construction Service finally acquired the much wanted influence **[+F7]** regarding the content of the construction and design process from here on forth **[+F4]** (Van Oorschot, 2010; Van Oorschot, 2001).

Beside the previously mentioned monthly directors' conferences, meetings were held more frequently between the project groups of the Construction Service and of the BMK **[+F3]**. These latter meetings openly discussed the construction and designs' progress, problems and solutions to these problems **[+F4]** (Olierook, 2010). Moreover, Construction Service employees interactively participated in the BMK work groups while formally testing the process **[+F3]**. However, conferences with other actors were also organized. A conference had been held with nautical stakeholders **[+F3]** regarding the method by which the concrete thresholds are put in place **[+F4]** (VenW, 1994a). Various conferences have been held **[+F3]** with the Rotterdam municipal harbour organization regarding **[+F4]** a series of tests to close the barrier **[+F1]** and the procedures involved (VenW, 1997). Moreover, three conferences with stakeholders have been held **[+F3]** regarding **[+F4]** the closing frequencies of the barrier that have to comply with certain laws **[+F7]** (VenW, 1997). The subsequent decision on the closing frequencies is published **[+F3]** to allow for appeals.



On completion of the detailed designs, construction of the respective barrier parts commenced. The costs of construction, i.e. wages and costs of materials, accounted for the most part of the resources mobilization at this stage. Nederend and Koopmans (2010) indicate that at this stage 200 to 400 people worked on the barrier **[+F6]**. Figure A2.3 indicates how the costs of the barrier progressed over time. Moreover, the figure gives and indication of how the expected costs [F4] changed over time. Additionally, unforeseen costs (costs that cannot be anticipated and are outside the contractors influence) are depicted over time to give an indication of the proportion of unforeseen costs compared to the total costs. The figure indicates that most of the cost increase is caused by inflation, especially the increasing costs of material resources **[+F6]**. The increase of these costs guided the search **[+F4]** to more economical solutions (VenW, 1992b). Moreover, in some cases the mobilization of material resources provided some difficulties **[-F6]** (VenW, 1993a), resulting in the focus on more expensive alternatives **[+F4]**.

Production of the ball-joint started in the second half of 1993 after completion of the detailed design. Although normally only BMK employees work on the elaboration of sub-designs, the elaboration of the ball-joint required a review **[+F2]** by an international panel of specialists **[+F6]** as the Construction Service was hesitant about the feasibility of such a device **[F4]** (Olierook, 2010). Accordingly, this review was funded by government **[+F6]** and administered in close cooperation with the BMK **[+F3]** (VenW, 1994a). The construction of the ball-joint took place in Czech Republic, as there was no other place in the world steel constructions could be crafted with the necessary precision **[-F6]** (Olierook, 2010). It had to be crafted manually, as no machines existed that could perform such large scale operations **[-F6]**. Because it was crafted manually, it contained an imperfect surface that would cause friction with the barrier's hinge-socket **[-F4]** (Olierook, 2010). This required subsequent studies **[+F2]** to focus on **[+F4]** ways to smear the socket and hinge construction. Initially, the solution was found in Verrobestos plates. However, these plates contained asbestos, a material that had recently been forbidden by European law **[-F7]** (Van Oorschot, 2010). Subsequently, studies by BMK **[+F2]** found a high-performance glide lacquer **[+F4]**, which contained too much chlorofluorocarbon [CFK] and was prohibited by environmental regulation **[-F7]** (Nederend and Koopmans, 2010; VenW, 1995). More studies followed over the next two years **[+F2]** and eventually, the BMK settled with a lower performance **[+F4]**, but legally supported glide lacquer **[+F7]** (VenW, 1995). During this time the Construction Service had, through studies **[+F2]**, also come up with a high-performance solution **[+F4]**, Teflon 'pillows', that would eventually be adopted two years after completion of the barrier (Olierook, 2010). However, the Construction Service could not provide this solution as the evidence for the incapacity of the glide lacquer was insufficient **[-F2]**. Moreover, would their solution be adopted by the BMK, the Construction Service acquired unwanted responsibilities **[-F7]** (Olierook, 2010). Ground-mechanical research on the ball-joint foundation **[+F2]** was out-sourced **[+F7]** to GeoDelft, leading to the conclusion that the ball-joint foundation should be kept in place by skirts instead of poles **[+F4]**. Other external organizations, enacted **[+F7]** by the BMK at this stage to perform research are KEMA, TNO, the IV engineering group and the Hydrological Laboratory (van Oorschot, 2010; Nederend and Koopmans, 2010).

Furthermore, application of the detailed designs **[+F1]** leads in more cases to new insights into practical problems [learning by using, **+F2**]. For example, tearing occurred in the seams of the steel frames that constitute the barrier's 'arms' **[-F4]**. This caused a series of studies **[+F2]** to focus on finding solutions to prevent this problem **[+F4]** (VenW, 1996a; 1996b). Moreover, pilot compartments have been installed **[+F1]** to test the proposed repair mechanisms (VenW, 1998). Another example is the expanding of the steel frames due to weather conditions **[-F4]**. This phenomenon resulted in research **[+F2]** that focussed on the extension of the effects, the consequences for the barrier, and ways to prevent further harm to the NSSB **[+F4]** (VenW, 1997). Additionally, construction of the gates' constrain rubber blocks also showed tears, resulting in the enactment of an independent specialist to study **[+F2]** the phenomenon **[+F4]** (VenW, 1998).

In 1994, a study **[+F2]** on seiches (waves with a period of a few minutes to an hour) pointed out that higher seiches could be created than expected **[-F4]** (VenW, 1995). These results led to **[+F4]** subsequent risk of failing analyses and hydrological studies **[+F2]**. These studies were reviewed by external specialists under governmental payment **[+F6]**, who supported the BMK's solution to adjust the operating system **[+F4]** (VenW, 1995). Subsequent studies

lasted a year **[+F2]** and led to the adjustment of the sector gates **[+F4]** (VenW, 1997). The costs involved in these adjustments are attributed to unforeseen costs **[+F6]** (VenW, 1996b).
A study is **[+F2]** performed by the Governmental Works Department on the safety- and health-demands of the construction process **[+F4]** that resulted in the establishing **[+F4]** of a safety and health precautionary plan **[+F4]** (VenW, 1996a). Moreover, research **[+F2]** pointed out that closing of the NSSB during calamities like oil-contaminations is not useful **[-F4]** (VenW, 1996a). The establishment of an information centre at the barrier is outsourced to a professional communications centre **[+supply side]** (VenW, 1995).

The creation of the operational system was put out to tender by the BMK **[+F7]** (Nederend and Hoogland, 2010); the respective risk of failing analysis was done by KEMA. After completion of the operational system, all forty operating procedures were critically tested **[+F2]** (VenW, 1995). Subsequently, in November 1996, the first testing of the individual barrier parts in a societal context commenced **[+F1]**, showing no problems **[+F4]** (VenW, 1997). Subsequently, the first complete barrier's closing tests **[+F1]** in 1997 indicated malfunctioning of the gates during closing **[-F4]**, resulting in the replacement of the barrier's valves (VenW, 1998a).

In May 1997, the barrier was officially opened by Queen Beatrix of the Netherlands. However, this would not mean the end to crucial improvements on the Maeslantkering. For example, the glide lacquer was eventually replaced for Teflon pillows to support the ball joints in their hinges (Olierook, 2010).

Appendix III: Technical description of the Afsluitdijk renewal case

On the 28th of May 1932, the Afsluitdijk was closed and became an icon for the Dutch water construction technology (SMO, 2007). The Afsluitdijk is actually a dam as it forms the division of the salt water Waddenzee and the fresh water IJsselmeer, thereby securing a fresh water supply on which 30 percent of the Netherlands depends. Moreover, it protects the Netherlands from storm surges from sea and forms an important connection between the provinces of North Holland and Friesland (VenW et al., 2009).

