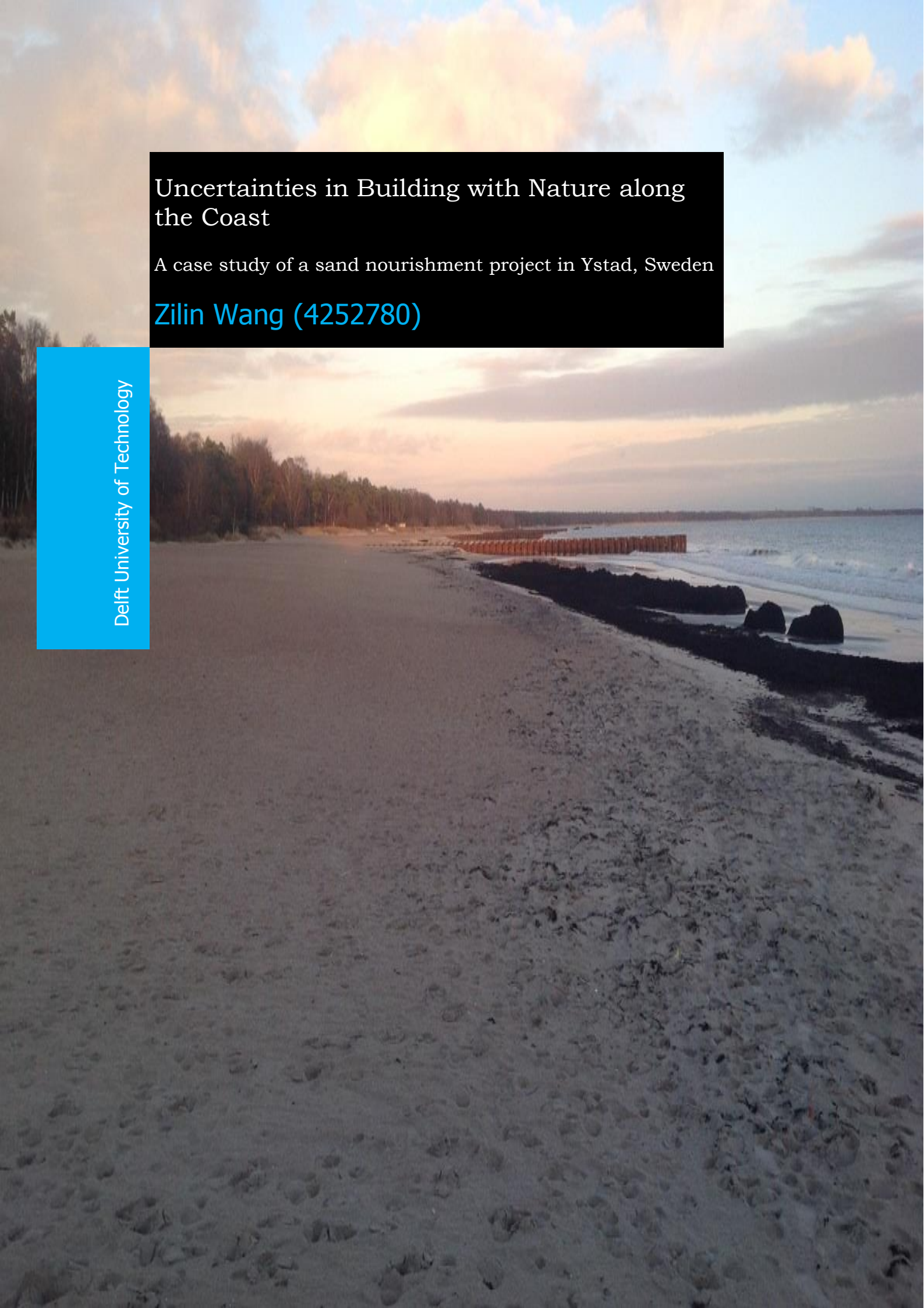

# Uncertainties in Building with Nature along the Coast

A case study of a sand nourishment project in Ystad, Sweden

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# Uncertainties in Building with Nature along the Coast

## A Case Study of a Sand Nourishment Project in Ystad, Sweden

By

**Zilin Wang**

in partial fulfillment of the requirements for the degree of

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in Engineering and Policy Analysis

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to be defended publicly on Tuesday March 31, 2015 at 14:00 PM.

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An electronic version of this thesis is available at http://repository.tudelft.nl/.

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Zilin (Aj) Wang
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# Executive Summary

Coastal erosion is a natural process caused by the actions of current and waves towards coastlines. Building with Nature (BwN), is an emerging methodology that utilizes natural process and natural materials to reduce the impacts of coastal erosion on nature and society. Because of the involvement of natural materials and natural processes, BwN proactively embraces uncertainties in the coastal management projects, which deviates from customary methods of coastal management that reduce uncertainties. Therefore, it is meaningful to investigate uncertainties in the BwN projects and how uncertainties influence decision making processes of the BwN projects.

This master thesis project selects a BwN sand nourishment project in Ystad, Sweden (in short, the Ystad project) for case study. The research aims to analyze uncertainties in the BwN sand nourishment projects and identify influential uncertainties in decision making processes of the BwN projects. In order to achieve the research objective, the master thesis project starts with a literature review on existing theories of uncertainty analysis, including different definitions and classifications of uncertainties. Based on previous research, a BwN uncertainty matrix is established to reveal uncertainties and different perceptions of uncertainties. Three dimensions, including the location, level and nature of uncertainty, are used to depict uncertainties in the BwN projects.

This master thesis project applies the BwN uncertainty matrix to analyze the data collected by desk research and the field research in Sweden. Uncertainties exist in all the natural, technical and societal systems in the decision making process of the Ystad project. Uncertainties regarding issues in the societal system are addressed most frequently, while technical uncertainties are rarely raised by respondents. Different perceptions of uncertainties, particularly regarding environmental impacts of sand nourishment and the availability of sand resource for sand nourishment are essential and affected the decision making process. Ystad Municipality, as project owner and local authority in Ystad, made a lot of efforts to break through the delayed decision making process by providing knowledge, persuasive communication and interactive scale framing.

The main contribution of the master thesis is developing an actor-based BwN uncertainty matrix to identify uncertainties and compare different perceptions of uncertainties in the BwN projects. It is also the first time to have a qualitative uncertainty analysis for the first sand nourishment project in Sweden.

**Keywords**: Building with Nature, sand nourishment, uncertainty, Ystad

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# 1

# Introduction

This chapter introduces the importance of uncertainties in the Building with Nature projects, and presents a brief introduction of the sand nourishment project in Ystad, Sweden, which is the target project for the case study. The research objective and research question are raised in Chapter 1.2, while the research scope follows in Chapter 1.3. The structure of the whole master thesis is introduced in Chapter 1.4.

## 1.1. Research background

### 1.1.1. Uncertainties in the decision making process of the Building with Nature projects

Uncertainty arises when people are confronted by complex problems. The uncertainties are not only related to external factors, such as climate change, economic growth and emerging technologies, but also to people's different preferences and interests which may change overtime. These uncertainties cause difficulties for people, particularly decision makers, to acquire a comprehensive understanding of projects, policies and the corresponding contexts for decision making. The traditional strategy of decision making is to choose the "best" option for the future, which may be a static "optimal" choice for a single "most likely" future or a static "robust" choice for the most plausible future worlds (Haasnoot et al., 2013). No matter which strategy is selected, uncertainties are always not welcome for decision makers. Reducing uncertainties or the impacts of uncertainties is always one of the main objectives in decision making processes.

However, a methodology embracing uncertainties is developed for water governance and coastal management, namely "Building with Nature" (BwN). BwN is a form of "ecological engineering"(Mitsch & Jørgensen, 2003), for purpose of coastal protection against sea level rise, land subsidence and coastal erosion (Anselm, 2006; van Slobbe et al., 2013). Compared with traditional "reactive" schemes of minimizing negative impacts and compensating for residual or secondary negative effects, BwN focuses on "proactively" utilizing natural process (e.g. waves, currents and wind) and natural materials (e.g. mangroves and wetlands) and providing nature opportunities involved in the infrastructure development process (de Vriend & van Koningsveld, 2012). This development process does not exclusively concentrate on the primary function of coastal protection infrastructures, but is comprised of multiple functionalities implying different interests of human beings, such as recreation and fishery. Therefore, the BwN principles provide an integrated methodology for designing infrastructures for coastal management coordinating the relations among nature, engineering and society (see Figure 1).


**Figure 1 Three perspectives of Building with Nature (BwN) methodology (van Slobbe et al., 2013)**

Because of the variability of nature, uncertainty is one of the intrinsic characteristics in the BwN projects. People are not able to obtain all the information and knowledge about the natural system completely and precisely. Meanwhile, BwN projects can hardly ignore possible uncertainties originating from different interests, preferences, values, perceptions and behaviors that may be in conflict among different actors, since the BwN methodology takes great considerations to the social values of coastal protection infrastructures. Consequently, it is necessary to investigate uncertainties in the BwN projects and how uncertainties influence decision making processes in the BwN projects.

Uncertainty is a popular issue for research in terms of definitions and classifications of uncertainty, and strategies for dealing with uncertainties (Brugnach et al., 2008; Funtowicz & Ravetz, 1990; Koppenjan & Klijn, 2004; Walker et al., 2003). The research on decision making process is wide spread, for instance, by using different conceptual models to depict and analyze decision making processes in the complex environment (De Bruijn & Heuvelhof, 2008; Enserink et al., 2010). For the BwN methodology, the existing research mainly focuses on technical issues in the BwN projects (Anselm, 2006), while few papers are related to decision making processes (van Slobbe & Lulofs, 2011) and uncertainties in the BwN projects (van den Hoek et al., 2012). In addition, since the concept of BwN was initiated by Dutch researchers and engineers, most of research projects are performed in the Dutch context. Accordingly, there is a research gap between the research regarding uncertainty, decision making processes and the BwN methodology, particularly in an international context, which is the research topic of this master thesis project (see Figure 2).

To investigate uncertainties in decision making processes of the BwN projects, this master thesis project undertakes a research on a Swedish BwN project, the sand nourishment project in Ystad, a single-case study.

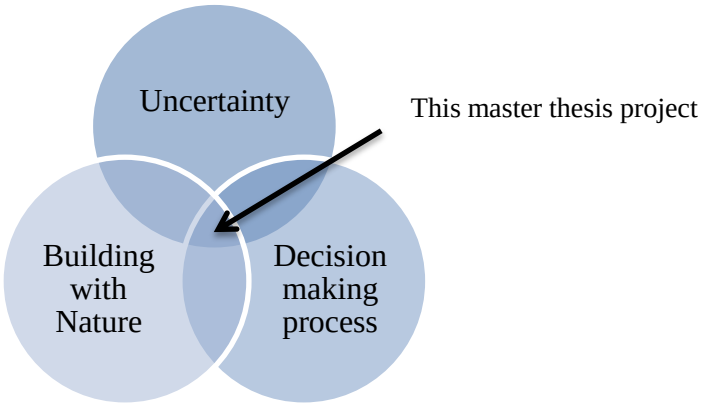


**Figure 2 Research gap among uncertainty, decision making process and BwN**

### 1.1.2. Case description: sand nourishment project in Ystad, Sweden

The Swedish coast is dominated by rocky coastlines (Bird, 1985; Bird & Schwartz, 1985), whereas sandy beaches exist in the southern part of Sweden, mainly in Scania County (in Swedish: *Skåne län*) with one of the worse examples in Ystad (Larson & Hanson, 2013). Ystad is located in Scania County with a sandy coastline of 40 km (see Figure 3) (Ystad Municipality, 2014). Coastal erosion in Ystad was firstly documented in 1820, whereas erosion may occur even earlier (SWECO, 2013). The coastlines in Löderups Strandbad (see Figure 4), which is located in the eastern Ystad, retreated landward for 150 m from 1818 to 1917 at the rate of approximately 1 m/year (SWECO, 2013). Coastal erosion threatens both public and private properties, and also affects local tourism (Eriksson & Persson, 2005), which is one of the main contributors for local economy. Therefore, the local authority of Ystad (Ystad Municipality, in Swedish: *Ystad kommun*) has been actively participating in the local coastal management.


**Figure 1 Ystad in Scania County, Sweden**

The local coastal management in Ystad started with hard infrastructures in 1950s, such as groins, detached breakwaters and rock revetments (Larson & Hanson, 2013). Hard infrastructures sometimes were temporarily effective in protecting buildings and properties along the coastlines, but were not able to stabilize the coastlines or even induce coastal erosion developing downshift. Considering the recreational use of sandy beaches, Ystad Municipality pursues a new coastal management methodology for balancing natural coastline evaluation and the recreation values of sandy beaches.

Figure 4 Coastal erosion in Löderups Strandbad, Ystad in 2003 (Photo by Swedish Geotechnical Institute)

Sand nourishment, a classical BwN technique, was supposed to be a possible solution to Ystad's coastal erosion. In 2011, Ystad Municipality was authorized to carry out a sand nourishment project (in short, the Ystad project) in Ystad Sandskog and Löderups Strandbad for 10 years, where suffered from the severest coastal erosion in Ystad. From 2011 to 2021, the sand is dredged up from the seafloor near the Sandhammer bank on every three years and put on the beaches in Ystad Sandskog and Löderups Strandbad (see Figure 5 & Figure 6). The total entitled amount of sand is 340,000 $m^3$, of which 100,000 $m^3$ were for 2011 and the residual amount are proposed to be equally split for the following three rounds of nourishment. Till now, two rounds of sand nourishment have already been completed in 2011 and 2014 with the sand amounts of 80,000 $m^3$ and 64,000 $m^3$, respectively.

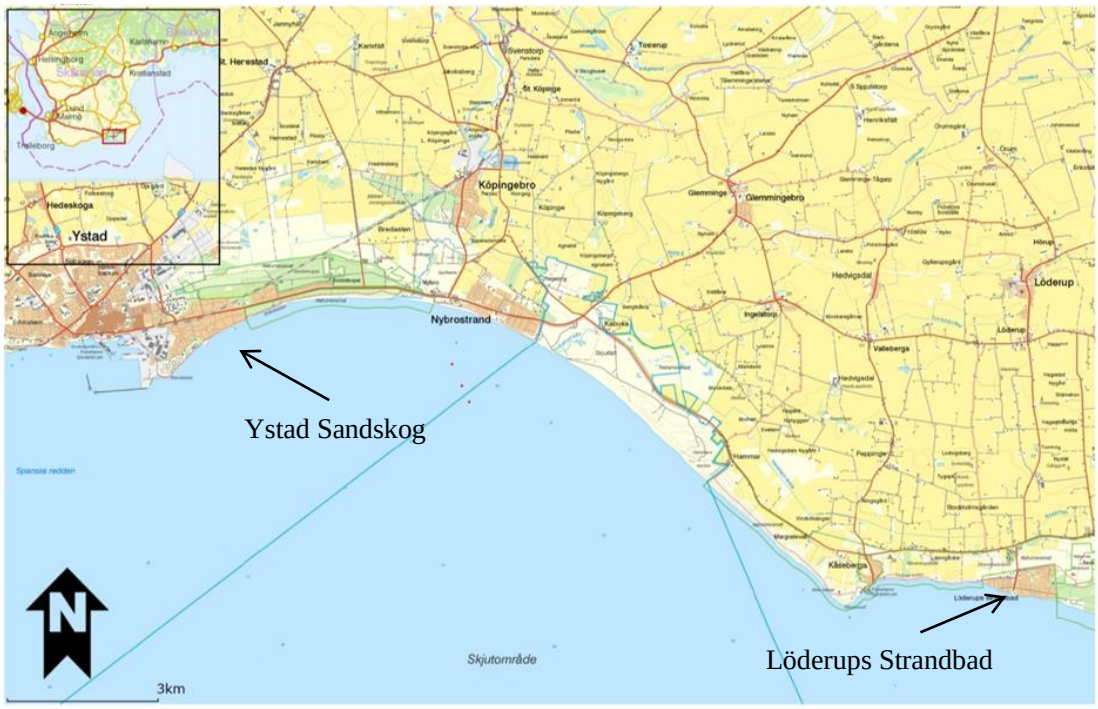


Figure 5 Locations of sand nourishment in Ystad (Left: Ystad Sandskog; Right: Löderups Strandbad; Map by County Administrative Board of Scania)

**Figure 6 Beaches in Ystad Sandskog (Left: before sand nourishment in 2011; Right: after the second round of sand nourishment in 2014; Photo by Mona Skoog)**

However, the decision making process of the Ystad project was rather difficult. The governmental authorities spent over one decade on making decisions in forms of granting Ystad Municipality the permits for sand nourishment. Although the Swedish Land and Environment Court issued Ystad Municipality the permit for sand nourishment in 2001, Geological Survey of Sweden (in Swedish: *Sveriges Geologiska Undersökning, SGU*) rejected Ystad's application of the permit for offshore sand extraction in 2003 and 2007 with reasons of imperfect information about potential negative impacts of sand extraction on environment and biological diversity. After supplementary investigation and lobbying, Ystad Municipality finally got the permit by SGU on April 11, 2011, when less than five months before the court's permit went invalid was (see Figure 7).