During the second round of safety tests in 2005, which was dictated by the Law on Dykes, it became clear that the Afsluitdijk no longer complies with safety norms and must therefore be renewed. This can be done in two ways. In the conventional way, by heightening and strengthening the Dam to comply only with the safety norms, thereby adding no additional values to the dam. This can be seen as the incumbent regime, since it is the conventional approach taken by the Governmental Works Department. Alternatively, it is possible to build a multifunctional Dam that foresees in not only the demand of safety, but also in additional demands,like sustainable energy generation and recreation (Rijksoverheid, 2010). Such an approach would indicate a new regime within the Governmental Works Department, in which multifunctional approaches to large infrastructural projects are the norm. To research the possibilities for such a multifunctional dam, the PBIS for the renewal of the Afsluitdijk is established: our unit of analysis in this second case. We describe a multifunctional dam in the light of RWS et al. (2009), in which the Afsluitdijk is seen as a complex spatial planning project in which various functions beside water safety can be fulfilled. Additional functions include sustainable energy generation, improving mobility, recreation, culture, nature and spatial quality (Rijksoverheid, 2010). We focus on the technological solutions that compete in the PBIS, of which each provides in some, but not necessarily all, of the above described functions.

To structure this PBIS, compulsory framework conditions were formulated and ambitions regarding additional functions were fulfilled. To create the framework conditions for the tender contest, the Research Integral Improvement Afsluitdijk (OIVA) project group uses the KNMI-'06 climate scenarios as point of reference for the Waddenzee water level rise and Afsluitdijk ground level decrease (RWS, 2008B). The tender's framework conditions firstly regard water defence, i.e. the height, breadth and slope of the Afsluitdijk. Secondly, they regard water maintenance, i.e. the number, location and cumulative breadth of the sluices. Thirdly, road traffic, which is expected to increase by four percent annually, requires two times two lanes for road traffic. Finally, they regard shipping activities, i.e. naval routes must be maintained and comply with current regulations (RWS, 2008B). These framework conditions build on existing reports and regulations. In 2013, a decision will be made on the potential IJsselmeer water level increase (VenW et al., 2009). However, the effects of this development is independent of these framework conditions that regard the renewal of the Afsluitdijk (Driebergen, 2010). The ambitions were formulated by various ministries in an interdepartmental consultation (RWS et al., 2009; Santhagens and Oosting, 2010) and were, tough not compulsory, seen as guidelines for the competing consortia to focus their technological solutions on. Ambitions not only focussed on the previously described additional functions, but also on ambitions regarding the level of technical and visual integration of the functions into a technological solution (RWS, 2008A).

With these ambitions and conditions as guidelines and the inventoried ideas of expert-sessions as input, eight consortia were selected to participate in the tender contest that had the goal to study the possibilities for a multifunctional dam and identify the most attractive solution in terms of a cost-benefit analysis. These eight consortia comprised 36 organizations, of which only four were involved in the tender contest of the Maeslantbarrier. Moreover, Bruggeman (2010) identifies 18 organizations that are new to large infrastructural projects in the DWCS and only 16 that are not. These 18 new organizations constitute mostly organizations from other sectors that are attracted by the multifunctionality of the DWCS's large infrastructural project. They include energy firms like Nuon; landscape artists like Alle Hosper; and consultancy firms like Ecorys. Together, they form diverse consortia of organizations that are able to combine the different functions into an integrated technological solution. Beside the consortia's eight designs, the governmental groups also created two designs to use as reference in rating the designs of the consortia. We shall provide a short discussion on these designs and on some of the technological interdependencies that can be found within these technological solutions.

The first consortium ‘Mudflats works’, proposes to build 1500 acres of mudflats in combination with a sand deposit to protect the Afsluitdijk from storm surges, while allowing additional demands to be met, especially nature and recreation (RWS et al., 2008). On the one hand, they intent to use the mudflats ‘technology’ to not only to break the incoming waves of the Waddenzee, but also to create ecological values (Fiselier, 2010; WADDENWERKEN, 2008). Because these mudflats alone cannot withstand storm surges during high tide, the consortium combines this technology with a sand deposit before the Afsluitdijk that provides sufficient protection under all circumstances. The combination of the two technologies provides three advantages (Fiselier, 2010; WADDENWERKEN, 2008): mudflats will break the waves so that firstly, the sand deposit does not need to be reinforced and secondly, the sand deposit will not erode as quickly as a results of wave power. Finally, the mudflats provide an equilibrium profile for the sand deposit so that it can be made smaller without the effects of erosion through hydrological effects like high- and low tide. Beside this combination, mudflats will also be able catch away a small percentage of the dirt in the salt water that is run into the Blue Energy installation, thereby slightly improving its performance (WADDENWERKEN, 2008). After the first phase of the tender contest, the Advice Commission rates this proposal the best of the designs that use sand supplements on the Waddenzee side to strengthen the Afsluitdijk, especially for its ecological contribution and extent of integration (C04).

The second consortium ‘Afsluitdijk 21st century’, also integrates a number of ideas to attain supportive feedback between technologies (Boddeke, 2010). The basic idea is to establish a brackish lake in between the Afsluitdijk and a second parallel running dam. To create ecological values, such a brackish lake is best attained through a controllable salt-fresh water transition (AFSLUITDIJK 21E EEUW, 2008). If this is done by installing the proposed pump-generators in the Afsluitdijk, not only will ecological values be created, but will tidal energy also be acquired (AFSLUITDIJK 21E EEUW, 2008). Moreover, the sand deposits required for installing the second dam, can be acquired by digging deeper wells in the Ijsselmeer that creates additional ecological values (Boddeke, 2010; AFSLUITDIJK 21E EEUW, 2008). This project is rated the best of the proposals that allows the Waddenzee dynamics to steadily affect the Ijsselmeer (C04).

The third consortium ‘Natural Afsluitdijk’, proposes to allow water to go over the Afsluitdijk and build an additional dam in the IJsselmeer, in parallel to the Afsluitdijk, to catch this water and created a brackish lake. The Natural Afsluitdijk consortium provides a similar solution in which the technology of establishing a brackish lake with ecological values is combined with the technology of an energy lake to attain cost advantages. In this case, the sand supplements required for building the second dam are acquired by digging the energy lake (Natuurlijk Afsluitdijk, 2008). The energy lake provides a technological advantage when combined with sustainable energy producing technologies to store their unpredictable and uncontrollable power output (Natuurlijk Afsluitdijk, 2008). Although the Advice Commission doubts the coherence of the individual aspects of this project and the cost estimate, this proposal is included into the next competition phase since it provides some elements not included in the other included proposals (C04). Moreover, the lobby activities by Ockels prove fruitful (Leendertse, 2010; Vrijling, 2010; Boddeke, 2010).

The technological interdependencies described in the above three cases indicate that technological solutions competing in a multifunctional project can indeed have complementary technologies. The remaining cases will be described more shortly.

The fourth consortium ‘Grietje Bosker’, proposes to transform the dam area gradually into a landscape that fulfils various demands (RWS et al., 2008). However, this project is excluded because it is insufficiently elaborated and its underlying choices are insufficiently supported (C04).

The fifth consortium ‘Ecorys-Imsa’, recommends to pump the water surplus of the IJsselmeer into the Waddenzee, in combination with a Blue Energy installation, thereby increasing the fresh water supply. Moreover, they suggest wave breakers in the Waddenzee to protect the Afsluitdijk from storm surges (RWS et al., 2008). However, their vision is also excluded as it lacks breadth and argumentation.

The sixth consortium ‘Monument Afsluitdijk’, attempts to strengthen the Afsluitdijk and complement it by building a steady transition from fresh to salt water. However, this project is excluded from the tender after the first round of competition, since it proves too risky, depletes the fresh water supply and anticipated insufficiently on societal effects (C04).

The seventh consortium ‘Tailpiece’, recommends to reinforce the Afsluitdijk with a dam in front of it. However, this recommendation is excluded since lacks argumentation and elaboration (C04).

Finally, the eighth proposal ‘Monument in balance’, proposes to reinforce the Afsluitdijk by installing a storm-shield, and focus the multifunctionality aspects on the onshore areas of Friesland and North Holland. Because this is the only consortium that attempts to do so, they are included into the second market phase.

The project of reference ‘basis reference’ provides a design in which the entire dam is enhanced to allowed water to pass over it. The second design of reference ‘2100-Robust’, embodies a design in which the Afsluitdijk is heightened and allows for only a minor overflow of salt water into the IJsselmeer (RWS et al., 2009). Hence, these solutions focus on water safety only.

Appendix IV: Results of the Afsluitdijk renewal case

Episode 1: the emergence of a demand for a multifunctional dam (2005-2008)

In 1996, the Law on the Dyke [*Dutch: Wet op de Waterkering*] was accepted, which states that once every five years the primary dykes must be tested against predefined safety norms (Noord-Holland, 2006). These norms entail that storm surges may not exceed a dyke (or dam) more than once every 10.000 years and dykes may not break more than once every 125.000 years **[guiding institution]** (De Bruijn et al., 2009). Because of this law, the Construction Service of the Governmental Works Department [*Dutch: Rijkswaterstaat*] administered the first series of complete safety tests to the Afsluitdijk in 2005, according to new hydrological framework conditions (Noord-Holland, 2006). Although the first- but incomplete series of tests indicated that the Afsluitdijk was protected sufficiently, the second series of studies **[+F2]** show that the Afsluitdijk is insufficiently able to withstand normative storm surges and does not comply with the previously mentioned norms (RWS, 2008B) **[+F4]**. Accordingly, in 2005 an explorative study **[+F2]** on the renewal of the Afsluitdijk is published which focuses primarily on the safety issues involved (BOUWDIENST RWS, 2005).

In 2006 the IJsselmeer area Directive of the Governmental Works Department commissions **[+F6]** an integral exploration on the possible solutions (Witteveen en Bos, 2006). This study **[+F2]** includes an inventarization and cost estimate of various solutions to reinforce the dam **[+F4]**, including heightening the dam, with or without a tunnel for the traffic to pass through; making it flood-proof, i.e. allowing some water to spill over the dam; wave-breakers on the mudflats in front of the dam. This research confirms that swift actions should be due 2011 to enhance the protection against high water and that a multifunctional dam has the potential to generate many profits, although these aspects should be further researched **[+F4]**. Moreover, the included market scan indicates that **[+F3]** the government should consult market parties in an early stage. Also during the last quarter of 2006, the institution ‘Foundation Society and Enterprise’ (SMO) was commissioned by the province of Friesland to stimulate, through workshops **[+F3]** and by other means **[+F2]**, inhabitants and other interested actors to formulate their ideas into projects that regard the province in general, but also the Afsluitdijk specifically (SMO & Provincie Fryslând, 2007). This resulted in positive expectations regarding a multifunctional Afsluitdijk among some of the inhabitants of Friesland **[+F4]**.

However, expectations for a multifunctional dam have not always been positive and still are not with respect to for example the installation of wind turbines on the Afsluitdijk (Dekker, 2004). A short illustration points out the clash of norms and values with respect to the different functions that can be fulfilled in the Afsluitdijk area. In 1999, the ‘Interprovincial Project Wind Turbine Park Afsluitdijk’ [IPWA] was studied with regard to the government’s goal of attaining 1500 MW of inland wind energy by 2010 (Haskoning, 1999). However, studies [+F2] indicated that such a park would cause significant environmental damage [-F4] (Dekker, 2004). Moreover, various interest groups, like recreational and environmental groups, fiercely lobbied [-F7] against this project (Steensma, 2003; Bax en Welgraven, 2006). Additionally, such a project would conflict with the declaration signed by the Netherlands in Stade, Germany (Augusteijn-Esser et al., 2002). Royal Haskoning performed a second study [+F2] in 2006, the conclusions of which coincided with their first (SEV III, 2009). As a result, the diplomatic note ‘Space’ [*Dutch: Nota Ruimte*] was accepted in 2006, of which article 4.8.3.1 states that wind turbines are not allowed to be placed in the Afsluitdijk area, due to environmental reasons and to maintain an open view of the horizon [-F4] (VROM, 2006; SMO, 2008). This article formed the major bottleneck to similar proposals that followed (Dekker, 2004). Other regulations that prevent wind turbines and other environment harming technologies to be placed in the area of the Afsluitdijk are composed in the ‘Flora and Fauna Law’ and in the Natura 2000 mandate [-F4], including the ‘Birds-guideline’ (Oosterhuis and van der Grijp, 2003). As a result, each proposal to place environment-damaging technology on and near the Afsluitdijk is inhibited, unless research points out that environmental damage is below the environmental norms (SEV III, 2009; RWS, 2008B). In conclusion, these are the regulations that might hamper the multi-purpose of the Afsluitdijk.

Other, more drastic ideas on a multifunctional Afsluitdijk – plans by Lievense and Ockels – were also developed before the safety test indicated the insufficient safety provided by the

Afsluitdijk **[+F2]**. However, these ideas did not receive significant attention and were considered not cost-effective **[+F4]**. Moreover, the ideas did not appeal to a problem experienced by the government (Leendertse, 2010).

In 2006 and 2007, the Ministry of Public Transport, Public Works and Water Management has attempted **[+F7]** to secure governmental funds for the renewal of the Afsluitdijk. Although, a reservation of 750 million euros for such a project was heavily debated in the cabinet in October 2006 (Waterforum online, 2006), the sum was promised – not officially reserved. The promise of such a large sum formed an extensive drive for market parties to get involved in the project of renewing the Afsluitdijk **[+F4]** (Vermey, 2010; Leendertse, 2010).

During this time, a political trend developed towards a more multifunctional approach in large infrastructural projects like the renewal of the Afsluitdijk. This perspective is made explicit in the government's Water Vision – the vision of the cabinet regarding water policy – of September 2007 **[+F4]** (DG Water, 2007). In line with these developments, the Directorate General Water (DG Water) commissions **[+F6]** a project that should focus **[+F4]** especially on the feasibility of additional demands in renewing the Afsluitdijk: demands that can be fulfilled beside the basic functionality, i.e. the possibilities of a multifunctional dam (SMO, 2008). This 'Research Integral Improvement Afsluitdijk' (OIVA) is executed by the Governmental Works Department, in intensive collaboration with the provinces Friesland and North Holland, the municipalities Wieringen and Wonseradeel, and interested market parties.

Episode 2: The tender contest (Nov. 2007-now)

The goal of the OIVA project is to explore the possibilities for a multifunctional dam, identify the most attractive solution through a tender contest in the project's planning phase; subsequently put this solution out to tender to find the most attractive variant and then realize this solution (Santhagens and Oosting, 2010). The approach to this project is, among others, influenced by the new – since May 2008 – project direction 'quicker and better' and the new – since July 2009 – project approach conditions MIRT (Multiple years programme Infrastructure, Space and Transport) for large infrastructural projects in the DWCS and the Dutch road sector (OEI, 2009). The MIRT program supports a multifunctional dam, as it stimulates various governmental departments to cooperate in large infrastructural projects to fulfil multiple demands at once **[+F4]** (Huizinga-Heringa, 2009). The project is divided into several stages, starting with the initiative stage and ending with the planning stage. The initiative stage is comprised on the one hand of the lobby activities to establish the OIVA's support structure, i.e. the groups and commissions that support its development. On the other hand, it is comprised of three events that take place in parallel, namely the inventarization of ideas through expert sessions; the formulation of ambitions by government; the formulation of the basic framework conditions (RWS et al., 2009). The subsequent planning stage is characterized by a tender contest, in which market parties attempt to develop plans (technological solutions) that integrate the previously inventoried ideas. This tender contest, which is also referred to as a market consultation (RWS et al., 2008; 2009), is comprised of four phases, prequalification; the first market phase; the second market phase and the elaborated tender contest phase. Each phase is discussed individually. The subsequent stages design, construct and possible maintain have at the time of writing not started yet and are therefore not included in this research.