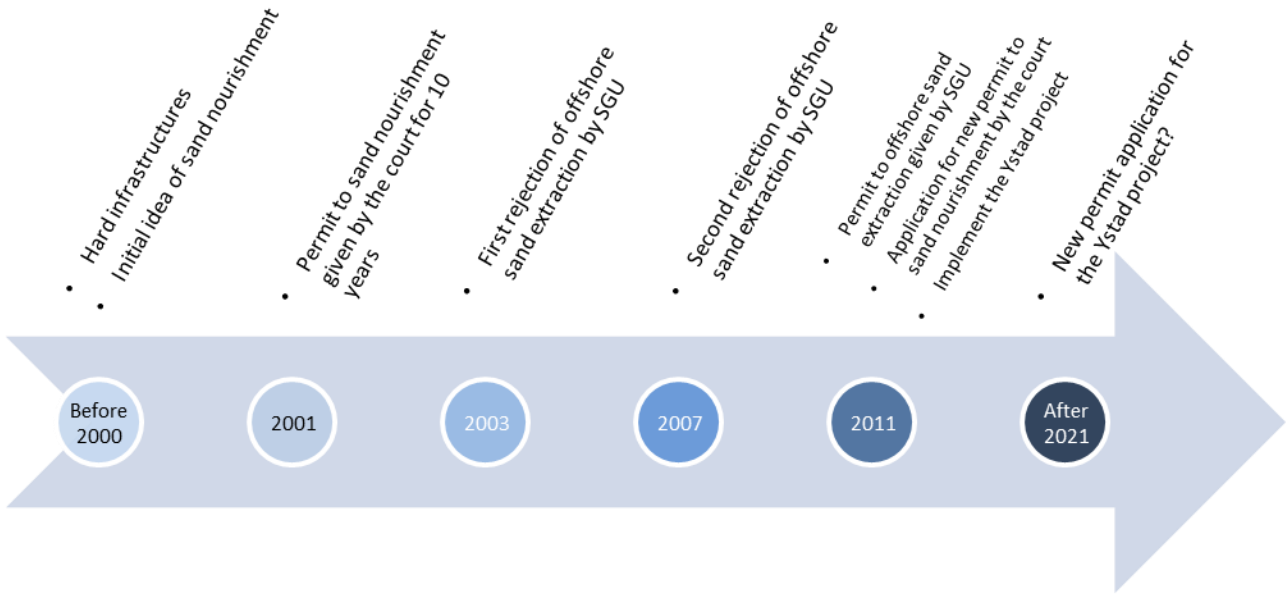


**Figure 7 Brief timeline of the Ystad project**

Ystad Municipality is satisfied with the nourished beaches and apparently would like to continue the Ystad project in the near future. Nevertheless, the permits for the Ystad project

are not permanent, thus Ystad Municipality has to go through the application process again. Considering the crawling decision making process in 2000s, it is meaningful to analyze the reason for the difficult and delayed decision making to improve the efficiency of decision making process of the BwN projects in Sweden.

## 1.2. Research objective and question

This master thesis project starts with uncertainties in the BwN projects to analyze uncertainties in the BwN sand nourishment projects and identify influential uncertainties in decision making processes of the BwN projects. In order to reach the objective, the main research question is raised as follows:

**Which uncertainties influence the decision making process of the BwN sand nourishment project in Ystad and how have actors dealt with the uncertainties?**

The research question will be answered by a particular case study of a sand nourishment project in Ystad, Sweden. In order to answer the main question, several sub-questions are formulated:

- What are the different perceptions on uncertainties from different actors in Ystad project?
- What are important uncertainties influencing the decision making process of the Ystad project?
- What efforts have been made to deal with uncertainties in the Ystad project, and by whom?

## 1.3. Research scope

This master thesis concentrates on a sand nourishment project in Ystad to investigate uncertainties and different perceptions of uncertainties in decision making processes of the BwN projects. The spatial scope of the target project corresponds to the locations and boundaries stipulated by the permits for the Ystad project. The sand nourishment is located in two separated sites along the coastlines of Ystad: Ystad Sandskog and Löderups Strandbad. The sand extraction is carried out on the continental shelf near the Sandhammer bank.

The temporal scope of the Ystad project starts from 1990s, when Ystad Municipality began to seek for new methodologies for coastal management as a substitute for hard infrastructures. By traditional definition, the decision making process of the Ystad project ended in 2011 when all the decisions were made and all the permits were issued to the project owner, hence the temporal scope boundary of the case study should be limited at that time. This understanding of decision making reflects a classic project-based methodology of decision making, which is well-structured with a number of distinctive phases, and comes to an end when decision is made. However, if taking a close look at the Ystad project, a process-based methodology is more suitable, which believes decision making is not a “one-off” process, but closely related to another rounds of decision making (De Bruijn & Heuvelhof, 2008). The Ystad project was approved to be executed for 10 years to 2021. For the project owner, sand

nourishment is a long-term strategy for coastal erosion. Decisions of continuing the Ystad project after 2021 have to be made and the ongoing project will definitely influence the following rounds of decision making. Therefore, the temporal scope of the case study extends from 1990s till now.

In addition, this master thesis project will not discuss the uncertainties in the computation models on coastal engineering, but may cover the outputs of models, which are used as reference for the decision making in the Ystad project. One reason is that the master thesis will analyze the perceived uncertainties of different actors, whereas the uncertainties in the computation process are not relevant. It is also because the student has no education background on coastal engineering, and is not able to grasp the knowledge on modeling and analyze uncertainties in the models in a short period of time.

## 1.4. Structure of the thesis

Chapter 1 has introduced the background information of the master thesis on uncertainties in decision making processes of the BwN projects, coastal erosion in southern Sweden and the Ystad project. Based on the background information, the research objective has been identified, and the main research questions and sub-questions are present. Chapter 2 will review the literature about uncertainty analysis and formulates an analytical framework for uncertainty analysis on the BwN projects. The research methodology, including the case selection, data collection and data analytical approach, will follow in Chapter 3 to present how the student answer the research questions and meet the research objective. Chapter 4 will show the preliminary results of the research, while Chapter 5 will present the discussion in-depth by answering the sub-questions step by step. The conclusions and recommendations derived from previous chapters will be in Chapter 6, and the reflections about the analytical framework and research methodology will be in Chapter 7.

# 2

# Literature Review

The second chapter includes the literature review of existing theories for uncertainty analysis. This chapter starts with the criteria that are used to select and develop the analytical framework for case study. Chapter 2.2 reviews the analytical frameworks by Brugnach et al. and Walker et al. Based on Walker's uncertainty matrix, a new actor-based BwN uncertainty matrix is formulated in Chapter 2.3, which integrates different perceptions of uncertainty in the analytical framework.

## 2.1. Introduction

This chapter deals with the theories of uncertainty analysis in the decision-making process. An analytical framework is developed for revealing and analyzing uncertainties in the BwN sand nourishment projects and answering the research questions. Considering the complexity of decision making processes in the BwN sand nourishment projects, there are four criteria for the framework using in this master thesis project. In brief, the analytical framework should meet following requirements:

- Base itself on *a comprehensive definition* of uncertainty. The definition must include different sources of uncertainties in the BwN sand nourishment projects. Besides incomplete knowledge which is commonly stated in the literatures, diverging perceptions of different actors should also be contained as one of the sources of uncertainty.

- Focus on *an actor-based perspective* of uncertainty. The framework should be an actor-based framework instead of a model-based one. A model-based analysis of uncertainty relies on a model with an exclusive definition of the boundaries of a model and its structure, including the elements, links, flows and relationship among elements (Walker, 2000). However, an actor-based framework can be favorable to analyze possible uncertainties originating from diverging perceptions of different actors since it is difficult to integrate the diverging perceptions into a united model or system.

- Disclose uncertainties involved in the BwN sand nourishment projects completely. The classification of uncertainty should maximally cover different aspects of uncertainties in the BwN sand nourishment projects. It should present the characteristics of uncertainty, for instance, *what are uncertainties, what are the sources of uncertainties and to what extent people feel uncertain about uncertainties*.

- Contribute to analyzing *alternatives* to uncertainties. The analytical framework should be widely applied in other research, and alternatives to uncertainties have been discussed based on the analytical framework.

## 2.2. Literature review: definitions and classifications of uncertainty

There is no commonly accepted definition of "uncertainty" in the literature. In general, uncertainty can be defined as limited knowledge about past, current and future events (Walker et al., 2013). Funtowicz and Ravetz (1990) argued that uncertainty is "*a situation of inadequate information"*, which can be categorized into *inexactness*, *unreliability* and *border with ignorance*. Sigel et al. (2010) also defined that a person is uncertain if "*he lacks confidence about his knowledge relating to a specific question*". These definitions of uncertainty imply that increasing availability, accessibility and quality of information or knowledge could partially reduce uncertainties. However, uncertainty could be raised when sufficient knowledge is introduced. Because abundant knowledge probably leads to an increasing awareness of knowledge gaps, a sense of inadequate information, and an emerging set of uncertainties (Koppenjan & Klijn, 2004; van Asselt & Rotmans, 2002). In addition, the profusion of knowledge and information cannot necessarily eliminate another component of uncertainties, which are defined as "*variability*" inherent to the system by Baroang et al. (2009) and Hoffman et al. (1994).

Besides incomplete knowledge and information, there is another category of uncertainty that comes from different perceptions of people in the decision making process. Those uncertainties from different perceptions are not always included in the definitions of uncertainty in the literature, and can hardly be simply reduced when ample information and knowledge are available. For instance, Koppenjan and Kijn (2004) introduced *strategic* uncertainty and *institutional* uncertainty to depict technical and social dimensions of uncertainty and complement the knowledge-oriented understanding of uncertainty, in other words, *substantive* uncertainty. According to Enserink et al. (2010), these differences in perceptions are related to the circumstances as: *the background and history of actors concerned*, *the position and interests of the actor*, *communication patterns*, *individual reference framework*, *the available vocabulary* and *the modeling method*. In the BwN sand nourishment projects, different actors do interact with each other under such circumstances in decision making processes, thus uncertainties from different actors' perceptions should be analyzed.

Among the theories on uncertainty analysis, Brugnach et al.(2008) and Walker et al.(2003) proposed their definitions of uncertainty, developed their uncertainty theories and used the theories to disclose uncertainties. The following sections will have a brief literature review of their theories.

### 2.2.1. Uncertainty matrix by Brugnach

Brugnach et al.(2008) argued that uncertainty is "*the situation in which there is not a unique and complete understanding of the system to be managed*", which particularly defined

uncertainty in a multi-actor system by emphasizing the uniqueness of system understanding. In the multi-actor decision making process, the objectiveness of knowledge and information may not be possible when knowledge and information are obtained and/or interpreted in different ways by people with diverging background, values, interests and preferences. This phenomenon is categorized as "*multiple knowledge frames*" or "*ambiguity*" by Brugnach et al. (2011).

Based on this definition, Brugnach et al. (2008) classified uncertainties and formulated an uncertainty matrix with two dimensions. One dimension is based on different sources of uncertainties: *unpredictability* is related to unpredictable or chaotic behavior of natural processes, human beings or social processes ("what we do not know and we will not know"); *incomplete knowledge* is the result of a lack of data and information, data imprecision and approximations, unreliability of data source, a lack of theoretical support, misuse of existing knowledge and ignorance ("we do not know but we could get to know"); *multiple knowledge frames is* due to different, sometimes even contending views about the same phenomenon, problem or situation (van den Hoek et al., 2012). The other dimension of uncertainty classification is in accordance with the contents of uncertainties in the natural, technical and social system. These two dimensions are interwoven with each other to formulate nine sub-categories of uncertainties (see Table 1).

**Table 1 Uncertainty matrix by Brugnach et al.(van den Hoek et al., 2012)**

| | Unpredictability | Incomplete knowledge | Multiple knowledge frames |
|---|---|---|---|
| **Natural System** Climate impacts, water quantity, water quality, ecosystems | *unpredictability of the natural system* | *incomplete knowledge of the natural system* | *multiple knowledge frames about the natural system* |
| **Technical System** Infrastructures, technologies, innovations | *unpredictability of the technical system* | *incomplete knowledge of the technical system* | *multiple knowledge frames about the technical system* |
| **Social System** Economic, cultural, legal, political, administrative and organizational aspects | *unpredictability of the social system* | *incomplete knowledge of the social system* | *multiple knowledge frames about the social system* |

Brugnach's matrix was used for analyzing uncertainties in the Sand Engine sand nourishment project in the Netherlands (van den Hoek et al., 2012). This matrix revealed uncertainties in the project, however, could hardly make contributions to investigating how uncertainties emerge. Therefore, this master thesis turns to another theory of uncertainty analysis by Walker et al. (2003).

### 2.2.2. Uncertainty matrices by Walker and Kwakkel

Walker et al. (2003) adopted a general definition of uncertainty as being "*any departure from the unachievable ideal of complete determinism"* and extended his definition in mathematical terms of "*if probability (event) ≠ 0 or 1, then the event is certain*" (Walker et al., 2013), which indicated that uncertainty becomes a mathematical concept that can be deterministically calculated and characterized (van den Hoek et al., 2012). However,

uncertainty is not only about if an event will happen or not, but also relevant to the indistinctness of how an event will happen, which could not be simply represented by possibilities. This master thesis is based on the original definition of uncertainty by Walker et al. (2003) without the mathematical interpretation. Moreover, Walker et al. formulated an uncertainty matrix with three dimensions: the *location*, *level* and *nature* of uncertainty (see Table 2).

**Table 2 Uncertainty matrix by Walker et al.(2003)**

| Location | | Level | | | Nature | |
|---|---|---|---|---|---|---|
| | | Statistical uncertainty | Scenario uncertainty | Recognised ignorance | Epistemic uncertainty | Variability uncertainty |
| Context | Natural, technological economic, social and political, representation | | | | | |
| Model | Model structure | | | | | |
| | Technical model | | | | | |
| Inputs | Driving forces | | | | | |
| | System data | | | | | |
| Parameters | | | | | | |
| Model Outcomes | | | | | | |

The *location* of uncertainty is an identification of where uncertainty manifests itself within the whole system. Based on various sources of uncertainty, uncertainties is identified to be located in the *context*, *model*, *inputs*, *parameters* and *outcomes* in a system (Walker et al., 2003). The *level* of uncertainty provides an entire spectrum of different levels of uncertainty, ranging from the unachievable ideal of *complete deterministic understanding* at one end of the scale to *total ignorance* at the other end (Walker et al., 2003). Between these two extreme situations, s*tatistical uncertainty, scenario uncertainty and recognized uncertainty* are put forward to indicate increasing degrees of being uncertain on an issue in people's mind, which range from uncertainties that can be described in statistical terms, to fundamental uncertainties that people can acknowledge the uncertainties but have no ideas about the mechanisms, interactions among variables, causal relationships being studied. The *nature* of uncertainty refers to reasons that people feel uncertain. It can be either due to the lack of knowledge or due to the inherent variability of the system (Walker et al., 2003).