Initiative stage

Wim Leendertse is seen as the initiator of the tender contest of the OIVA project. The tender contest is innovative in the way that market parties never before were enacted in the planning stage of a project (Driebergen, 2010; Leendertse, 2010). Due to Leendertse's position at Staff DG Market & Purchase, and his extensive contacts with market parties, he was in a good position to organise the tender contest **[+F7]** (Leendertse, 2010). He enacted selectors at various levels, located within his personal network. Firstly, he enacts the newly appointed Director-General Water, A. Nijhof **[+F7]**, whom had a mindset open for a new policy approach. The support of the director of DG Water would provide extensive legitimacy at the national level of government. Secondly, he enacted E. Nijpels **[+F7]**, who was just relieved of his function as commissioner of the queen and had significant political influence, which he would use to lobby in The Hague. Thirdly, Leendertse lobbied towards the Innovationplatform

[+F7], with the result that the renewal of the Afsluitdijk became the Innovationplatform's icon of innovation (SMO, 2008). Fourthly, because commission Elverding's 'Quicker and Better'-policy was recently finished, the Governmental Works Department required a test case in which to experiment with this new policy approach. Again, the Afsluitdijk renewal provided a perfect project and became the icon of the 'Quicker and Better' approach as well **[+F7]** (Leendertse, 2010). Fifthly, the director of the Governmental Works Department's Service Ijsselmeer-area was looking for a project that would raise the Service's status that was perceived as rather weak at that moment (Leendertse, 2010). The renewal of the Afsluitdijk fitted perfectly, resulting in the director's full support **[+F7]**; the director would be instated in the tender contest's steering group as well as the advice commission. Sixthly, because municipalities clashed with the Governmental Works Department during the construction tender for the sluice-complexes in the Afsluitdijk, Leendertse offer the municipalities to be involved in the decision making process from the start, allowing them a place in the steering group. Attracted by this prominent position in the decision making process, Leendertse also acquired the support of the municipalities **[+F7]**.

The selectors within this network created by Leendertse also adopted an enactor role in developing the organizational structure that would facilitate the Integral Study Afsluitdijk Renewal (OIVA), see figure A3.1. Nijhof and the State Secretary would chair the steering group that was responsible for the renewal of the Afsluitdijk project towards the cabinet. The steering group, also referred to as the Administrative Consultation, is responsible for the tender contest and consists of regional governors and the State Secretary (RWS et al., 2009). This group selects the consortia during the various phases of selection and will form the structure-vision. The structure-vision is the final document on which the Cabinet bases the decision regarding what the Afsluitdijk renewal will precisely encompass (Driebergen, 2010). Leendertse and Nijpels would compose the independent advise commission and in the process selected only critical experts that where positive to such a new approach (Leendertse, 2010). Nijpels subsequently chaired this commission. The advice commission is an independent commission, comprised of experts of the public and private sector, that provides asked and unasked advice on which the steering group acts (Driebergen, 2010). Leendertse in his new role of process manager composed the project group that is instituted with the goal to facilitate the diffusion of knowledge [F3] and expectations [F4] between governmental and private organizations, so that the market parties' projects comply with the demands of the steering group. This is done through dialogue sessions between the project group and market parties (RWS IJsselmeergebied, 2008). The project group is comprised of mostly Governmental Works Department employees, two consultants and four regional representatives. Moreover, various experts support this group in their dialogue sessions. Moreover, technical, societal and administrative experts from numerous organizations like TU Delft, Deltares and different levels of government were also available for more in-depth questions (Driebergen, 2010; Leendertse, 2010). Finally, Leendertse also takes seat in the interdepartmental work group comprised of representatives of several ministries that were also involved in the definition of ambitions and the reservation of governmental funds to secure these ambitions (Santhagens and Oosting, 2010). This group occasionally meets (increasingly more often as the planning stage progresses) to ensure that the ambitions of every department are retained (Driebergen, 2010; Leenderste, 2010). Figure A3.1 shows the overall structure.

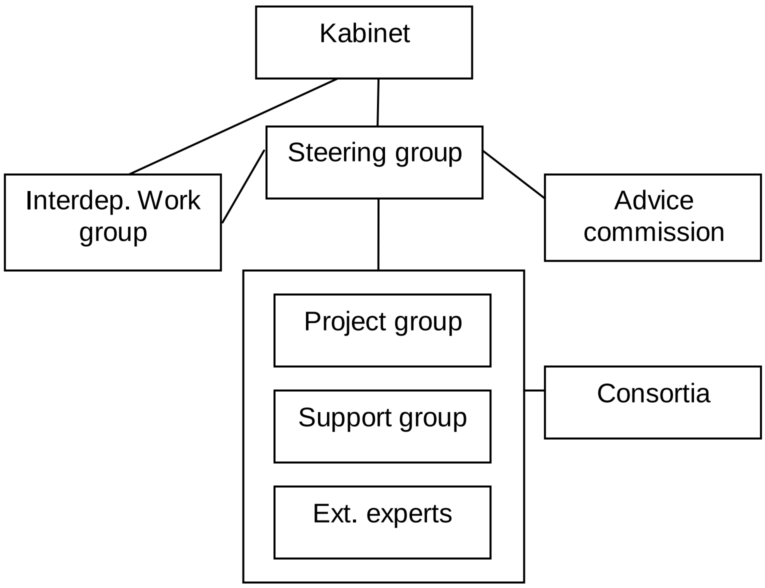


Figure A3.1, the organisational structure of the tender contest

The OIVA project starts in November 2007, when the institution SMO was issued by the DG Water to catalogue and rubricate all ideas regarding the renewal of the Afsluitdijk. Three reasons underlie this study (Leendertse, 2010). Firstly, it provided the basis of ideas on which integrated technological solutions could be developed. Secondly, it provided an opportunity for involving the many interest groups that were already sending their ideas for an Afsluitdijk renewal to the organizational structure. Thirdly, it provided an opportunity to gain attention in the media and show that the OIVA was actively developing. With these purposes the SMO organized five workshops in January and February 2008 with experts and stakeholder groups (the latter had to pay to be included) **[+F3]** (SMO, 2008). Input to these workshops was a starting note that incorporated all existing ideas on the renewal of the Afsluitdijk as well as similar solutions elsewhere in the world **[+F3]** (SMO, 2008). Examples of such solutions are the plan Waterlely and plan Lievense that both involve a multifunctional vision of the Afsluitdijk, including an energiebuffer (RWS and CURNET, 2008; Wassink, 2008). The participative exploration resulted in a report in which various ideas for a multifunctional Afsluitdijk are described **[+F2]**. Moreover, it resulted in more support for a multifunctional Afsluitdijk **[+F7]** (SMO, 2008). At the same time, a group of representatives of various ministries – the interdepartmental work group – attempts to formulate their ambitions regarding the additional values to be generated by renewing the Afsluitdijk **[+F4]** (SMO, 2008). Moreover, the technical framework conditions or ‘basic demands’ for the Afsluitdijk renewal are explored **[+F2]** and formulated in accordance with the Law on the Dyke **[+F4]** (RWS, 2008B). These ambitions and basic demands are integrated into an information document that, together with the report on the participative exploration by SMO, will serve as the input for the market parties to guide their studies during the subsequent tender contest **[+F4]** (RWS et al., 2009). Leendertse (2010) stresses that governmental agents formulate the ambitions and framework conditions that serve as information documents to the tender contest broadly **[broad F4]** with a purpose, namely to provide room for creativity in which the innovative capacity of the market parties can be exploited. Governmental agents believe that innovative designs are required to provide in additional demands beside safety (RWS et al., 2009).

Planning stage, prequalification phase (March – May 2008)

The tender contest starts with the publication of its respective advertisement on March 14, 2008. In it, market parties were asked to develop a vision (technological solution) that integrates the predefined demands into one project, comprised of an implementation scheme, stakeholder analysis, cost estimate and feasibility study (RWS IJSSELMEERGEBIED, 2008). Market parties were invited to sign in for the tender contest and to join the information day **[+F3]**. During this day, the project team provided information and explained the conditions of the contest (Driebergen, 2010). The consortia indicate that before this day, some market parties where under the impression that realisation of the winning design would follow this tender contest (Boddeke, 2010; Vermey, 2010). However, under the direction of enactor Leendertse, these inconsistencies in expectations were removed by the clear vision that this contest was merely a tender contest that is independent of subsequent realisation of the technological solutions (Boddeke, 2010) **[+F4]**. This information day also provided an opportunity for interested market parties to meet and lobby towards other parties to form consortia (RWS IJSSELMEERGEBIED, 2008). However, consortium representatives indicate that mostly existing networks were used to form consortia (Lenferink et al., 2009; Vermey, 2010; Fiselier, 2010). Arcadis did meet Dredging International during the information day, resulting in their formation of a consortium (Boddeke, 2010). Boddeke (2010) also illustrates that market parties outside their network had been contacted.