Compared with Brugnach's uncertainty matrix, Walker's framework has a more comprehensive description of uncertainty. Walker's uncertainty matrix was widely used in a variety of domains for uncertainty analyses (Krayer von Krauss et al., 2004; Kwakkel et al., 2008; Warmink et al., 2010). These studies started from Walker's matrix but modified the matrix for their own uncertainty analyses, which were reviewed by Kwakkel et al. (2010).

Kwakkel et al. (2010) summarized two issues in the evolution of Walker's matrix: "*various modifications of level dimension*" and "*a shift to perceived uncertainties and the role of frames*". For the first issue, Kwakkel et al. (2010) revised the level dimension and made five subdivisions of levels of uncertainty. Unfortunately, the starting point of each revised level is whether or not people are able to "enumerate multiple alternatives to the problem"(Walker et al., 2003), which can also be found in the statement of Kwakkel et al. (2010). It indicates two implications in those statements: uncertainty is located in alternatives, and there is a situation with multiple alternatives. The former implication obscures the distinction between the level and the location of uncertainty, thus emphasizes that the level of uncertainty is necessarily relevant to alternatives. The latter implication shows multiple alternatives can always be discovered or formulated which may affect decision making processes. However, it is easy to find out another situation that people are not able to make decisions with a single alternative, just like the target case in this master thesis project. For the second issue on the nature of uncertainty, Kwakkel et al. (2010) introduced *ambiguity* by Brugnach et al. (2008) as a third kind of the nature of uncertainty, which is a major contribution of Kwakkel's work is the involvement of multiple frames in the uncertainty analysis (see Table 3).

**Table 3 Synthesized uncertainty matrix by Kwakkel et al.(2010)**

| | | *Level* | | | | *Nature* | | |
|---|---|---|---|---|---|---|---|---|
| *Location* | | *Level 1: shallow uncertainty* | *Level 2: medium uncertainty* | *Level 3: deep uncertainty* | *Level 4: recognised ignorance* | *Ambiguity* | *Epistemology* | *Ontology* |
| System boundary | | | | | | | | |
| Conceptual model | | | | | | | | |
| Computer model | Model structure | | | | | | | |
| | Parameters inside the model | | | | | | | |
| | Input parameters to the model | | | | | | | |
| Input data | | | | | | | | |
| Model implementation | | | | | | | | |
| Processed output data | | | | | | | | |

Walker's uncertainty matrix and following evolution by Kwakkel et al. provide a great insight into possible dimensions for uncertainty analysis. However, though the concept of "model-based" decision making process is supposed to be associated with both conceptual model and computer model, some uncertainty categories, such as *model technical uncertainty* and *parameter uncertainty* are in fact not applicable for conceptual models. In practice, most of the applications of Walker's matrix were computer-model-based research and few were found for conceptual-model-based research. Kwakkel's synthesized matrix also did not concentrate on the possibility of analyzing uncertainties in conceptual models. Therefore, it is important to establish an analytical framework to reveal uncertainties in conceptual models, which can hardly be depicted by mathematical terms.

## 2.3. A synthesized analytical framework: BwN uncertainty matrix

Based on Walker's uncertainty matrix, an analytical framework, the BwN uncertainty matrix, is formulated combining with the BwN methodology for analyzing uncertainties in the BwN projects.

Walker's definition of uncertainty as being "*any departure from the unachievable ideal of complete determinism"* is adopted in this master thesis since it corresponds to the amending uncertainty matrix by Walker et al. (2003). The synthesized framework keeps three dimensions of uncertainty by Walker et al. (2003): *location*, *level* and *nature* of uncertainty, to depict the uncertainties in a conceptual model.

For the location of uncertainty, the student re-defines perceived components of uncertainty by following the system analysis routes by Slinger et al. (2012) and Enserink et al. (2010) as five different locations. *Context uncertainty* is located in the conditions and circumstances related to the choice of the boundaries of a system, the framing of issues and the formulation of the problems; *system uncertainty* is in the behaviors of the system and interrelationships among the elements in the system; *external factor uncertainty* refers to the uncertainties in uncontrollable forces that influence the system significantly; *policy uncertainty* represents the uncertainties in the interventions designed and implemented purposively by human beings to influence the system; *outcome uncertainty* is about the uncertainties in the accumulated performance of the context, system, external factors and policies (see Figure 8).

This synthesized framework does not overemphasize the mathematical terms in the model. The model structure is not necessarily constructed via formula and function. *Model technical uncertainty* (i.e. uncertainties in computation processes) and *parameter uncertainty* (i.e. uncertainties of supposedly invariant constants in computer models) are no longer applicable in the BwN uncertainty matrix, because interrelationships among elements in the system do not always play roles when there is no computation in the conceptual model. The *system uncertainty* is then focusing on causal relationships among elements and issues in decision making processes which are not necessarily shown in mathematical terms. For instance, with the respect of potential environmental impacts of sand nourishment projects, uncertainty may arise regarding whether the offshore sand extraction is the reason of marine biodiversity decline.

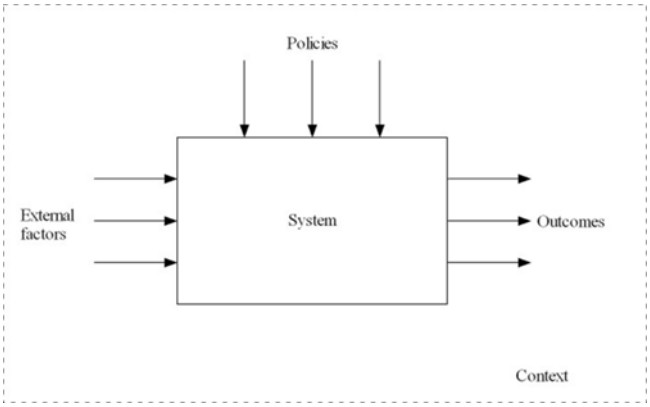


**Figure 8 Perceived locations of uncertainty (Slinger et al., 2012)**

For the level of uncertainty, the original categorization of different levels by Walker et al. (2003) is adopted. In the BwN uncertainty matrix, *statistical uncertainty* refers to the uncertainties that can be described adequately in statistical terms; *scenario uncertainty* manifests itself as a (range of) possible outcome(s) without clear statistical expressions; *recognized uncertainty* is related to the uncertainties that cannot be understood in terms of the functional relationships or the statistical properties.

For the nature of uncertainty, the BwN uncertainty matrix adopts the modification by Kwakkel et al. (2010) in which *ambiguity* by Brugnach et al. (2008) was introduced as the third nature of uncertainty. Therefore, there are three categories in this dimension: *epistemic uncertainty* indicates the uncertainties due to the imperfection of knowledge; *variability* represents the uncertainties originating from inherent variability of the system; *ambiguity* is due to the simultaneous presence of multiple frames of reference about a certain phenomenon.

According to the contents, uncertainties can also be categorized into different sub-categories, such as uncertainties in the natural system, technical and societal system, which has be done by Bruganch et al.(2008) and corresponds to the BwN methodology. Strictly speaking, this categorization is not a dimension, but an approach to aggregate uncertainties on similar topics in the same sub-systems.

Table 4 shows an example of the BwN uncertainty matrix. Each uncertainty will be first categorized into different sub-systems (i.e. natural, technical and social systems). One box of each dimension will be colored for representing the location, level and nature of an uncertainty.

**Table 4 An example of the BwN uncertainty matrix**

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty in the natural system** | | | | | | | | | | | |
| Uncertainty A | | | | | | | | | | | |
| Uncertainty B | | | | | | | | | | | |
| Uncertainty C | | | | | | | | | | | |
| **Uncertainty in the technical system** | | | | | | | | | | | |
| Uncertainty D | | | | | | | | | | | |
| Uncertainty E | | | | | | | | | | | |
| Uncertainty F | | | | | | | | | | | |
| **Uncertainty in the societal system** | | | | | | | | | | | |
| Uncertainty G | | | | | | | | | | | |
| Uncertainty H | | | | | | | | | | | |
| Uncertainty I | | | | | | | | | | | |

Reviewing the criteria of the analytical framework in Chapter 2.1, the BwN uncertainty matrix starts with a comprehensive definition of uncertainty by Walker et al. (2003) (criterion 1) and fully discloses possible uncertainties in the BwN projects (criterion 3), particularly the level and nature of uncertainty which are propitious for analyzing strategies dealing with uncertainties. For criterion 2 in terms of an actor-based analytical framework, the BwN uncertainty matrix is supposed to be applied for different actors in the BwN projects separately to meet the actor-based criterion, which will be interpreted in details in Chapter 3.

# 3

# Methodology

The chapter presents the methodology that is used in the master thesis project to achieve the research objectives and answer the research questions. This chapter starts with a short introduction about the overall procedure of the research in Chapter 3.1. Chapter 3.2 introduces the case study approach in the master thesis project, including the case selection, data collection and data analysis approach.

## 3.1. Introduction

In the master thesis project, two research activities in parallel need to be conducted. On the one hand, a literature review is for developing an analytical framework to study uncertainties in decision making processes of the BwN projects, which has been done in Chapter 2. The outcome of this process is a BwN uncertainty matrix. On the other hand, the case study is to gather empirical data on a specific BwN sand nourishment project. The outcomes of the case study are data from field observations, participatory observations, documents and interviews. These two processes are combined when the student uses the BwN uncertainty matrix to analyze the data and reveal uncertainties, different perceptions of uncertainties and strategies dealing with uncertainties in the Ystad project, which will be shown in the result and discussion parts. The conclusions will focus on the uncertainties hinder the decision making process, and the recommendations will raise some possible strategies from other BwN experience.

The overall methodology of the master thesis project is shown in Figure 9. The rest of this chapter will introduce the case study approach of the master thesis project.

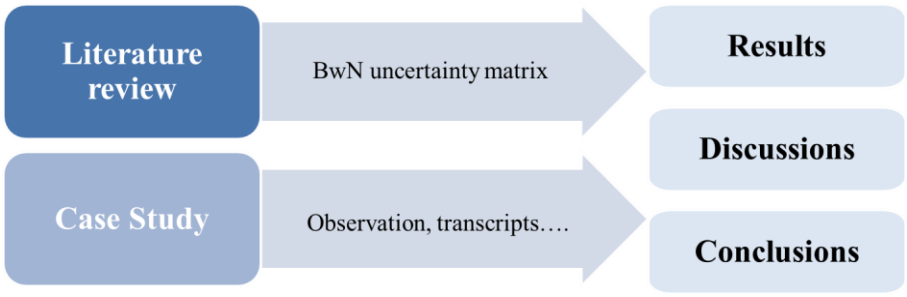


Figure 9 Overall research methodology of the master thesis project

## 3.2. Case study approach

A qualitative research approach is employed to investigate uncertainties involved in the Ystad project. Considering the research questions, case study is selected as the specific research approach according to Verschuren and Doorewaard (2010), and Yin (2014). On the

one hand, the master thesis project works on a *limited* number of research units, in fact refers to a *single* case, which concentrates on *depth* rather than *breadth* of the research (Verschuren & Doorewaard, 2010). By using case study method, the master thesis project is expected to gain a profound insight into the uncertainties in the Ystad project which is confined in time and location. The data collection aims to use various methods and sources for gathering data to realize the depth of research. On the other hand, case study is applicable for research questions asking about a *contemporary* set of events especially when boundaries between the case and the context are not clearly evident (Yin, 2014). The context is pertinent to the case and the interaction between the case and the context is essential for the research. The Ystad project takes root in a specific Swedish environment, which may be a crucial factor influencing the processing of the project. Therefore, it is difficult to isolate the case from its contextual conditions like what experiments always do. Other approaches, such as history analysis and archival analysis defined by Yin (2014), are not suitable for a contemporary research.

### 3.2.1. Case selection

The Ystad project is selected for case study for following reasons.

Firstly, one of the supervisors has good connections with the researchers at Lund University, Sweden, who are knowledgeable and experienced in coastal erosion issues in Ystad. These researchers can provide us a lot of information about the Ystad project, and contribute to connecting with respondents who have been participated in the Ystad project.

Secondly, the Ystad project is the first large-scale sand nourishment project in Sweden. The exploratory phase of the master thesis project showed that the Ystad project, particularly the decision making process of the project, did not go smoothly because of the inexperience of Swedish participators. In addition, one respondent in the exploratory interview stated that, the decision makers did always keep asking for more information but not take a decision. It is interesting to analyze to what extent the lack of information and knowledge affected the decision making process of the Ystad project, which is the initial idea of the master thesis project.

Lastly, sand nourishment has been widely applied in the Netherlands for decades but is rarely used in Sweden. It is of great significance to analyze some sand nourishment projects in other countries and make a comparison between similar projects in different international contexts. This master thesis project may contribute to the comparison by firstly analyzing a Swedish case. Existing research on the sand nourishment projects in the Netherlands will also instruct the master thesis project on the Ystad project.

### 3.2.2. Data collection

The research starts with an exploratory data collection on the Internet about the project information and the Swedish political system. In addition, two exploratory interviews with one Dutch and one Swedish participator were done beforehand to verify the obtained information and to have a better understanding of sand nourishment projects.

The field research in Sweden started from November 19 to December 2, 2014 in Scania County where the Ystad project is located. During the field research, the student participated in a regional meeting about coastal management, investigated nourished beaches in Ystad for twice and had twelve interviews with fourteen respondents. The respondents were partly connected beforehand with the help of the respondents in the exploratory interviews, and the rest were recommended by earlier respondents. For each interview, main interview questions are prepared specifically based on the respondent's position and role in the Ystad project, and sent to the respondents in advance. The interviews were semi-structured, with less than five main interview questions. Each interview was recorded by laptop and tablet synchronously, and then transcribed into a summary of the interview for coding (see Appendix 3). The summary of each interview was sent to the respondent for feedbacks on January 26, 2015. According to the categorization of sources of evidence by Yin (2014), several different data sources were used for data collection, including documentation, archival records, interviews and (participatory) observations (see Table 5) .

**Table 5 Data sources in the master thesis project**

| Data Source | Contexts |
|---|---|
| **Documentation** | ❖ Administrative permits by the Swedish authorities<br>❖ Swedish and European laws and regulations<br>❖ Agendas, announcements, memos and minutes of Erosionsskadecentrum<br>❖ Reports on:<br>➢ Action plans of regional development, environmental protection and coastal management in Sweden<br>➢ Research studies on coastal erosion and climate change in Sweden<br>❖ News clippings and articles<br>❖ Documentary films<br>❖ Other documentation on the Internet |
| **Archival Records** | ❖ Statistical data<br>❖ (GIS-) Maps of Scania County |
| **Interviews** | ❖ 2 exploratory interviews with Dutch and Swedish participators on the coastal management in Sweden<br>❖ 12 formal interviews with 14 Swedish participators in the Ystad project<br>❖ Several informal conversations with Swedish participators |
| **Observations** | ❖ Attendance in the Erosionsskadecentrum meeting on Nov 19, 2014<br>❖ 2 field observations on the beaches in Ystad |

***Documentation***

*Administrative permits* by the Swedish authorities refer to two permits given by the Swedish Land and Environmental Court and SGU for the Ystad projects. These two documents not only state the permission to carry out the project, but also elaborate the permitting process, the location and scale of the project, and more importantly, the underlying concerns of different governmental agencies. Documentation provides a foundation for the stakeholder analysis and uncertainty analysis in this research.

*Laws and regulations* related to the case study can be used as another source of data. In the Swedish legislation, Environmental Code and Continental Shelf Act are two principal laws to be followed in the sand nourishment projects for granting permits. In addition, the Natura 2000 policy in EU framework is also essential for environmental issues in Sweden, which are the focusing points in the Ystad project.

EC (in Swedish: *Erosionsskadecentrum*) is a coalition of coastal municipalities in Scania County to deal with coastal erosion issues. In each quarter of a year, there will be a meeting be held in which representatives of member municipalities report the progresses of coastal management, exchange information and discuss strategies dealing with coastal erosion. The storyline and progress of the Ystad project are recorded in the *agenda, announcements, memos and minutes* of each EC meeting.

Ystad Municipality proposed an action plan to combat coastal erosion. Other authorities, such as the Swedish national government and County Administrative Board of Scania also published *reports* about climate change adaption, which covered coastal erosion issues. These reports are helpful to gain a better understanding of each actor's perception on coastal erosion and coastal management. Moreover, researchers from SGU, SGI, SMHI and Lund University conducted *academic studies* on coastal erosion which are used as data sources.

*News clippings and articles* and *documentary films* about coastal erosion in Ystad are also collected as data source. News clippings are mainly from the local newspaper, *Ystad Allehanda*, of which previous news reports can be searched on the Internet. Documentary films were made by the EC, both in English and Swedish.

***Archival Records***

Two sorts of archival records are used in the case study. *Statistic data* are for the characteristic information about the demographics and economy of Ystad. *GIS Maps* are found on the websites of European Environmental Agency, Swedish National Land Survey (in Swedish: *Lantmäteriet*), County Administrative Board of Scania and SGU. These maps contain geological information of Ystad Municipality and Scania County, and identify natural reservation areas, eroded areas, historical coastlines, beach characteristics, and impacts of sea level rises in different scenarios.

***Interviews***

Two *exploratory interviews* with two participators in the Ystad project were done in the initial phase of data collection in the Netherlands. One respondent has been working for coastal management in the Netherlands for decades, and was invited to Sweden to share Dutch experience on the BwN sand nourishment projects. The other respondent had worked as a consultant in SWECO in the Ystad project. The contents of exploratory interviews concentrate on the sand nourishment technique, Swedish administrative structures, Swedish history of coastal management and respondents' personal experience in sand nourishment projects. In the field trip in Sweden, *interviews* were accomplished within two weeks. The respondents cover all levels of administrative structures in Sweden: municipalities (Ystad

Municipality), county administrative boards (County Administrative Board of Scania) and national government, which is represented by SGU and SGI, plus a regional parliamentary body (Regional Council of Scania). Other actors involved in the Ystad project are also included, such as consultants from two consulting companies (SWECO and Trapezia) and researchers from Lund University. Most of the interviews were conducted face-to-face except two interviews by Skype or telephone (see Appendix 1).

Besides exploratory and formal interviews, *informal conversations* are also parts of the data sources. Informal conversations may happen during coffee breaks, lunch breaks and driving.

***Observations***

On November 19, 2014, there was a quarterly meeting of the EC in Skurup, Sweden. The student was invited to attend the meeting, which provided a great opportunity to make a *participatory observation* of how the EC works on regional coastal management, and positions and functionalities of municipalities and governmental agencies (County Administrative Board of Scania and SGI) in EC, though the meeting was in Swedish.

With the help of two respondents, the student made two *field observations* on the nourished beaches in Ystad Sandskog and Löderups Strandbad as well as unnourished beaches along the coastlines of Ystad. The observations brought a deep insight into the severity of coastal erosion in Ystad, the position and scale of the Ystad project and historic efforts on the coastal management in Ystad.

### 3.2.3. Data analysis approach

The first step of data analysis is the stakeholder analysis, which aims to map actors involved in the Ystad project and their corresponding interests, preferences and values of coastal management in Sweden. The stakeholder analysis follows the methodology given by Enserink et al. (2010) based on the information collected from interviews, literature review and official introduction by the Swedish national government (Government Offices of Sweden, 2015). The result of stakeholder analysis will be shown in Chapter 4.

In parallel with stakeholder analysis, the other task is to code the data. Coding is to mark on a summary of an interview a word or phrase that represents what the student thinks a given passage means (Rubin & Rubin, 2011). By coding summaries, uncertainties in the Ystad project are exposed. The keywords for coding in this master thesis project come from literature review and document collections. For instance, van den Hoek (2012) studied uncertainties in the Sand Engine sand nourishment project in the Netherlands with Brugnach's uncertainty matrix, which gives a strong hint of possible uncertainties in the BwN sand nourishment projects. The second source of coding keywords is from data collection. For instance, in the appendix of the administrative permits, some concerns by different actors or governmental agencies were recorded in forms of comments on the permits. The reports by different participators in the Ystad project are also a possible source exploring uncertainties in the project. However, before adopting uncertainties from documentation, there must be a pre-analysis process to identify the owner of uncertainties,

because individuals in an organization may have different opinions on an uncertainty but documents are always published in name of a collective body.

After coding the data, identified uncertainties in the Ystad project are examined by the BwN uncertainty matrix. Based on the location, level, nature and content of uncertainty, each uncertainty is put into the matrix of each respondent's uncertainty matrix in three dimensions. Then each respondent's perception of uncertainties in the Ystad project can be obtained, including what issues are uncertain, what are sources of uncertainties, to what extent the respondent feels uncertain on those issues, and what the reasons that the respondent feels uncertain are. By comparing uncertainty matrices of respondents, different perceptions of uncertainties in the Ystad project will be disclosed. Furthermore, the student can diagnose the reason for the delayed decision making process in the Ystad project with a lens of uncertainty, including to what extent the uncertainties and different perceptions of uncertainties affected the decision making process. The student can also analyze the strategies which have been applied to reduce the impacts of uncertainties and seek the theoretical interpretations for those efforts. The results of in-depth analysis will be in Chapter 5.

# 4

# Results

This chapter introduces preliminary research results of the master thesis project. By revealing key issues in the Ystad project in Chapter 4.1, the master thesis gives a brief introduction of the important issues in the Ystad project. Chapter 4.2 presents results of the stakeholder analysis that identifies actors' different interests in the Ystad project and Swedish coastal management. In Chapter 4.3, the accumulated analytical results by the BwN uncertainty matrix are given.

## 4.1. Key issues in the Ystad project

The Ystad project covers multiple issues in nature and society. Besides coastal management, the Ystad project has to take care of key issues about environment, sand resource, economy and recreation, and archeological value on the continental shelf. These issues are recorded in the documents and difficult to be dealt with in practice (see Figure 10).

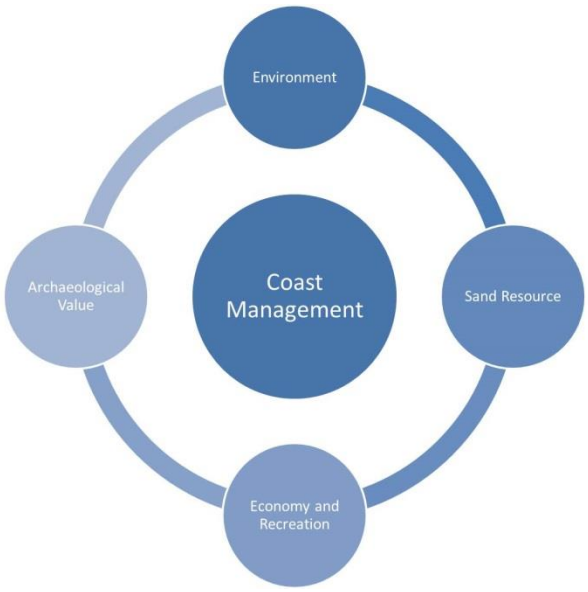


**Figure 10 Multiple key issues in the Ystad projects**

### 4.1.1. Environment and sand resource

The concerns about environmental and sand resource issues in the Ystad project have been completely shown by means of the permits that were applied for sand nourishment. According to the Swedish legislation, Ystad Municipality has to apply for two permits to carry out the Ystad project. The first permit should be issued by the Swedish Land and Environment Court, while the second should be given by SGU, which is a Swedish governmental expert agency for issues relating to bedrocks, soil and groundwater (SGU, 2014). For Ystad project, this former permit is to evaluate the integrated impacts of sand

nourishment on onshore and marine environment in accordance with the Swedish Water Act (1983: 291) or Environmental Code (1998: 808), which presents the environmental values of the Ystad project. The latter one is associated with the sand extraction process on the Swedish continental shelf in accordance with the Swedish Continental Shelf Act (1966: 341) since sand is preserved as a national resource in Sweden, which embodies the value of sand resource in the project.

### 4.1.2. Economy and recreation

Economic and recreational issues do not manifest themselves obviously in the permits, however, are important for local people and Ystad Municipality. The beach-based tourism in Ystad makes a great contribution to local economy. It is estimated that sandy beaches in Ystad attract one million tourists with a turnover of over 500 million SEK per year (Ohlsson, 2012). Considering that municipalities in Sweden are authorized to levy taxes, Ystad Municipality would like to restore sandy beaches which are attractive to tourists, even though each round of sand nourishment will cost approximately ten million SEK and has to be completely financed by Ystad Municipality.

### 4.1.3. Archaeological value on the continental shelf

When sand is dredged from the continental shelf in the sea, archeological values are always discussed because undetected relics may be found on the seafloor which may influence the sand extraction process (e.g. in Sand Engine project by van den Hoek (2012)). In Sweden, Swedish National Heritage Board (in Swedish: *Riksantikvarieämbetet*) is responsible for the heritage and historic environment issues. Since the Ystad project plans to extract sand from the continental shelf near the Sandhammer bank, it is very important for Swedish National Heritage Board, as the representative of the Swedish national government, to investigate potential archeological value in the sand extraction area. However, archaeological issues can only be found in one document. In the appendix of the official permit by SGU, Swedish National Heritage Board commented on possible existences of shipwrecks in the sand extraction area. Besides, limited information was found and few of respondents mentioned archeological issues in the Ystad project. In practice, shipwrecks were detected on the boarder of the sand extraction area, which had relatively slight influence on the Ystad project, while the sand extraction activity would hardly affect the shipwrecks in the sea.

## 4.2. Stakeholder analysis

Stakeholder analysis is employed for the exploratory actor analysis in the master thesis project. The stakeholder analysis aims to identify the actors, which refer to a social entity, person or organization that able to act on or exert influence on a decision (Enserink et al., 2010), and their relations in the Ystad project.

### 4.2.1. Actors and their relations in the Ystad project

Figure 11 shows the roles and relations of actors in the Ystad project. The actors include national, regional and local authorities in Sweden, companies and other organizations.

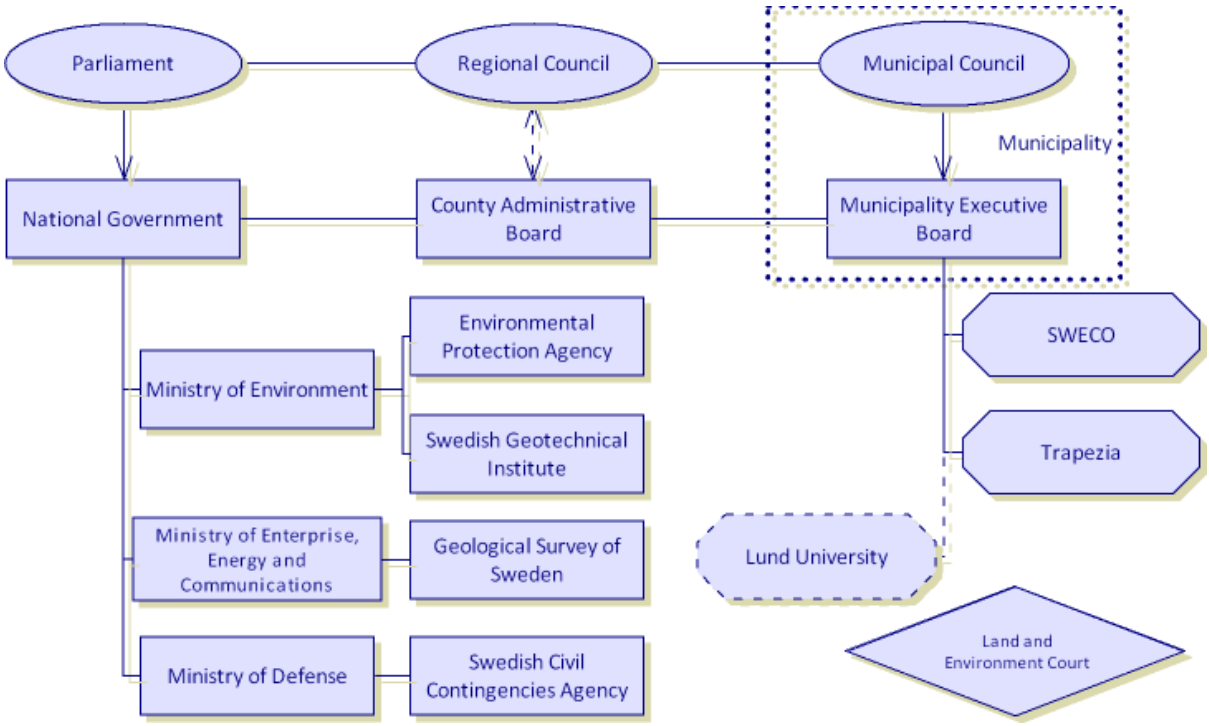


**Figure 11 Actors in the decision making process of the Ystad project (Ovals: parliamentary agencies; rectangles: governmental agencies; octagons with solid lines: consulting companies; octagons with dashed lines: research institutes; rhombuses: courts)**

Sweden has three levels of administration: national, regional and local. At the national level, the Swedish people are represented by the Swedish parliament (in Swedish: *Riksdag*). The Swedish national government, on the other hand, governs various ministries and governmental agencies that ensure the decisions by the Swedish parliament and national government to be implemented. In addition, the Swedish national government is the superior of county administrative boards (in Swedish: *Länsstyrelse*), which are led by county governors appointed by the national government.

County administrative board is the national government's regional representative to coordinate regional development in line with national interests, governmental policies and the Swedish legislation. In Scania County, the responsibilities of the county administrative board span diverse social issues, such as regional growth, infrastructure planning, sustainable community planning and housing, energy and climate, protection against disaster and emergency preparedness and civil defense, nature conservation and environmental and public health, agricultural and rural areas, and fishing equality, etc.

Regional council (in Swedish: *Landsting*) is the highest political body for local self-governance and its members are elected by the electorate. Regional councils are financed by governmental grants, county council taxes and charges. Compared with county administrative boards, regional councils have more financial resource to invest in regional projects and promote regional development[1]. In Scania County, Regional Council of Scania (in Swedish:

[1] Respondent E

*Region Skåne*) is responsible for health care, regional growth and sustainable development, infrastructure development, urban planning and environmental and climate issues, etc.

At the local level, municipality is the smallest governmental unit, which consists of an elected municipal council and a municipal executive board which is appointed by the municipal council. The municipal council takes decisions on education, healthcare, infrastructures, water and sewage, etc. Local polices are implemented by the municipal executive board with the financial support from municipal taxes, government grants and charges. Municipalities particularly have the monopoly on local urban planning under the scope prescribed by the Swedish laws. In the Ystad project, Ystad Municipal Council and Municipal Executive Board of Ystad are the project owners of the Ystad project. In this research, these two agencies showed a great uniformity in coastal erosion and the Ystad project; therefore they are treated as a joint force, namely Ystad Municipality, to present and analyze the local authority's role in the Ystad project. Ystad Municipality has the monopoly on urban planning which includes coastal erosion and sand nourishment, and is able to finance sand nourishment projects by approving the local budget.

In Sweden, ministries in the national government are not immediate decision makers in the Ystad project. The decisions are officially made in forms of permits issued by Land and Environment Court and SGU. Without permits, Ystad Municipality is not able to extract sand from the seafloor and put the sand on the beaches.