Accordingly, both relatively new **[+F1]** and incumbent **[+F7]** market parties were enacted and decided to enter the contest, which can be seen as still an emerging market due to its premature stage. Bruggeman (2010) identifies 18 organizations that are new to large infrastructural projects in the DWCS and only 16 incumbents. The most important reason for entering the contest was exposure (Lenferink et al., 2009; Vermey, 2010; Fiselier, 2010); with specific goals for each organisation. Nuon wanted to focus more on sustainable energy; Arcadis wanted to manifest itself more strongly in the water sector and Derdging International wanted a stronger position in the Dutch market (Boddeke, 2010). By entering the contest and acquiring positive exposure, the market parties hope to get closer to their goal. Another reason for joining the tender contest was to increase their changes at acquiring the 750 million euros that had finally been reserved for the renewal of the Afsluitdijk, due to lobby activities by various governmental actors (Leendertse, 2010; Boddeke, 2010). However, various prominent incumbent organizations did not enter the contest for numerous reasons **[bottlenecks to F7]**. The demanded investments were too high compared to the benefits (Lenferink et al., 2009). Organizations believed to be involved in a too early phase had negative experiences with such tender contests in other sectors. They perceived a lack of time, money and human resources (Lenferink et al., 2009). Moreover, they feared for ‘cherry picking’ due to ill formulated intellectual property rights policy, although this policy was tailored according to the Covenant Intellectual Property so that the property of the intellectual rights remained – although not exclusive to the government – with the market parties (Lenferink et al., 2009; RWS et al., 2009). Furthermore, some organizations were not able to enact prominent knowledge organizations and therefore did not form a consortium (Lenferink et al., 2009).

After deciding to enter the contest, organisations lobbied amongst each other to form consortia **[+F7]** with supporting competences that enabled them to comply with the basic and additional demands of the tender described in the tender supporting document (RWS IJsselmeergebied, 2008). Eventually, nine ‘consortia’ attempted to sign in for the prequalification round.

During this prequalification, a maximum of eight consortia would be selected that all had to comply with the prequalification requirements (Driebergen, 2010). These requirements demanded expertise and experience in developing integral technological solutions on relevant projects; in financing and exploiting of such projects, and experience in cooperating with governments in complex societal problems **[+F4]** (RWS IJsselmeergebied, 2008). Only one party did not pass the prequalification round, as it was a political group (the Party of the Friessen) that did not comply with the prequalification requirements (Driebergen, 2010). Partly because most interactions with the steering- and project group are in Dutch and because advertisements were placed in Dutch newspapers, all responding consortia comprise Dutch organizations, or organizations with subsidiaries in the Netherlands (RWS et al., 2008).

The eight consortia that have been selected vary extensively in composition and accordingly, also in their incentive for participation. On the one hand, Waddenwerken, Afsluitdijk 21st century, Tailpiece and Natural Afsluitdijk are consortia that comprise, beside landscape artists and consultants, large contractors and in some cases energy companies. It is their goal to increase their chance of realizing the technological solution they create (Vermey, 2010; Boddeke, 2010). On the other hand, the other four consortia do not comprise large contractors. Accordingly, it is their goal to only create a high quality design and benefit from exposure (Fiselier, 2010). Moreover, the consortia are comprised of two to seven member organisations.

Planning stage, tender contest phase 1(March 2008 – September 2008)

Before developing their technological solution, the consortia determine the structure under which the technological solution is created. Boddeke (2010) indicates that the consortium 21st century established a project group of seven employees of the different firms. This group was supported by other employees and directed by a steering group comprised of four of the member firms' directors **[+F6]**. In accordance, Fiselier (2010) indicates that the consortium 'Mudflat works' established a six person project group, supported by five to seven others. However, not all consortia establish such a distinctive project oriented structure. Vermey (2010) indicates that consortium Tailpiece attributed the project to the regional divisions of Grontmij and from thereon developed their technological solution. Moreover, the strategic behaviour of the consortia differs also with regard to the financial funds allocated **[+F6]** by the consortia to the project. The organizations that did form project groups also determined the height of the financial funds before initiating the project (Boddeke, 2010; Fiselier, 2010), whereas the others simply share the costs afterwards (Vermey, 2010). Moreover, the height of investments during this first market phase differ, ranging from 70.000 euros for Mudflat works (Fiselier, 2010) to 100.000 for Tailpiece (Vermey, 2010) and even 139.000 euros for Afsluitdijk 21st century (Boddeke, 2010). The percentages in which the consortia's member organisations partake in the costs were in by all consortia set in advance (Boddeken, 2010; Fiselier, 2010; Vermey, 2010). The financial compensation of 35,000 euros **[+F5]** offered by the government (RWS IJSSELMEERGEBIED, 2008; Driebergen, 2010) was perceived as too low by many of the consortia (Lenferink et al., 2009), but the interviewees experience this as a learning experience for the government (Boddeke, 2010; Vermey, 2010).

With resources allocated to the project, the consortia started developing their technological solution **[+F2]**, mostly by combining the existing knowledge that is shared through brainstorm sessions within the consortium **[+F3]** (Boddeke, 2010). However, external actors are also involved. In this process of knowledge diffusion, external experts, stakeholders and the project group are involved in different extents, depending on the consortia's strategy. In this respect, the consortia's strategies differ. Vermey (2010) indicates that the consortium Tailpiece initially organized an intensive two-day conference **[+F3]** in which stakeholders, experts and the project group were invited to share their views and expectations regarding the renewal of the Afsluitdijk. Boddeke (2010) on the other hand indicates that involvement of stakeholders was not pivotal to the establishment of consortium Afsluitdijk 21st century's vision, because they believed to be already sufficiently aware of the stakeholders' need through the past interactions they had within their elaborate network. Moreover, the perception of stakeholders can often be discovered through other channels of communication, like the internet. In order to facilitate the diffusion of knowledge as well as the guidance of search, the project team was assigned with the task to provide the consortium with dialogue sessions (RWS IJsselmeergebied, 2008). This resulted in between 2-4 dialogue sessions per consortia **[+F3]**, in which the project group and its support structure attempted to provide answers to the consortia's technical, societal and/or managerial questions (Driebergen, 2010; Leendertse, 2010; RWS IJsselmeergebied, 2008). However, the consortia indicate that the quality of this feedback was lacking in the technical aspect. Boddeke (2010) indicates that though the societal and managerial expertise of the project group was sufficient, their technical expertise was very weak during the first market phase. This hampered the diffusion of more technical knowledge **[-technical F3]** (Lenferink et al., 2009). Moreover, Vermey (2010) indicates that due to their strategic decision to have a two-day conference, no other dialogue sessions could be used. Overall, the consortia see the transparency between government and market, i.e. the diffusion of knowledge, as a driver to innovation (Lenferink et al., 2009).

To maintain legitimacy of the OIVA study, Leendertse also provided the opportunity for stakeholder groups to influence the tender contest, by taking place in the dialogue sessions and by studying and reflecting on the technological solutions.

Some consortia use completely new technologies or apply existing technologies to a new setting and therefore have to perform more studies **[+F2]** than the other consortia to reduce the risk level of their technological solution. An example of such a consortium is Mudflat works, although such in-depth studies were a more common occurrence during later phases (Santhagens and Oosting, 2010). However, these studies were not performed to a large extent during this phase, as such a level of specificity was not demanded by the project group (Boddeke, 2010).

Although the consortia's proposals have to comply with numerous formal and informal institutions (RWS, 2008B), the framework conditions for the first competition phase are formulated very broadly, to allow as many levee designs as possible (Leendertse, 2010; RWS IJsselmeergebied, 2008). However, the consortia do not just see the guidance of search as broad, but also as weak, since it remains unclear fro them what the project group wants **[-F4]** (Lenferink et al., 2009; Vermey, 2010). The consortium Tailpiece perceived this and the inability to have more dialogue sessions, as a bottleneck because they did not know whether to interpret this tender contest as a question of technical implementation or as a question of regional organisation (Vermey, 2010). Although this seems to be an exceptional case in which the lack of guidance by the project group resulted in a mismatching technological solution (Lenferink et al., 2009; C04), DG Water acknowledges that every misunderstanding is one too many and that guidance should be better performed (Santhagens and Oosting, 2010). To facilitate the guidance of search, an additional information document was shared with the consortia, in which the specificities for ranking were described **[+F4]**. Moreover, many consortia expected that their technological solution mainly had to satisfy the demand of the Governmental Works Department, that is, to provide sufficient safety (Vermey, 2010; Lenferink et al., 2009). Therefore, the focus was mainly on safety.