Land and Environmental Court in Sweden is a special court which hears issues about environmental and water issues, property registration and building matters. The court will settle cases and matters (e.g. an application for a permit) independently. For most of cases and matters, a legally trained judge adjudicates alongside a technical advisor who has a technical or scientific education background[2]. Particular members may be included for complicated cases and matters (Swedish Courts, 2012).

Swedish Environmental Protection Agency (in Swedish: *Naturvårdsverket*), which is accountable for the Ministry of Environment, has responsibilities for developing and implementing environmental policies to ensure a good living environment of humans. Swedish Environmental Protection Agency did not directly participate in the permitting process, but the other agencies strongly rely on its information, knowledge and guidelines on environmental issues for decision making.

Swedish Geotechnical Institute (in Swedish: *Statens Geotekniska Institute, SGI*) is a geotechnical and geo-environmental research institute that contributes to safe, economical and environmentally sustainable development in geotechnical field. This institute has coordinative responsibilities in regard to coastal erosion with a comprehensive perspective based on society's interests, and also acts as a referral body for governmental agencies concerning coastal erosion issues.

[2] Respondent M and N

Swedish Civil Contingencies Agency (in Swedish: *Myndigheten för samhällsskydd och beredskap, MSB*) reacts to issues concerning civil protection, public safety, emergency management and civil defense. It concentrates on minimizing the risk and consequences of emergencies, such as natural disasters. It also supports the preparedness for emergencies and finance infrastructure construction projects combating natural disasters, such landslides and erosion.

Since Ystad Municipality is inexperienced in sand nourishment, it hired several consulting companies to assist with permit applications: SWECO is working on consultation of coastal engineering; Trapezia is specialized in the biological area. Ystad Municipality also has a great cooperative relationship with Respondent N, who is a researcher on coastal engineering. Respondent N has been studied on the coastal erosion in southern Sweden for nearly forty years.

Figure 12 shows the participation of actors and organizations in the events and milestones in the decision making process of the Ystad project. As discussed before, ministries are rarely involved in the Ystad project. County Administrative Board of Scania, SGU and SGI are active in the project, plus Ystad Municipality as the project owner. County Administrative Board of Scania is not the decision maker, but plays an important role of assisting Ystad Municipality on permit application, especially after two rejections. It is not able to have a direct rejection of an application, but can ask for modification during application if the Ystad project is against national interests. SGU and Land and Environment Court are decision makers for permit application. Since SGU is a governmental agency, SGU is involved in the Ystad project more than Land and Environment Court, such as giving comments on the decision by Land and Environment Court and attending the meeting in the Swedish Parliament.

SGI is appointed as the national coordinative agency of coastal erosion in Sweden. It is also one of the attenders in the EC. However, according to the participatory observation, it was found that compared with SGU, SGI's position in the Ystad project is relatively weak. On the one hand, SGI has no administrative power for granting permits to Ystad Municipality, so its coordination will not always lead to smooth decision making process. On the other hand, the original task of SGI is on landslides and erosions in the rivers and streams. SGI's interest of coastal erosion is currently stipulated by the government, and SGI relies a lot on the research of other institutes and is not a knowledge provider to support the decision making process of the Ystad project. Therefore, SGI has limited resources in terms of both knowledge and power.

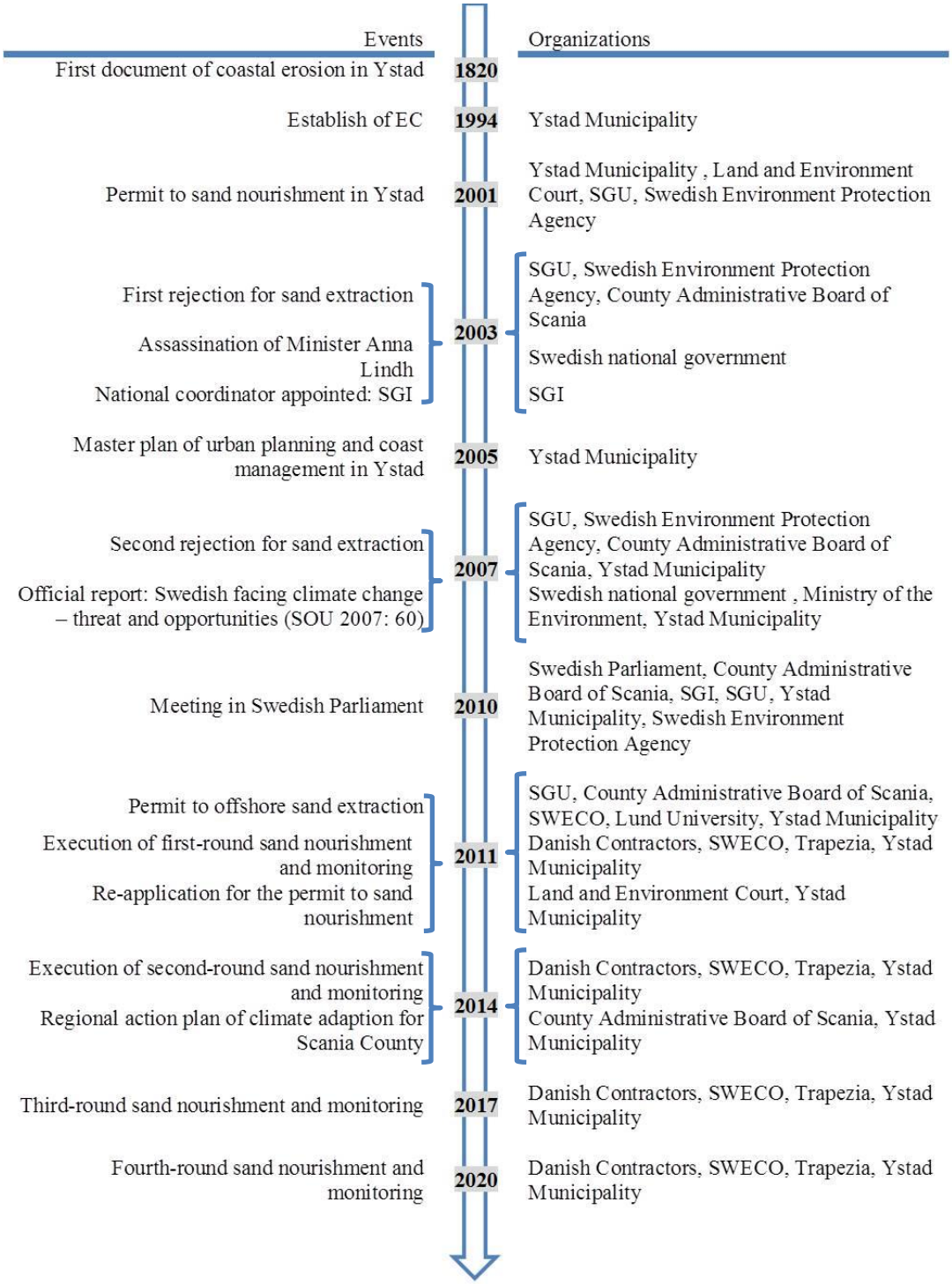


**Figure 12 Participation of organizations in the Ystad project**

Regional Council of Scania participated in the Ystad project as well. Since it is not a regional administrative authority, its position in the project is not as strong as County Administrative Board of Scania. Its position can be reflected on the comments of Regional Council of Scania on the report of "Regional Action plan of climate adaption of Scania County" by County Administrative Board of Scania, which refers to how Regional Council of Scania could be involved in the coastal management in Scania County.

SWECO, Trapezia, Danish contractors and Lund University are cooperating with Ystad Municipality. The relations between the first three actors and Ystad Municipality are kept by commercial contracts. Respondent N from Lund University is the main knowledge source on coastal management for all the other actors in the Ystad project.

If examining the participation of different actors in the Ystad project, MSB is not involved in the project at all. In the interviews, we found an intermezzo affecting the involvement of MSB, which refers to the assassination of Minister Anna Lindh in 2003. Anna Lindh was supposed to be new party chairman of the Swedish Social Democratic Party and prime minister of Sweden before her assassination in September 2003. Ystad Municipality established a great connection with Anna Lindh, who had agreed on the involvement of MSB on coastal erosion issues in Ystad, particularly in terms of financial support[3]. However, since the assassination, Ystad Municipality lost a strong alliance in the national government, and MSB has not taken part in the Ystad project any more.

### 4.2.2. Interests and resources of actors in the Ystad project

Chapter 4.1 enumerates the key issues involved in the Ystad project. This section will discuss the interests of actors on these key issues and their resources that may be used to support their interests. Archaeological value of the Ystad project is not taken into consideration in this part since few respondents have mentioned archaeological issues in the Ystad project. In addition, sand nourishment is the only preferable technique for Ystad Municipality to combat coastal erosion in Ystad. Therefore, this section will also investigate the actors' interests in sand nourishment.

Table 6 presents the interests and resources of different actors in the Ystad project. The plus sign (+) represents that an actor has similar or supportive interests on one issue, or abundant resources to support problem solving or to prevent the successful implementation of the Ystad project. The minus sign (-) means that an actor has conflicting interests on one issue, or is deficient in resources to influence the decision making process of the Ystad project. Multiple plus (or minus) signs indicate an actor's interest is more supportive (or conflicting) on an issue, or has more (or less) resources. Zero means (0) that an actor's interest of one issue is neutral, or resources the actor obtains are not relevant to problem solving. The sign with slash (e.g. +/0, 0/-) represents that the interests or resources of the actor are inconsistent or unstable. The signs with brackets (e.g. (+), (+/0)) illustrate there is no direct evidence to prove the interests and resources of an actor, which however can be deduced by some circumstantial evidences. The question mark (?) means that limited information is available to determine the interests or resources that an actor has.

[3] Respondent C and N

**Table 6 Interests and resources of the actors in the Ystad project**

| Organization | Interests | | | | | Resources | | |
|---|---|---|---|---|---|---|---|---|
| | Sand nourishment | Coast management | Sand resource | Environment | Economy & Recreation | Information/ Knowledge | Finance | Power/ Authority |
| **Swedish Parliament** | ? | (+/0) | ? | +++ | +++ | --- | +++ | +++ |
| **Regional Council of Scania** | + | ++ | + | +++ | +++ | -- | ++ | + |
| **Swedish National Government** | ? | +/0 | +++ | +++ | +++ | --- | +++ | +++ |
| **County Administrative Board of Scania** | 0/- | ++ | +++ | +++ | +++ | -- | ++ | ++ |
| **Ystad Municipality** | +++ | +++ | ++ | +++ | +++ | -- | +++ | ++ |
| **Environmental Protection Agency** | 0/- | 0 | ? | +++ | + | + | (+) | +++ |
| **SGI** | + | ++ | ++ | ++ | + | +/0 | (+) | + |
| **SGU** | 0/- | +++ | +++ | +++ | + | ++ | (+) | +++ |
| **MSB** | 0 | 0 | 0 | ? | + | ? | + | + |
| **Land and Environment Court** | + | + | + | +++ | + | ++ | --- | +++ |
| **SWECO** | +++ | +++ | ++ | +++ | + | ++ | -- | -- |
| **Trapezia** | + | ++ | ++ | +++ | + | ++ | -- | -- |
| **Lund University** | +++ | ++ | ++ | + | + | +++ | 0 | -- |

For the interests, actors in the Ystad project basically share the same interests of sand resource, environmental issues and economic issues. However, on coastal management and sand nourishment, some actors' attitudes are not always positive. SGU rejected Ystad Municipality's application of permit for sand nourishment. Swedish Environmental Protection Agency preferred hard infrastructures rather than sand nourishment as a solution to coastal erosion in Ystad. The interest of County Administrative Board of Scania on sand nourishment varies inside the agency: some officials are positive to sand nourishment and cooperate with municipalities very well, while the others may be not so interested in sand nourishment.

The resources that actors have in the Ystad project can be categorized into three types: *information and knowledge*, *financial resource* and *power and authorities*. For information and knowledge, the deficiency of knowledge is increasingly severe on the higher level of governments. SGI and SGU possess much more information and knowledge than the other governmental agencies on coastal management since they are expert and referral agencies for the Swedish national government. Land and Environment Court and consulting companies (i.e. SWECO and Trapezia) have some knowledge on marine environment, marine biology and coastal engineering, but they are more like using the knowledge instead of generating knowledge. Lund University (i.e. Respondent N) is powerful in terms of knowledge since it is the only local knowledge provider on coastal management in Sweden.

The distribution of financial resource basically corresponds to actor's administrative power or authority in the Swedish political hierarchy. The Swedish national government and municipalities have more power than county administrative boards which are the linkage between national and local governments and aim to safeguard national interests. Regional

Council of Scania has financial resource to invest research on regional coastal management, however, its administrative authority on coastal management and urban planning is much weaker than County Administrative Board of Scania. No information is available about the financial resource of governmental agencies, such as Swedish Environmental Protection Agency, SGI and SGU. Considering MSB was very close to support coastal management in Scania County in 2003, it is supposed that the other governmental agencies also have funds can be invested in coastal management.

The stakeholder analysis provides us an insight of the relations of the actors in the decision making process of the Ystad project, and their interests and resources. Interestingly, in contrast to the initial understanding that knowledge and information might be lacking for decision making in Ystad, Table 6 reveals that knowledge and information are possessed by some actors. The knowledge of sand nourishment and coastal management in Sweden are limited, but might be sufficient to make the decision. The main reason for delayed decision making of the Ystad project may not be the lack of knowledge, but related to communication on uncertainties in the decision making. Therefore, combing with the results of stakeholder analysis, the BwN uncertainty matrix will be used to analyze the uncertainties of different respondents in the Ystad project.

## 4.3. Uncertainties in the Ystad project

In the field research in Sweden, twelve interviews have been done with fourteen respondents on the topics of the Ystad project, coastal management and urban planning. Two interviews concentrated on strategies of dealing with uncertainties in the Ystad project, and one interview is fruitless due to the bad quality of telephone line so that no record has been made. Therefore, nine BwN uncertainty matrices for eleven respondents are made to reveal the uncertainties in the Ystad project (see Table 7 and Appendix 2).

After coding summaries of interviews, there are overall 76 uncertainties in the Ystad project that have been mentioned by nine respondents: 28 are in the natural system; 7 are in the technical system; 41 are in the societal system. The uncertainties involved in the Ystad project concentrate on the aspects of nature and society. The uncertainties about nature include, for instance, potential environmental impacts of the Ystad project, sediment dynamics and sea level rise in the future. The social aspect of uncertainties focuses on the uncertainties that human beings are closely related to, including socio-economic value of the Ystad project and the interactions among participators in the decision making process. However, limited data are available to reveal the uncertainties regarding engineering or technical issues. It is partly because no interview is conducted with the Danish contractors, who carried out the Ystad project. Another reason is the respondents may think the contractors are experienced in sand nourishment projects. Therefore uncertainties about technical issues in the Ystad project are relatively low.