During this phase, the consortia have oriented on different ideas **[+broad F4]**, even the ones that had already developed distinctive ideas before the tender contest. For example, the Afsluitdijk 21st century consortium not only looked at their plan 'Water Lilly' (referring to a second dam in the Ijsselmeer, with a brackish lake in-between), but also discussed the possibilities for a protective wall on the dam or sand deposit before it (Boddeke, 2010). However, the consortia indicate that they have not studied each other's progress (Boddeke, 2010). Eventually, eight distinctive visions or technological solutions were created (RWS et al., 2008) that differ in the location of dam reinforcement structures, and pursuit of additional demands. There are various explanations for this divergence, beside the fact that most consortia have already very different starting points due to their experiences. The initial tender contest document, in which the ambitions were described, was very broad, leaving a lot of room for the consortia to weight and allocate these ambitions (Santhagens and Oosting, 2010; Leendertse, 2010). Landscape artists maintain different architectural principles in their visions (Fiselier, 2010). Regulations like Natura 2000 are interpreted ambiguously, for example, consortia have different views of whether construction on the Waddenzee side is permitted. Finally, as we have already indicated, the consortia have different goals in their participation of this tender and therefore put their focus on different aspects (Fiselier, 2010).

Near the end of this phase, the consortia present their project to the jury of experts and the project team (Driebergen, 2010). The fact that the advice commission was not present was experienced as a bottleneck to knowledge diffusion according to the consortia **[Bottleneck to F3]** (Lenferink et al., 2009). The consortia are enabled to incorporate the feedback they receive after their presentation into their technological solution **[+F3]**. This final project is handed in; including the steps that the consortium plans to take to elaborate their technological solution in the next market phase. These projects are first reviewed and selected by the project group, resulting in the selection in table A3.1 (Leendertse, 2010). On August 25 2008, the advice commission reviews the documents handed in by the consortia and selects three leading projects for further elaboration, with the possible selection of a fourth (C04). This selection is supported by the intention to maintain the divergence of the technological trajectories that constitute the difference between the consortia's projects **[broad F4]**. Each of the three leading projects represents a completely different way of water protection, namely by reinforcing the mudflats in the Waddenzee, creating a brackish zone on the Ijsselmeer side or by 'simply' reinforcing the Afsluitdijk (C04). Because the Afsluitdijk should serve as an icon for Dutch capabilities, government perceives innovation as an important condition **[+F4] (**RWS et al., 2009). Therefore, the Innovatieplatform was commissioned to study the innovativeness of each project **[+F2]** and accordingly recommend the selection of four consortia on September 4 **[+F4]** (De Boer et al., 2008). Furthermore, the 'College van Rijksadviseurs' (CRA) also studied the various projects **[+F2]**, and recommended the selection of four consortia **[+F4]**. Finally, on September 16 2008, the steering group selected four consortia to proceed to the next round (RWS, 2008C). Table A3.1 provides an overview of the decisions of the various actor groups. It is interesting to find that the steering group does not take over the preferences of the other groups, which would imply that the consortium Monument Afsluitdijk advanced to the next round of competition. Instead, the consortium of Wubbo Ockels – Natural Afsluitdijk – won. Leendertse explains that the ranking by the advice commission was initially the same as that of the project group. However, due to extensive lobbying activities of Ockels among political The Hague and the Innovationplatform **[+F7]**, it was politically unattractive to exclude such a consortium (Vrijling, 2010; Leendertse, 2010; Vermey, 2010). Hence, it is interesting to see that the Innovationplatform also included Ockels' consortium. The other consortia are aware that selection decisions can be politically supported (Vermey, 2010) and have had the opportunity to meet with these politicians to explain the political background of their technological solution **[+F7]**, i.e. what aspects do they find important: landscape, recreation, sustainable energy or innovation in general (Leendertse, 2010)?

	Mudflats works	Afsluitdijk 21st century	Monument Afsluitdijk	Grietje Bosker	Ecorys-Imsa	Natural Afsluitdijk	Tailpiece	Monument in balance
Project group	X	X	X					X
Advice Commission	X	X				(X)		X
CRA	X	X	X					X
Innovation platform	X	X	X			X		
Steering group	**X**	**X**				**X**		**X**

Table A3.1, proposed selection of consortia in first market phase by various actors

Planning stage, tender contest phase 2 (September 2008 – December 2008)

With the selection of the four consortia that proceed to the second tender contest phase, the project support structure also guides their search **[+F4]** for this subsequent phase by formulating specific questions to the consortia regarding aspects of their technological solutions (Lenferink et al., 2009). Although these questions provided an important guidance of the search, they were also too numerous and too demanding according to the consortia (Lenferink et al., 2009). Accordingly, the largest bottleneck to answering these questions was the lack of time, which forced the consortia to make assumptions and process new information attained from dialogue sessions too quickly. This resulted in operational errors that cost the consortia even more time. Another bottleneck to answer these questions is the lack of financial compensation [F6] with respect to the marketing opportunities of the elaborated technological solutions (Boddeke, 2010; Lenferink et al., 2010). The consortia's expenses increased during this episode for some consortia, e.g. Afsluitdijk 21st century spent 169.000 euros, while the expenses remained at the same level for other consortia, e.g. Mudflats Works whom spent approximately 70.000 euros. The consortia indicate that, besides the lack of time, no bottlenecks including the economical crisis influenced the consortia's spending on the development of their technological solutions (Boddeke, 2010).

Beside the elaboration of the four consortia's technological solutions **[+F2]**, the Service Ijsselmeer area of the Governmental Works Department also commences the creation of two shadow designs **[+F2]** because this is compulsory to manage large infrastructural projects. Before initiation of these studies, the consortia attribute financial funds **[+F6]**, divided among its members, to elaborate the technological solutions during this phase. When additional costs arise at the end of the phase, they are shared by predefined percentages among the consortium members (Boddeke, 2010).

The consortia indicate that the publication **[+F3]** of the results of the first tender contest phase leads (unconsciously) to converging technological solutions **[+F4]**. In order to elaborate their technological designs in the second phase, additional state-of-the-art studies **[+F2]** are required to support technological progress, e.g. on the morphological aspects of mudflats (Fiselier, 2010; Waddenwerken, 2008). For example, the Mudflat Works found that their mudflats improved – although very slightly – the performance of a Blue energy installation by capturing sludge particles that would otherwise congest the installations saltwater input **[+F4]** (Waddenwerken, 2008). Moreover, existing knowledge at the sharing thereof through brainstorm sessions remains an important source for the development of the technological solutions **[+F3]** (Fiselier, 2010; Lenferink et al., 2009). In addition, the project group commissions TU Delft and Deltares to validate the innovative aspects of the consortia's technological solutions, e.g. do mudflats actually work? (Driebergen, 2010; Santhagens and Oosting, 2010).

The consortia indicate that during the second tender contest phase dialogue sessions became more numerous – three to five times per consortium (Leendertse, 2010; Boddeke, 2010) – and acquired more technical depth, due to the inclusion of technical experts from the Governmental Works Department **[+F3]** (Boddeke, 2010). Moreover, these sessions attributed in prioritizing the questions asked at the initiation of this phase **[+F4]** (Lenferink et el., 2009). Hence, they also guided the search toward the attribution of state-of-the-art studies. Accordingly, these sessions strongly stimulated the development of the technological solutions (Boddeke, 2010; Lenferink et al., 2009). At the end of this phase, each consortium had to present its technological solution and defend it in the discussion that followed (Lenferink et al., 2010) **[+F3]**.

A bottleneck identified during this second phase is the lack of competition between the consortia, because there is no tacit reward in providing the best technological solution, only exposure that is reduced due to the expected cherry-picking of the government after this tender contest (Lenferink et al., 2009). Moreover, in reflection Boddeke (2010) stresses that the rewards in tender contests like these cannot be used frequently, as the exposure benefits will be reduced: what is now seen as a unique icon project might in other cases become an ordinary project that does not provide much opportunity for exposure. Moreover, it would also not be beneficial to such projects if the government decided to continue with one of the reference designs. However, all consortia agree that exposure was very beneficial and made the project a success.

On December 1 2008 all consortia's technological solutions are handed in and presented for the Advice Commission, the project group and interest groups **[+F3]**. Moreover, in December 2008, the concept for the National Waterplan 2010-2015 is published, which stressed the importance of multifunctional approaches to large infrastructural projects like the Afsluitdijk renewal **[+F7]** (Nationaal Waterplan, 2009).

During this time, two of the four remaining consortia – Natural Afsluitdijk and Afsluitdijk 21st century – did not sign the contract that stated that the consortia's ideas could be used by the government and that they would be compensated with 70.000 euros for their efforts at this stage. The reason was that the consortia wanted to increase their chances of implementation by possessing crucial Intellectual Property Rights (Boddeke, 2010). Subsequent discussions with governmental lawyers lasts 1.5 years **[+F7]**, leading to the agreement in May 2010, stating that if the government decides to use the Intellectual Property Rights during the design and construction phase, a financial compensation of approximately 2-7 million euros is offered **[+F5]** (Leendertse, 2010).

The tender contest has resulted in good and innovative technological solutions, which would not have been created by the government themselves (Santhagens and Oosting, 2010).

Planning stage, decision phase (January 2009 – now)

During this stage, the tender contest is officially over, although the four remaining consortia and their buyer-supplier relation with the project-organization is retained. The goal of the organizational structure is not necessarily to point out a winning design, they can also combine parts of each technological solution and integrate them into a winning solution

(Santhagens and Oosting, 2010; Van der Meulen, 2010; Driebergen, 2010). This goal is in accordance with commission Elverding's advice stressing that a broad scope should be maintained during the planning phase of an infrastructural project, that is to be narrowed down to a the final technological solution **[+F4]** (Sneller en Beter, 2009). The technological solution provides room for optimization, as multiple variants are possible; these variants will compete during a future tender contest in the design phase (Santhagens and Oosting, 2010).

During this expected decision phase, the OIVA's organisational structure, although the same governmental actors are involved as during the tender contest[5]. It is comprised of five consultations at different levels, see figure A3.2 (Van der Meulen, 2010; Santhagens and Oosting, 2010). The organizational structure consultation is comprised of the provinces, regional water authorities and municipalities, chaired by the project director of the Governmental Works Department and takes place on a daily basis (Van der Meulen, 2010; Santhagens and Oosting, 2010). This consultation focuses on the technological implications of the consortia's solutions, facilitates the acquisition of knowledge on these issues and maintains contacts with consortia and interest groups (Vrugt and van de Beek, 2009). Moreover, this consultation provides the input for the preparatory management consultation, which is also chaired by the Governmental Works Department and prepares the selection of the final technological solution. Moreover, it attempts to tune the interest at the various levels of governance (Vrugt and van de Beek, 2009). In the approximately monthly interdepartmental work group consultation, various ministries discuss the fulfilment of additional functions with the DG Water (Van der Meulen, 2010). The interdepartmental directors' consultation bases its input of the interdepartmental work group consultation and includes ministry representatives that discuss approximately twice every three months the allocation of governmental funds to support the fulfilment of additional functions in the OIVA (Van der Meulen, 2010). This consultation provides the input for the interdepartmental director's consultation, in which delegates, 'dike graves' and council members attempt to agree on the administrative plan for the Afsluitdijk renewal (Vrugt and van de Beek, 2009). The management consultation is prepared by both the preparatory management consultation and the interdepartmental director's consultation and decides on the decision regarding the final technological solution, which it presents to the State Secretary whom is responsible for the project. Furthermore, the independent advice commission that provides asked and unasked advice supports these consultations (Van der Meulen, 2010).

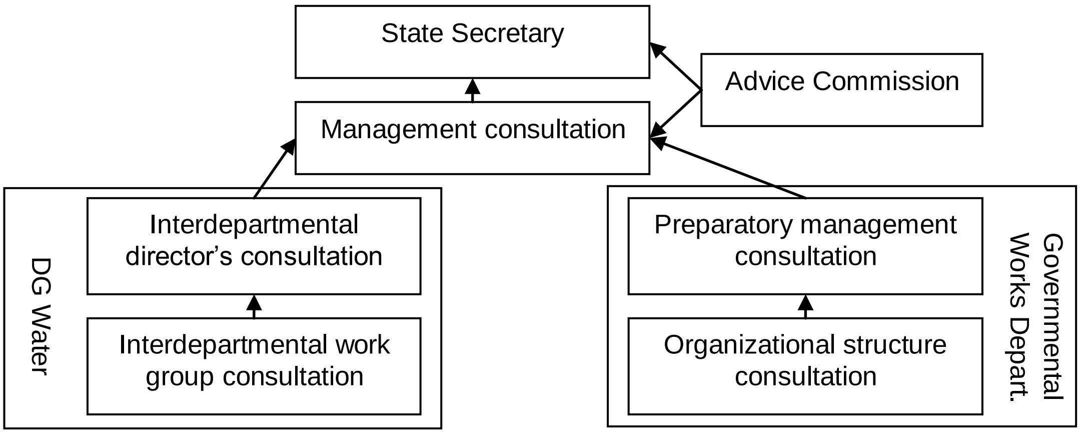


Figure A3.2, The organization structure during the decision phase of the tender contest episode of the OIVA

Although the OIVA organization attempts to stimulate innovation through this project, the directors of DG Water also state that innovative solutions that are not proven, i.e. inventions, have a small chance of becoming integrated in the final technological solution (Santhagens and Oosting, 2010). Accordingly, it is the goal of this decision phase to acquire more technical knowledge on the remaining uncertainties of consortia's technological solutions as well as on the possibilities for increasing their performance before selecting the best alternative.

[5] These are ministries of VenW, VROm, EZ, LNV, OCW, Finanance, and Defense; the Provinces Fryslan and Noord-Holland, and the municipalities Wunseradiel and Wieringen.

Therefore, DG Water and the Governmental Works Department have reserved 2.4 and 1.9 million euros respectively **[+F5]** (Vrugt and van de Beek, 2009). With these funds, the technological solutions are sent to expert organizations – external organizations and public institutes – for verification on specific points **[+F2]**. For example, ECN studies the energy aspect of the technological solutions (Lako and Wakker, 2009), whereas TU Delft studies the safety aspect (Vrijling and Kanning, 2009). The ECN study indicates that a Blue energy installation is not yet profitable on the Afsluitdijk, but that it might be in 2030 due to technological development. Therefore, the OIVA management considers reserving space for a pilot Blue energy installation that can be scaled up once economically feasible **[+F4]** (Santhagens and Oosting, 2010). Moreover, the solutions are sent to interest groups that subsequently voice their support for the OIVA project and give their opinion in regard to the solutions **[+F4]** (RWS et al., 2009). This way, the project group attempts to maintain support for the OIVA project **[+F7]** and the technological solution that will be selected. Furthermore, expert sessions **[+F3]** are held on the safety issues of the technological solution's dam reinforcement component (Vrugt and van de Beek, 2009).

Moreover, the organizational structure asks the consortia specific question to elaborate their technological solutions **[+F4]** (Vrugt and Van de Beek, 2009). In contrast to the tender contest, the consortia are paid by the government for the time they invest in the researching the answers to these questions with the funds already reserved [F5] (Santhagens and Oosting, 2010; Van der Meulen, 2010). As a result, the consortia perform various studies **[+F2]** to reduce the uncertainties of their technological solutions and to explore the possibilities for performance improvement.

Meanwhile, in December 2009 the Dutch National Waterplan is published which supports the notion of a multifunctional dam, providing legitimacy to the goal of the OIVA **[+F7]** (VenW et al., 2009).

As a result of the expectations **[+F4]** generated by the consortia's studies, an additional study **[+F2]** is commissioned by the Governmental Works Department and executed by the TU Delft. The study focuses on the risk profiles of the innovative safety designs by Mudflats Works and Monument Afsluitdijk, indicating that these solutions, although possibly cheaper, involve higher risks than the conventional safety solutions do **[+F4]**.