## Table 1 Summary of uncertainties in the Ystad project

| Uncertainty | Respondent | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | H | I & J | K & L | |
| **Uncertainty about nature** | **4** | **4** | **1** | **5** | **1** | **1** | **1** | **5** | **6** | **28** |
| Sand resource | | 1 | | 1 | | 1 | | | 1 | 4 |
| Sediment dynamics | 1 | 1 | | | 1 | | 1 | 1 | 1 | 6 |
| Sea level rise | | | | 1 | | | | | 1 | 2 |
| Extreme weather | | | 1 | 1 | | | | | | 2 |
| Environmental impacts | 2 | | | 1 | | | | 2 | 2 | 7 |
| Dunes and beach profiles | 1 | 1 | | | | | | 1 | | 3 |
| Others | | 1 | | 1 | | | | 1 | 1 | 4 |
| **Uncertainty about engineering** | | | | **2** | | **1** | | **3** | **1** | **7** |
| Possible alternatives for coastal erosion | | | | 1 | | 1 | | | 1 | 3 |
| Monitoring program of the Ystad project | | | | | | | | 3 | | 3 |
| Investigation for permit application | | | | 1 | | | | | | 1 |
| **Uncertainty about society** | **6** | **2** | **4** | **7** | **4** | **4** | **5** | **3** | **6** | **41** |
| Buildings, areas and properties | 1 | 1 | 1 | | 1 | 1 | | | 1 | 6 |
| Administrative and finacial responsibilities | | 1 | 1 | 2 | | 1 | 1 | 1 | 1 | 8 |
| Cost-effectiveness of coast management | 2 | | | 2 | | | | | 1 | 5 |
| Permits to sand nourishment | 1 | | | 1 | | | 1 | | | 3 |
| Priority of sand nourishment and coast management | | | | | 2 | | | | 3 | 5 |
| Offcials and/or deicison makers on coast management | 2 | | 1 | | 1 | 2 | 2 | | | 8 |
| Archaeological value of sand extration area | | | | 1 | | | | 1 | | 2 |
| Others | | | 1 | 1 | | | 1 | 1 | | 4 |
| Total | 10 | 6 | 5 | 14 | 5 | 6 | 6 | 11 | 13 | 76 |

### 4.3.1. Uncertainties in the nature system

The first group of uncertainties is in regard to potential environmental impacts of the Ystad project. Four respondents mentioned for six times that the potential impacts of the Ystad project on the environment and biological diversity are one of the most critical sub-categories of uncertainties to be dealt with. However, the focuses of respondents on environmental issues are distinct. Some respondents have the tendency to think of the environmental uncertainties concisely, but other respondents may specify their detailed concerns. For instance, two respondents[4] stated that they acknowledged that they had little information about what kinds of species exists in the sand extraction area, which is used as the reference to investigate the marine biological diversity. No matter how the respondents formulated their uncertainties about environmental impacts of sand nourishment, they admitted that this sub-category of uncertainties is one of the main issues that hampered the decision-making process. The decision makers in this project were not sure about the effects of offshore sand extraction on the marine environment and biological diversity, and the effects of sand nourishment on the environment and inland eco-system. Considering the bad examples of offshore sand extraction projects in Denmark which are thought by the Swedish people to cause unacceptable negative impacts on environment[5], actors involved in the Ystad project had every intention of clarifying if the sand extraction and sand nourishment would have any adverse impacts on the environment in Sweden.

The second sub-category of uncertainties is about sediment dynamics along the coastlines of Ystad and Scania County. Eight respondents have stated that they acknowledged that they obtained limited knowledge on how sediments move along the coastlines of Ystad and how the Ystad project will influence beach profiles and sediment dynamics. Sediment dynamics is one crucial factor which determines the lifetime of the nourished beaches, in turns determines the amount of sand to be dredged, the interval of nourishment and the cost of the Ystad project. The constant sediment dynamics also give an unfavorable condition for research and investigation. The unstable and changeable sediment distribution along the coast asks the researchers to develop an adaptive research methodology.

The third sub-category of uncertainties is related to the sand resource on the Swedish continental shelf. This sub-category of uncertainties emerged in chronological order of two phases. In the initial phase of the Ystad projects, the respondents were aware that they had limited information about whether, and how much, sand resource was available on the Swedish continental shelf for sand nourishment. This uncertainty was then solved when sand was found near the Sandhammar bank. However, since the Ystad project has implemented sand nourishment, other coastal municipalities threatened by coastal erosion in Scania County are also seeking sand resource for their potential sand nourishment projects. Therefore, for the regional authorities and governmental agencies, the availability of sand

[4] Respondent I and J
[5] Respondent D

resource offshore is an important issue in the near future, which was confirmed by four respondents[6] in the interviews.

Besides the uncertainties that were commonly mentioned, diverse additional uncertainties in the natural system were mentioned by the respondents:

- Four respondents[7] mentioned the uncertainties about potential impacts of the Ystad project on dunes and beach profiles.
- Two respondents[8] expressed that sea level rise along the coastlines of Scania County was precarious.
- Two respondents[9] wondered how extreme weather could affect the Ystad project. The uncertainty was "total ignorance" before the project and then turned to "recognized" uncertainty when the storm in 2012 caused serious coastal erosion on nourished beaches unexpectedly.
- One respondent [10] said that the grain-size characteristics of dredged sand are a problem. Before the sand nourishment, the color of the offshore sand was supposed to be darker than that on sandy beaches in Ystad.
- Two respondents[11] questioned offshore sand extraction might influence the currents, waves and sediment dynamics, but limited knowledge was available on those topics.

### 4.3.2. Uncertainties in the technical system

Since there is no interview conducted with Danish contractors who carried out the Ystad project, limited information was obtained about the uncertainties regarding engineering or technical issues that are relevant to the nourishment process. But some interviewees stated uncertainties about other technical issues. For instance, two respondents[12] stated that limited reference data were available for the monitoring program of the Ystad project, and the methodologies for detecting biological and environmental impacts of the Ystad project were not completely prepared. Another example is that four respondents [13] believed it was relatively uncertain if there were other solutions to coastal erosion in Ystad.

In an informal conversation, one respondent [14] indicated one uncertainty that caused difficulties in the Ystad project, namely the scope and geological scale of the investigation to be undertaken when Ystad Municipality applied for a permit for offshore sand extraction. There was no clear instruction about how large the area was to be investigated and monitored before and after the Ystad project. Ystad Municipality thought it was impractical and unaffordable for a single municipality to have a large-scale investigation. From Ystad Municipality's point of view, the requests of the Swedish authorities sometimes were rather

[6] Respondent B, F, K and L
[7] Respondent A, B, K and L
[8] Respondent D, K and L
[9] Respondent C and D
[10] Respondent D
[11] Respondent K and L
[12] Respondent I and J
[13] Respondent D, F, K and L
[14] Respondent D

"crazy": one official once pointed to four dots on the map and called for an investigation on the bounded area in the sea, nevertheless the official had no idea about the exact extent of that area.

### 4.3.3. Uncertainties in the societal system

In this case study, uncertainties about society includes economic, cultural, legal, political, administrative and organizational aspects discussed by the respondents working on the Ystad project.

The first sub-category of uncertainties in the societal system is in the complexity of administrative and financial responsibilities in the Swedish political hierarchy. Nine respondents[15] admitted that it was unknown that which ministries or governmental agencies should take the administrative or financial responsibilities for coastal management in Sweden. This uncertainty can also be confirmed by the minutes of a meeting in the Swedish Parliament in March 17, 2010. Several ministries and governmental agencies were considered to be relevant to coastal erosion issues, but nobody knew the specific responsibility of each agency in dealing with coastal erosion. This uncertainty is even more profound at the national governmental level, and is the barrier to effective communication when the decision making process reaches an impasse.

Another sub-category of uncertainties is closely related to the first one about officials and decision makers. Two respondents[16] said that it was difficult for them to find the "right" persons to communicate with on the Ystad project, and no governmental official dared to make the decision and grant the permit to Ystad Municipality for sand extraction. Two respondents[17] felt that the conflicting attitudes of different officials at the regional level towards sand nourishment made the decision making process of the Ystad project difficult.

The third sub-category of uncertainties mentioned by respondents is about the lands, buildings and properties threaten by coastal erosion in Ystad and Scania County. Seven respondents[18] said this uncertainty was relatively low. GIS-maps can reveal the areas and buildings under the threat of coastal erosion in different scenarios of sea level rise. But the values of properties may be much difficult to be calculated and the strategies for coastal management highly depend on the economic values behind eroded coastlines.

Cost-effectiveness of coastal management project is an important issue in the Ystad project. Three respondents[19] did not completely know the cost and benefit of the Ystad project, even though two of them believed that the Ystad project must be cost-effective and is able to bring more tourists. It is very interesting that one respondent[20] is very interested in the cost-

[15] Respondent B, C, D, F, H, I, J, K and L
[16] Respondent A and C
[17] Respondent F and H
[18] Respondent A, B, C, E, F, K and L
[19] Respondent D, K and L
[20] Respondent A

effectiveness of other plans dealing with coastal erosion, such as relocation. However, there is no information available on that topic.

The fifth part of uncertainties is raised by the respondents working in regional administrations of Scania County. Three respondents[21] from County Administrative Board of Scania and Regional Council of Scania stated respectively that investigation and analysis should be made to demonstrate the priority of sand nourishment and coastal management for regional development in Scania County. One respondent[22] stated that it should be clarified which parts of coastlines need to be protected in Scania County and which part of coastlines can be protected by sand nourishment.

Several uncertainties about society are also described by different actors, for instance:

- Three respondents[23] acknowledged that they had little information about whether and when SGU could grant Ystad Municipality the permit for offshore sand extraction. Ystad Municipality had to sign the contract with contractors with a precondition that the contract was no binding force if Ystad Municipality could not get the permit by SGU.
- Three respondents[24] mentioned uncertainties regarding archeological value (e.g. shipwrecks) of the sand extraction areas near Sandhammar bank.
- Two respondents[25] said they did not consider beforehand how the media would introduce and describe the Ystad project to the public. The Ystad project was once reported on the radio but was unexpectedly compared with a Danish sand extraction project which was believed to affect the environment severely by Swedish people. According to the respondents, the comparison prejudiced the image of the Ystad project in public.

Based on these results from the BwN uncertainty matrices, an in-depth analysis will be conducted in the following chapter on different perceptions of uncertainties in the BwN sand nourishment projects by answering the research question and sub-questions.

[21] Respondent E, K and L
[22] Respondent K and L
[23] Respondent A, D, and H
[24] Respondent D, I and J
[25] Respondent D and H

# 5

# Discussion

This chapter aims to answer the research question and sub-questions. Chapter 5.1 presents different perceptions of uncertainties from different actors in the Ystad project. Uncertainties that affected the decision making process of the Ystad project are enumerated in Chapter 5.2. Chapter 5.3 analyzes the strategies that the actors used for dealing with uncertainties and accelerating the decision making process in the Ystad project.

## 5.1. Different perceptions of uncertainties in the Ystad project

Comparing the BwN uncertainty matrix of each respondent, the different perceptions of uncertainties in the Ystad projects manifest themselves when respondents have different ideas about the *location*, *level* and *nature* of an uncertainty. In the following sections, the different uncertainty perceptions from these perspectives will be examined.

### 5.1.1. The location of uncertainty

In the matrices, only one uncertainty is seen to be located in the context of uncertainty. But it does not represent there is no difference between different perceptions of the location of uncertainty. The differences are evident when taking a close look at how the respondents formulated and stated their uncertainties in different scales. Their perceptions are based on their different positions in the administrative hierarchy or their different roles in the Ystad project.

When discussing coastal erosion and the Ystad project, the officials in the regional administrative agencies would like to talk about regional strategies of coastal management, urban planning and regional development. They had to keep the equality for all the municipalities in Scania County on coastal management issues and prevent discrimination in favor of the Ystad project. For instance, they had uncertainties about the availability of sand resource in the Swedish territories for all the potential sand nourishment projects and other usages (e.g. building materials). In their mind, sand is a scarce resource. In contrast, when Ystad Municipality, as the project owner and local authority, considered the availability of sand resource, it was unnecessary for them to think about sand resource of an extensive scale. They paid more attention to where was sufficient sand for their own project. Therefore, though the local and regional officials shared the same uncertainty about the availability of sand resource, the boundaries of their systems are divergent. For sand resource, the scale of the system that the sand resource is embedded for regional administrators is broader than that for Ystad Municipality.

The uncertainties regarding the priorities for sand nourishment and coastal management in regional development is another example revealing that different perceptions of uncertainties are derived from different system scales in people's minds. Because of the sandy beaches, Ystad is one of the most popular cities for tourists in Sweden. Keeping the sandy beaches in Ystad from eroding is protecting the local economy. Therefore, for Ystad Municipality, coastal management is consistent with local development, and there is no uncertainty about if sand nourishment has the priority in local development. However, for regional and national governments, there is no evidence that coastal management should receive priority in the regional development, thus coastal erosion is not necessarily high on their agenda. Because different actors think about the uncertainties at different scales, some uncertainties may be present in some matrices but absent in the others.

It looks like people involved in the Ystad project would like to discuss uncertainties within their limited and stable scales that cohere with their positions in the political hierarchy. In other words, the higher the political hierarchical level of, the more extensive scale at which the respondent thinks about the uncertainties. However, when facing the administrative and financial responsibilities for coastal management in Sweden, the perceptions of different actors on uncertainties turn the other way around. Ystad Municipality considered coastal management a matter of vital national interests, hence coastal erosion is a national problem, and regional and national governments ought to take the administrative and financial responsibilities. The Swedish national government, in contrast, considered coastal erosion a local problem that should be financed by municipalities and private landowners. County Administrative Board of Scania, on the one hand, agreed that coastal erosion is relevant to national interests since the owners of lands and buildings along the coastlines of Scania County are not limited to local residents, but covering people in Sweden from north to south. One the other hand, County Administrative Board of Scania, as the representative of the Swedish national government, supposed that municipalities and private landowners should take the financial responsibilities to pay for the coastal management projects by themselves.

Table 8 summarizes the different scales that were used when different Swedish authorities formulated and stated their perceptions of uncertainties in the Ystad project. Each authority has its own perception of different uncertainties. However, the scale of each authority is flexible on different topics. Therefore, it is challenging for different authorities to work on coastal management together. In the interviews, when the authorities talked about the Ystad project, they preferred to confine themselves within their predetermined perceptions on different topics.

Table 8 Different scales of different Swedish authorities on different uncertainties in the Ystad project

| Issues | Scales | | |
|---|---|---|---|
| | Local | Regional | National |
| Sand resource | Ystad Municipality | County Administrative Board of Scania | Swedish National Government |
| Regional development and urban planning | Ystad Municipality | County Administrative Board of Scania | Swedish National Government |
| Financial responsibility for sand nourishment | County Administrative Board of Scania, Swedish National Government | | Ystad Municipality |
| Coastal erosion and coastal management | Swedish National Government | | Ystad Municipality County, Administrative Board of Scania |

### 5.1.2. The level of uncertainty

The differences in the level of uncertainty can only be analyzed when uncertainties are shared by different respondents. In this section, the different levels of uncertainties among respondents are compared.

It is very interesting that uncertainties from actors who consent to sand nourishment are relatively minor, particularly about nature issues. They admitted that they were not completely satisfied with their understandings about nature, which are slight and always categorized into "statistical" or "scenario" uncertainties (e.g. sand resource availability, environmental impacts). However, other actors who are not fully interested in sand nourishment believed that they had no information and knowledge about the nature and the uncertainties are rather deep: the sand resource in the Swedish territories should be explored; the environmental impacts of the Ystad project should be investigated; the sediment dynamics along the coastlines of Scania County have to be studied. All these uncertainties are classified as "recognized" uncertainties. Furthermore, it seems that even till now when the Ystad project is approved and ongoing, the "recognized" uncertainties keep "recognized" and are rarely transformed to shallower uncertainties.

This phenomenon also occurs when the respondents have different perceptions on the cost-effectiveness of the Ystad project. Ystad Municipality estimated the cost and benefits of the Ystad project; therefore the uncertainty of the cost-effectiveness is "statistical" according to two respondents[26]. For other respondents[27], the cost-effectiveness of the Ystad project remained "recognized" uncertainty since no information is available for uncertainty clarification. This example indicates that deep uncertainties cannot be easily transformed into lower level of uncertainties by providing information and knowledge.

[26] Respondent A and D
[27] Respondent K and L

It is common practice that a project owner employs consultants to cope with uncertainties which cannot be handled easily by the project owner. In this case study, Ystad Municipality also cooperated with several consulting companies on the uncertainties in the Ystad project. In the research, however, there are not any significant differences observed on the level of uncertainties between project owner and consultants. There are at least three uncertainties sharing by Ystad Municipality and consulting companies, with regards to the impacts of offshore sand extraction on marine environment and biological diversity, the cost-effectiveness of the project, and the responsibilities of different governments and officials. Within these three uncertainties, the consultants do not show a lower degree of uncertain and no improvement is found regarding the levels of uncertainty. The participation of another group of consultants in the Ystad project did not reduce or eliminate uncertainties and even generated new uncertainties (e.g. impacts of sediment dynamics on monitoring), partly because they had more knowledge and acknowledged the variability of nature (e.g. constant sediment dynamics).

### 5.1.3. The nature of uncertainty

There are not many differences regarding the nature of uncertainty from different perceptions. All the respondents recognized that parts of their uncertainties derive from ambiguity, in other words, multiple frames of reference about a certain phenomenon, especially regarding about social issues, such as responsibilities. The differences can only be revealed on some natural issues. For instance, some respondents[28] stated that the reason for the uncertainty about sediment dynamics is because of incomplete knowledge, therefore in-depth research and investigation should be done to obtain more information for decision making. Some respondents[29] emphasized that sediment has its own dynamics which can be obtained incompletely and vary naturally, therefore the nature of uncertainty regarding sediment dynamics is more related to "variability". The variability contributes to other uncertainties. For instance, sediment dynamics will exert influences on the methodologies of monitoring the marine environment and biological diversity, which are classified as "variability".

## 5.2. Uncertainties affecting the decision making process

This chapter will figure out which uncertainties affected the decision making process of the Ystad project.

The uncertainties regarding the permits for sand nourishment are the most remarkable uncertainty that affected the Ystad project. Ystad Municipality was not able to perform the project without the permits, but had limited information about when they could get the permits, particularly the one issued by SGU for sand extraction. However, the permit uncertainty does not exist in isolation but is strongly related to the other uncertainties, such as the uncertainties about the environmental issues. It can be seen as the outcomes of other uncertainties in the decision making process.

[28] Respondent B, E, H, K and L
[29] Respondent I, J and N

### 5.2.1. Uncertainties about environmental issues

Uncertainties about *environmental issues* are important in the decision making process and are the official reasons of rejecting Ystad's permit application for offshore sand extraction in 2003 and 2007 (County Administrative Board of Scania, 2010), though the Swedish Land and Environmental Court issued the permits for sand nourishment in Ystad in accordance with Environmental Code in 2001. However, according to one respondent[30], the permit application with the court did not go smoothly as well. In fact, the court rejected the permit application once and Ystad Municipality finally got the permit after appealing to the superior court, regardless of SGU's concerns about the potential impacts of the Ystad project on marine and inland environment. When Ystad Municipality applied for the permit to extract sand, SGU became the decision maker, and the unsolved environmental issues manifested themselves again and hampered the permit application.

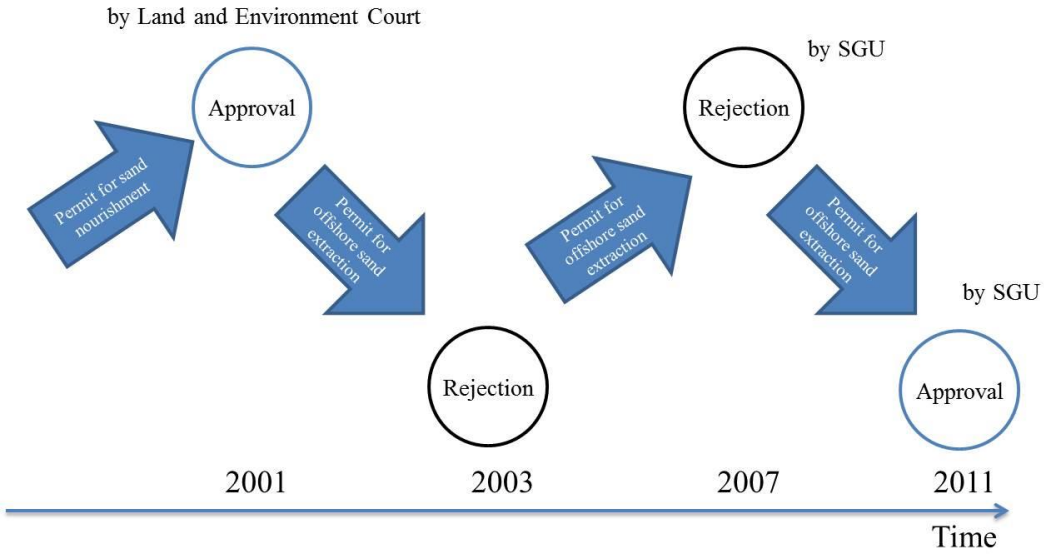


**Figure 13 Round model of the decision making process of the Ystad project**

In fact, the decision making process follows the round model by van Bueren et al. (2003) (see Figure 13). In each round, the actors define problems, explore solutions and look for an opportunity to reach an agreement. The outcome of each round may be an impasse or a breakthrough, which may influence following rounds of decision making. In the first round, Ystad Municipality got the permit by court. When the second and third rounds came, the involvement of actors in these rounds changed: Land and Environment Court was not involved and the power of SGU and Swedish Environmental Protection Agency were much stronger than before. The environmental issues that SGU and Swedish Environmental Protection Agency might think not to be fully solved in the first round were on the negotiating table again. In 2011, SGU re-defined the involvement of actors in the fourth round. Swedish Environmental Protection Agency was excluded in this round, which is probably the reason that an agreement was made eventually.

[30] Respondent N

### 5.2.2. Uncertainties about sand resource

*Sand resource* is another source of uncertainties in the Ystad project, referring to the availability of sand resource in the Swedish territories and the amount of sand that can be used for sand nourishment. Firstly, if Ystad Municipality did not find any sand resource in the Swedish territories, sand import from other European countries could have introduced a cluster of new uncertainties to the Ystad project. When the sand resource was found near the Sandhammer bank, the uncertainties turned out to be about how much sand should be used for sand nourishment. In fact, different perceptions of uncertainties about sand resource were identified as one of the reasons for the difficult and delayed decision making process, which has been explained in Chapter 5.1.1. The dissonant definitions of the system boundaries made it rather difficult for different actors to negotiate at the same scale. Therefore, the decision making process was hampered.

Interestingly, some respondents[31] mentioned that the uncertainties affecting the Ystad project did not only come from the project itself, but originated from the (un)expected reactions of other municipalities when the Ystad project would be approved. If Ystad Municipality was allowed to extract sand offshore and undertake sand nourishment inland, or aided financially by the Swedish regional or national governments, it was unclear whether the other coastal municipalities in southern Sweden would press their demands regarding coastal management or other issues. Therefore, the decision makers were apt to behave like a "goalkeeper" in the decision making process and avoid a "ripple effect" among the coastal municipalities in Scania County. This impediment also comes from the different contexts of the uncertainty for different actors. As argued above, different actors put the Ystad project in different contexts. When the Ystad project was viewed as in a limited single-project, the "ripple effect" on the other municipalities was not considered to be important. If the Ystad project was considered at a broader scale such as the scale of regional planning for coastal management, the "ripple effect" should be taken into account.

For the uncertainties about sand resource, game theory can be a possible theory to interpret the multiple perceptions of sand resource in the Ystad project. Assuming that actors in the project are rational, their goals are to maximize their own outcomes in the "game" of the Ystad project. Therefore, their perceptions concentrate on how to maximally reach their goals at the least expense. For Ystad Municipality, the optimal alternative is to have the Ystad project with financial support from the Swedish national government, while keeping its monopoly on local urban planning. For governments at higher levels, they prefer to protect national interests (i.e. sand resource) and prevent the "ripple effect", which can be seen as their goals in the decision making process. Breakthrough is not always welcome for decision makers, and maintaining the *status quo* might not be an unacceptable option. So "goalkeepers" in the decision making process arise. Their goals in the "game" are certainly related to combating with coastal erosion and promoting regional development. But if a situation must be changed, the solutions with limited and recognized risks that decision makers are conversant with are much preferable and overweighed than the innovative

[31] Respondent H, K and L

solutions with unforeseen impacts in the future. This can explain the reason that the Swedish Environmental Protection Agency recommended hard infrastructures to Ystad Municipality for coping with coastal erosion, though the negative impacts of hard infrastructures had clearly been known[32]. Since sand nourishment accepts uncertainties instead of reducing them, apparently the Ystad project is not the option for decision makers. So a "win-win" situation may not be achieved. Considering the inequality of power in the decision making process, Ystad Municipality was not able to ignore the decision makers or sacrifice their outcomes to reach its own goals. As a result, the rejections are inevitable.

### 5.2.3. Intermezzo: Connections among uncertainties

Uncertainties are not isolated but connected with each other. Several scholars have acknowledged that there is a relationship between different uncertainties. Van den Hoek et al. (2014) used the *cascades of uncertainty* to analyze the generation of ambiguity and the interconnections between different uncertainties. In short, the cascades show how uncertainties in the natural and technical systems influence the societal system and generate ambiguity. In this section, the cascades of uncertainty are applied to explore the reasons that some uncertainties affecting the decision making process of the Ystad project.

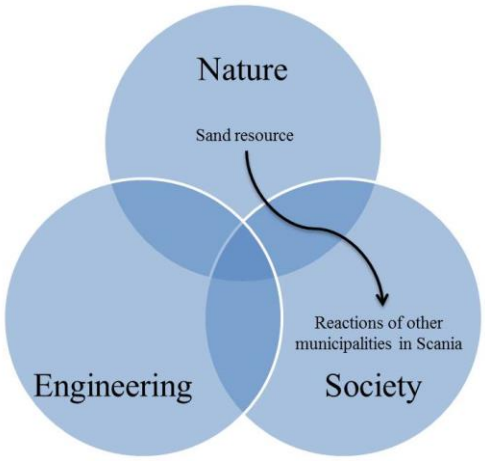


**Figure 14 Cascade of uncertainty regarding sand resource and reactions of other municipalities in Scania County**

Figure 14 indicates that uncertainties regarding sand resource contribute to uncertainties about the reactions of other municipalities. Roughly speaking, sand resource is the reason for the generation of uncertainties about other municipalities' reactions. Similar connection can also be found between other uncertainties, for instance, uncertainties between sediment dynamics and cost-effectiveness of sand nourishment (which may not be so influential in the Ystad project since Ystad Municipality financed the project by itself, see Figure 15).

[32] Respondent D

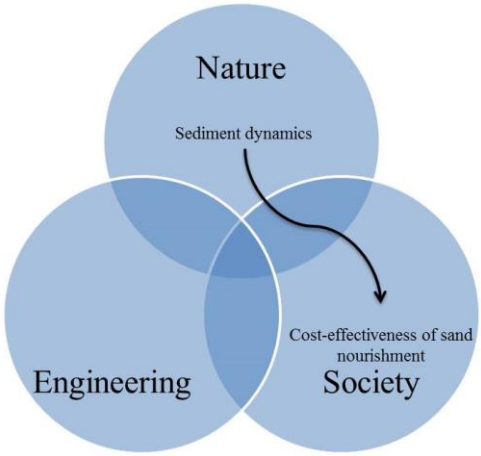


**Figure 15 Cascade of uncertainty regarding sediment dynamics and cost-effectiveness of sand nourishment**

For the environmental impacts of sand nourishment, it is difficult to find an uncertainty to correspond to in the case study. In this master thesis, it is supposed that the Swedish culture may be in the downstream of the cascade for uncertainties regarding environmental issues. Sweden is well-known as its close relationships with nature, which come from its agricultural history[33]. This culture may influence the decision making process of the Ystad project, and decision makers have relatively low tolerance of possible environmental impacts of sand nourishment.

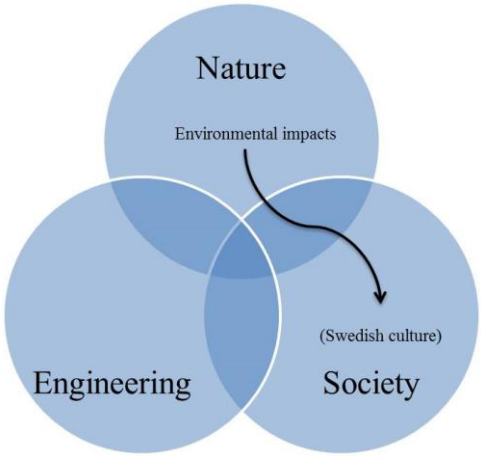


**Figure 16 Cascade of uncertainty regarding environmental impacts and the Swedish culture**

During this field research in Sweden, it is interesting to know that respondents basically accept the uncertainties about administrative and financial responsibilities in Sweden, which seem not to severely affect the decision making process. The cascade of uncertainty may provide us a lens to find out the reason. Figure 17 shows that there is no uncertainty in the natural or engineering system as the upstream in the cascade of uncertainty. It does not mean that these uncertainties come from nowhere, but indicates these uncertainties are created solely in the societal system without any other influences from nature and engineering. If coping with upstream uncertainties is a possible strategy of dealing with uncertainties downstream, the uncertainties regarding responsibilities should be much more difficult to be handled. Therefore, decision makers and actors in the Ystad project have to accept and respect these uncertainties and the efforts on these uncertainties may not be effective.

[33] Respondent H

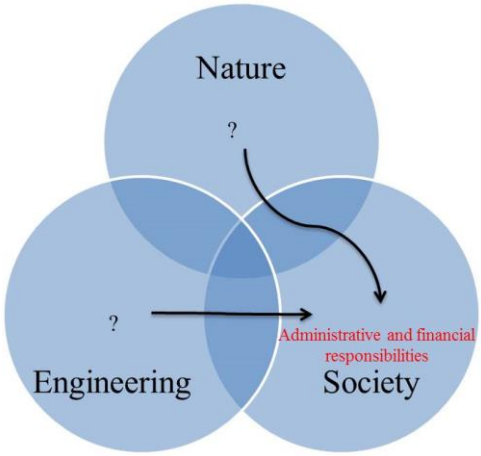


**Figure 17 Possible cascade of uncertainty regarding administrative and financial responsibilities for coastal management in Sweden**

## 5.3. Strategies dealing with uncertainties

### 5.3.1. Interactive scale framing: upscaling and downscaling

In 1994, EC was established by coastal municipalities on coastal erosion issues in Scania County. It is a collaborative forum that aims to share information and knowledge among members and to promote the involvement of governments on coastal erosion issues. Ystad Municipality is in the leading position in EC, cooperates with the other 21 municipalities and 7 companies, governmental agencies and organizations. EC, as a joint force of municipalities in Scania County, is very active in the Ystad project, particularly after two rejections by SGU. On behalf of EC, Ystad Municipality made major efforts in negotiating with decision makers and putting coastal erosion on the agenda of the Swedish national government. They invited officials at each level of the Swedish governments, such as regional governors, ministers and even the king and queen of Sweden in 2005, to visit eroded beaches and to bring coastal erosion to their notice. They preferred to express their opinions on coastal management in the name of EC when communicating with other officials or governments, and exerted their influence on coast erosion issues (e.g. sending a letter to the former prime minister of Sweden, making comments on the report of climate change by national government in 2007, etc.). EC also helped Ystad Municipality to be involved in some research projects in EU frameworks, such as the Messina project and the EUROSION project.

The second main effort on different contexts of uncertainties is the Ystad Municipality's cooperation with Regional Council of Scania. The cooperation can be formulated since Regional Council of Scania is an elected parliamentary administrative agency that represents the interests of regional and local citizens. Regional Council of Scania and Ystad Municipality share common language on coastal management, urban planning and regional development. In contrast, County Administrative Board of Scania is less close to Ystad Municipality since it represents the Swedish national government. Because of the cooperation with Regional Council of Scania, Ystad Municipality has a closer connection to members of the Swedish Parliament, who are able to promote coastal erosion issues in a parliamentary discussion.