Subsequently, based on the previously discussed studies by both the consortia and expert organizations, a planMER (plan environment effects report) study commences in January 2010 **[+F2]** (projectteam, 2010). Such a study combines the results of all studies that have reviewed the technological solutions and subsequently researches their respective environmental effects, forming a basis for comparing the solutions. This study is compulsory according to European guideline 2001/42/EG. The study is administered by Grontmij, an organization of the consortium Tailpiece that lost during the first competition round. The organizational structure choose a market party that has no stakes in the current decision process (Santhagens and Oosting, 2010; Van der Meulen, 2010). At this stage, the organizational structure still attempts to involve stakeholder groups to discuss the feasibility of and objections against the technological solutions [F3] (Van der Meulen, 2010). For example, the planMER, published in May, is discussed with stakeholder groups so that comments can be quickly taken along in the decision process **[+F3]**.

In some cases, additional studies lead to clashing results between the consortia and the expert organizations. For example, the Waddenzee-lobby indicates that mudflats in the Waddenzee is bad for the environment and clings on the Natura 2000 regulation that forbids such developments **[-F4]** (Fiselier, 2010). However, the Mudflat Works consortium is convinced that their solution – although in conflict with Natura 2000 – will lead to surplus in ecological values **[+F4]** (Fiselier, 2010). Such conflicting results are being studied during this decision phase, so that a well-founded decision can be made regarding the winning technological solution. Yet, consortia indicate that there is not enough knowledge to make the important decision of selecting a final technological solution, since the project's organizational structure focuses too much on comparing the independent components instead of also researching the opportunities for optimization of the components and solution as a whole **[-F4]** (Fiselier, 2010). On the other hand, governmental actors perceive this difference because of optimization to be so small, that it will not effect the decision making process (Santhagens and Oosting, 2010).

During this phase, a kKBA (cost-benefit analysis) **[+F2]** and a subsequent MKBA (societal cost-benefit analysis) **[+F2]** are also administered. The first is a cost and benefit analysis of the consortia's technological solutions performed by Decisio and Tauw. However, due to the different levels of elaboration, a full MKBA can only be administered after the consortia have answered some of the questions discussed earlier (Decisio and Tauw, 2009). The MKBA translates determines the societal costs and benefits according to the Dutch (OEI-) guidelines for infrastructural projects and is executed by the Netherlands Bureau for Economic Policy Analysis, Decisio and Tauw (Santhagens and Oosting, 2010). At the time of writing, it remains uncertain who is going to pay for the additional values of the consortia's technological solutions. Although, the Governmental Works Department has reserved money for the safety measures to be taken, no funds have been reserved for example for a Blue energy installation (Van der Meulen, 2010). Government pays for the functions like safety, nature, landscape and possibly recreation, but sustainable energy installations are to be paid by private funds as well (Van der Meulen, 2010).

Together, the MKBA and planMER provide the input for the decision regarding the final technological solution (Projectteam, 2010). This decision is made according to the deliberate framework **[+F4]**, a framework developed by the interdepartmental director's consultation that translates the government's ambitions and demands into a framework to which the technological solutions can be ranked (Santhagens and Oosting, 2010). During this phase, the interdepartmental work group and director's consultation attempt to rank the individual parts of each technological solution, e.g. the dam reinforcement apart from the sustainable energy installation and location, as well as the integrated technological solution as a whole (Santhagens and Oosting, 2010; Driebergen, 2010). A preliminary analysis already indicates that some components of the technological solutions are not feasible or cannot be combined **[-F4]** (Santhagens and Oosting, 2010).

The decision for the selection of the final technological solution will not only be based on the elaborated technological solutions, the planMer and the MKBA, but also on the political agenda of the cabinet. However, this decision is delayed by to the fall of the Dutch Cabinet in February 2010, since this decision is labelled as 'controversial'. Accordingly, the decision will have to wait for the new cabinet to be established. Interviewees expect this decision will be made in 2011 (Santhagens and Oosting, 2010; RWS.nl, 2010a). Moreover, another important external influence on the decision making process is the current financial crisis, which hampers the ability of the ministries to reserve funds for the additional demands **[bottleneck to F5]** (van der Meulen, 2010; Santhagens and Oosting, 2010). This event for example negatively influences the chances of the Natural Afsluitdijk consortium's technological solution to be selected, as this solution involves many additional demands that require a lot of additional funds (RWS et al., 2009).

Appendix V: Roles of the interviewees of the Maeslantkering case

Schreuders, A.M.

- Director and enactor of the ‘Study storm surge barrier New Waterway’
- Initiator of the Design and Construct tender in the Dutch Water Construction Sector
- Advisor to the Minister of the Governmental Works Department

Hoogland, MSc. J.R.

- Enactor of the feasibility study in 1985
- Until 1987, head of the Dyke Service of the Governmental Works Department (now named ‘DG Water’), thereby also involved in the ‘Oosterschelde kering’ barrier.
- Advisor of the minister of the Governmental Works Department on dykes
- Responsible for the MER on the NSSB in the New Waterway
- Member of the Steer group of the CSW support structure
- Chairman of the Coordination group of the CSW support structure

Huis in 't Veld, MSc. J.C.

- Involved in the construction of the ‘Oosterschelde kering’ barrier
- Head of the feasibility study in 1985
- Member of the Coordination group of the CSW support structure
- Member of the Test group of the CSW support structure
- Chairman of the Work group Technique of the CSW support structure

Visser, T.

- Head of the Sluices and Dam Service [Directie Sluizen en Stuwen] and head of the Bridges Service [Directie Bruggen]. As such also involved in the construction of the ‘Oosterschelde kering’ barrier. These Services combined into the Construction Service [Bouwdienst] of the Governmental Works Department, of which he was the Head-engineer director until 1996.
- Member of the Steer group of the CSW support structure

Vrijling, Prof. MSc. J.K.

- Member of the Work group Hydraulics of the CSW support structure
- Member of the Work group Technique of the CSW support structure

Olierook, MSc. R.

- Employed by the Bridges Service, department Steel, mechanical engineering and electronics until 1989 involved in the selection process of the consortia’s proposals
- Head of the Construction Service [Bouwdienst] from 1993 to the finishing of the Maeslantkering.

Toussaint, MSc. B.

- Historian of the Governmental Works Department

Van Oorschot, MSc. J.H.

- Leader tender team of the BMK during the tender contest period (’87-’89)
- Project leader of the sector gates design by the BMK (’89 on)
- Board of Directors that supervised the construction of the barrier

Nederend, MSc. J.M.

- Employed by the BMK and involved in the creation and up-scaling of the BMK design
- Team leader of part of the BMK design until the barrier construction was complete in ’97.

Den Ouden, J.

- Principal of Mercon Steel Structures B.V., member of the Storcom consortium
- Member of the Board of the Storcom consortium

Koopmans, G.

- Employee of the BMK consortium

Appendix VI: Roles of the interviewees of the Afsluitdijk renewal case

Driebergen, J.

- Member of the project group that facilitated the study Integral Improvement Afsluitdijk, representing the Governmental Work department's 'IJsselmeergebied' division.

Vermey, P.

- Head of department River & Maritime Works, Grontmij
- Member of project group of the consortium 'Tailpiece' [*Dutch: Sluitstuk*]

Boddeke, CE D.

- Project leader of the consortium 'Afsluitdijk 21st century' [*Dutch: Afsluitdijk 21ste eeuw*], representative of the organisation Arcadis

Fiselier, J.

- Project leader of the consortium 'Mudflats works' [*Dutch: Waddenwerken*], representative of the organisation DHV

Van der Vermeulen, Y.

- Project director of the study Integral Improvement Afsluitdijk

Oosting, LLM R.G.H.

- Involved in the Afsluitdijk renewal project as project leader Toekomst Afsluitdijk

Santhagens, MSc L.R.

- Involved in the Afsluitdijk renewal project as Head of Department Regions [gebieden] from September 2009 until now
- Involved in the Afsluitdijk renewal project as Head of Department Water and User functions from 2007 until September 2009

Leendertse, CE W.L.

- member of the interdepartmental workgroup
- member of the project team
- initiator of the market exploration through his function at the Governmental Works Department at Staff DG Market & Incount