As discussed in the previous sections, different perceptions of the contexts of uncertainties in the Ystad project always differ not only for one single actor but also among the actors in the project. The efforts that Ystad Municipality has made, including establishing EC and cooperating with Regional Council of Scania, aim to connect with decision makers as much as possible. In fact, Ystad Municipality (unintentionally) attempted to influence the other actors' framings of the contexts of uncertainties in the Ystad project and even the whole Ystad project. In particular, Ystad Municipality would like to drag governmental decision makers' perceptions of coastal erosion and coastal management from the local level to the other end of the national level, which is preferred by Ystad Municipality. A similar strategy was also applied for the uncertainties about financial responsibility for sand nourishment. Ystad Municipality depicted sandy beaches as a national interest and coastal erosion in Ystad as a national problem; hence the Ystad project was supposed to safeguard the national interests. This re-framing process expanded Ystad Municipality's perceptions of uncertainties to a high level that catered to decision makers in the governments and provided a thorough foundation for the other attempts of influencing others' framings and accelerating the decision making process.

Some research showed that scale preference influence the design of a water innovation (Vreugdenhil et al., 2010), and the scale framing plays an important role in complex policy issues and can be re-framed by the actors in the decision making process by means of, for instance, upscaling and downscaling (van Lieshout et al., 2012). Actors downscale an uncertainty to a lower and less problematic level, or upscale an uncertainty to a higher and more problematic or more influential level. Gupta (2011) summarized the reasons of upscaling (or "scale up") and downscaling (or "scale down"). Upscaling can enhance understanding of a problem, promote effective and inclusive governance, promote domestic interests and promote external interests, while downscaling can enhance understanding of a problem through greater resolution and grain regarding critical local and contextual elements, promote effective governance through using existing institutions and mobilizing local people, promote domestic interests by avoiding liability for externalized effects and protecting national interests and promote external interests through divide and control, inclusion and exclusion strategies (Gupta, 2011).

In practice, Ystad Municipality's strategy was to scale up issues on coastal management to promote inclusive governance of the Swedish national government. However, Ystad Municipality was not able to influence and re-frame all the perceptions of decision makers. There are some "fixed" perceptions that can hardly be re-framed. For instance, the monopoly of Ystad Municipality in urban planning and local development is prescribed by the Swedish laws. Therefore, Ystad Municipality had to keep these issues downscaling and maximally use existing institutions and resources to reach the goal, such as financing the Ystad project by itself.

### 5.3.2. Hybrid strategy: rational problem solving and persuasive communication

Since the Ystad project is the first BwN sand nourishment project in Sweden, most of the actors in the decision making process have limited knowledge and experience on and nourishment, which are essential for final decisions. Ystad Municipality and other organizations made great efforts on providing knowledge to support the decision making process. Besides original academic research in the Swedish universities and research institutes, external knowledge sources also made a great contribution to transferring knowledge and experience on sand nourishment to Sweden, such as Deltares and DHI. In addition, the research projects in EU framework, such as the Messina project and the EUROSION project, also generated knowledge on coastal erosion and coastal management.

However, abundant knowledge may solve the uncertainties from "not knowing enough", while there is another sort of uncertainties from "knowing differently", in other words, different perceptions or ambiguity, that cannot easily be clarified by abundant knowledge (van den Hoek et al., 2014). Brugnach et al. (2011) discussed the strategies of dealing with uncertainties in the natural resource management, including *rational problem solving*, *persuasive communication*, *dialogical learning*, *negotiations* and *oppositional modes of actions*. Abundant knowledge can be classified in "rational problem solving" which relies on expert knowledge to arbitrate uncertainties (van den Hoek et al., 2014). Besides knowledge, Ystad Municipality and some researchers (e.g. Respondent N) spent much time and energy on lobbying and "educating" the Swedish decision makers, which are attributed to persuasive communication by convincing others of the meaningfulness of one particular frame of reference.

An example is how researchers re-framed the sediment dynamics on nourished beaches. An intuitive framing of sand nourishment is that the sand which is artificially laid on the beaches will be washed away anyhow by currents, waves and storms in the near future, therefore sand nourishment is to" throw money into the sea". However, Ystad Municipality did not agree on that. For instance, one researcher[34] re-framed the nourished beaches: "the nourishment will never disappear" (see Figure 18), which indicated that filled sand is "relocated" landwards and coastal erosion will occur on the nourished beaches instead of protected beaches. This argument follows the natural dynamics of sand but re-frames the disappearance of nourished beaches, which may influence the decision makers to be more easily to accept sand nourishment technique. It is a typical process of persuasive communication that educates decision makers about the "right" approach to understand sand nourishment and the Ystad project. Ystad Municipality have already known the effectiveness of framing and re-framing in the decision making process. That might be the reason that two respondents[35] mentioned their uncertainties about how the media report, compare and evaluate the Ystad project to the public, which may influence the public's attitude towards the Ystad project.

[34] Respondent N
[35] Respondent C and D

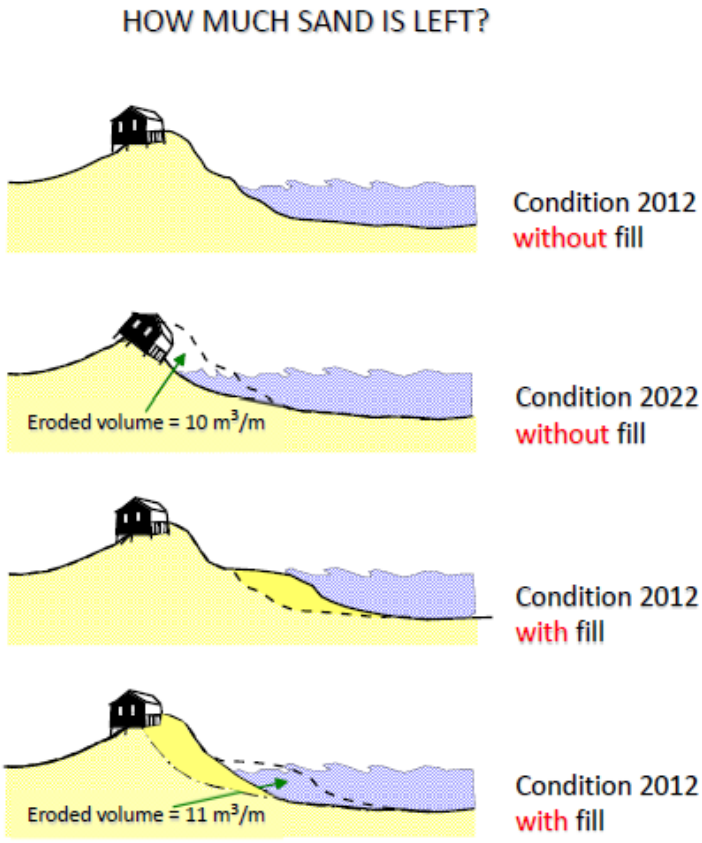


**Figure 18 Re-framing of sand nourishment in the Ystad project (by Hans Hanson)**

For the Ystad project, researchers on coast engineering provided information and knowledge to the decision makers while attempted to re-frame decision makers' perceptions of sand nourishment. According to the categorization of strategies dealing with uncertainties by Brugnach et al. (2011), Ystad Municipality and the researcher used a hybrid strategy of rational problem solving and persuasive communication to fill the gaps of information and knowledge in the Ystad project.

# 6

# Conclusions & Recommendations

Based on the research outcomes in the previous chapters, Chapter 6.1 answers the main research question and sub-questions in details. The recommendations follow in Chapter 6.2.

## 6.1. Conclusions

Chapter 1.2 raises the research question and sub-questions about uncertainties in decision making processes of the BwN sand nourishment projects. In Chapter 4 and 5, the BwN sand nourishment project in Ystad has been analyzed on the uncertainties in the project by case study. Based on the previous chapters, the following conclusions are drawn.

Firstly, according to the location, level and nature of uncertainty, the theory-based BwN uncertainty matrix is capable of disclosing the uncertainties in the BwN sand nourishment projects in the natural, technical and societal systems. This analytical framework is also valuable for revealing different perceptions of uncertainties from different actors in decision making processes, and analyzing the essence of strategies dealing with uncertainties.

Secondly, despite the initial understanding, the lack of knowledge and information is not the principle reason of the delayed decision making process of the Ystad project. Instead, problems lie in the communication about uncertainties among the actors. Uncertainties and different perceptions of uncertainties are widely spread in the decision making process of the Ystad project. Most of uncertainties concentrate in the natural and societal systems, while some are embedded in the technical system. The comparison among the BwN uncertainty matrices of different actors showed that the perceptions of uncertainties vary in all the three dimensions of uncertainty, namely the *location*, *level* and *nature* of uncertainty. For the location of uncertainty, the actors in the Ystad project have their own scale preferences. These preferences intrinsically differ: the actors prefer different scales on different uncertain issues in the Ystad project. For the level of uncertainty, different preferences of sand nourishment may influence perceptions of uncertainties, and the level of uncertainty cannot be easily reduced when abundant knowledge and information are introduced. For the nature of uncertainty, the differences manifest themselves between epistemic uncertainty and variability on sediment dynamics along the coastlines of Ystad.

Thirdly, in combination with empirical data about the decision making process of the Ystad project, uncertainties regarding potential environmental impacts of sand nourishment and sand resource are critical in the Ystad project. Environmental uncertainty had not been

handled well in the early stage of decision making and was inherited in the following rounds of decision making. The influence of sand resource uncertainty can possibly be attributed to actors' rational behaviors in the "game" of the Ystad project. Brugnach's cascades of uncertainty demonstrate that the uncertainties in the natural system are able to affect the decision making process if they can be reflected on the uncertainties in the societal system. The uncertainties which are not influential in the societal system (e.g. uncertainties about administrative and financial responsibilities) may be due to the absences of uncertainties in the natural or technical system upstream in the cascades of uncertainty.

At last, two strategies dealing with uncertainties in the Ystad project are refined. On the one hand, Ystad Municipality used interactive scale framing to influence different scale preferences of different actors by upscaling and downscaling different uncertainties in the project. For instance, Ystad Municipality intended to upscale the coastal erosion and coastal management as a national issue, in order to attract attentions of the Swedish national government. On the other hand, a hybrid strategy containing rational problem solving and persuasive communication was applied to fill the gaps of epistemic uncertainty and ambiguity. Ystad Municipality and researchers at Lund University "educated" the Swedish decision makers by abundant knowledge on coastal engineering and re-framed their perceptions on sand nourishment.

To sum up, in the Swedish context, uncertainties regarding environmental impacts and sand resource are of great importance in the decision making process of the BwN sand nourishment projects. To cope with uncertainties and different perceived uncertainties, abundant knowledge and information, persuasive communication (re-framing) and interactive scale framing are proved to be effective to accelerate the decision making process of the BwN projects. The project owner and academic researchers are the main actors implementing those strategies.

## 6.2. Recommendations

Although the decision making process of the Ystad project was delayed by uncertainties, Ystad Municipality got all the permits for sand nourishment. The Ystad project now is ongoing, but it does not imply that the temporary agreement on sand nourishment in 2011 will be inevitably preserved after 2021. Considering that sand nourishment is seen as a long-term strategy for coastal management in Ystad, this section will provide recommendations based on the empirical research.

*Abundant knowledge on multiple research areas from multiple knowledge sources*

Knowledge is the foundation of the decision making process. In Sweden, only a few of universities, research institutes and governmental agencies possess the knowledge about sand nourishment, marine environment and biology, and integrated coastal management. Most of the knowledge is generated by limited number of knowledge providers, such as Lund University. The knowledge gap of coastal management in Sweden is not only related to the availability of knowledge but also concerning with knowledge generation. Abundant knowledge is necessary to reduce the epistemic uncertainty and maybe part of variability.

Therefore, knowledge generation on multiple issues from multiple sources on coastal management in Sweden should be encouraged.

*Keep cooperation with Swedish regional authorities*

For the Ystad project, Ystad Municipality as the project owner cooperated with regional authorities in Scania County. In this research, we recognized that different preferences of sand nourishment and different perceptions of uncertainties in sand nourishment exist within each regional authority. Even though regional authorities are not decision makers in the permitting process, the influence of officials in the Swedish regional authorities should be taken care of. One respondent[36] mentioned that there is an uncertainty about the changes in the positions in regional authorities because of, for instance, retirement and election. Ystad Municipality should establish connections broadly with regional officials or even "educate" and re-frame their perceptions beforehand.

*Reorder the permit process of coastal management projects in Sweden*

The complexity of administrative and financial responsibilities for coastal management in Sweden has been accepted by most of the respondents as a "natural" Swedish phenomenon. In order to accelerate the decision making process of the BwN project, a long-term strategy for the Swedish authorities is to reorder the permit process and re-allocate the responsibilities of each level of governments and parliamentary organizations and governmental agencies. Some coastal countries threaten by water problems (e.g. the Netherlands) form national water governance agencies to cope with all the water issues in the counties (e.g. Rijkswaterstaat in the Netherlands), which might be good examples for Sweden.

[36] Respondent F

# 7

# Reflections

This master thesis project aims to develop a theoretical framework for investigating uncertainties in the BwN sand nourishment projects by a case study of the sand nourishment project in Ystad, Sweden.

Firstly, the revised analytical framework, BwN uncertainty matrix, is based on a hypothesis that people's perception is system-based, which is characterized by system, context, external factors, policies and outcomes. This hypothesis makes a distinct categorization of different components in a system and contributes to analyzing the relations and interconnections among components. However, there is not always a "system" in respondents mind when they formulate their perceptions of, for instance, a project, and the distinctions among different elements in a system sometimes may be blurred. Since the respondent could hardly give a clear definition of a "system", the formulation of the system and the boundary of the system highly rely on how the researcher code, analyze and interpret the data. Unfortunately, there are no criteria that can be followed when categorizing uncertainties by the BwN uncertainty matrix. For instance, the difference between context uncertainty and external factor uncertainty is related to whether an uncertain issue directly exerts influences on the perceived system.

Secondly, the results of uncertainty analysis by the BwN uncertainty matrix are sensitive to how the respondents describe their perceptions of uncertainties and how the researcher rephrases the statements that will be used in the BwN uncertainty matrix. This problem may introduce the researcher's bias and cause difficulties when categorizing the location, level and nature of uncertainties. For instance, one respondent may mention his uncertainty regarding "environmental impacts" of a BwN project. It is sometimes ambiguous because this uncertainty can be categorized to be located in either "system" which refers to the reason and mechanism of the environmental impacts, or "outcomes" which focuses on apparent consequences of the environmental impacts. Therefore, the theoretical framework necessitates high-quality skills of data collection and interviewing, or an iterative data collection process to obtain more concrete and precise information to deal with the "uncertainties" in the research. The student would like to reduce the uncertainties as much as possible. But considering the limitations of time in Sweden, funds for the field research and the capability of the student, the uncertainties might remain and need to be fixed in the future.

Thirdly, the nature of uncertainties in the BwN uncertainty matrix sometimes is not able to represent accurately the reason of people's feeling of being uncertain. In some conditions, the reasons of being uncertain are multiple and mixed, which can hardly be classified within a single category of the nature of uncertainty. For example, one respondent may have uncertainties in the nature system, which seems to be related to "epistemic" uncertainty therefore additional information and knowledge could reduce the uncertainty. However, the respondent may also mention that he acknowledges the "variability" of nature system that cannot be fully obtained. The "epistemic" and "variability" uncertainties are distinctive nature of uncertainties in the BwN uncertainty matrix, but both of them are applicable to some uncertainties in the nature system. One "quick and dirty' solution is simultaneously using two different types of nature to characterize one uncertain issue. But it is imperative to introspect if the existing subdivisions are able to present an entire spectrum of different nature of uncertainties, and furthermore, if our understandings of the nature of uncertainties are incomplete. This master thesis project does not aim to give an answer to the questions above, which might be a possible direction for further research.

In addition, it is difficult to formulate relatively objective criteria when discussing uncertainties affecting the decision making process in a BwN project. In this research, the student is only able to refer to the accumulated frequency of each uncertainty in all the interviews with the combination of empirical data (i.e. the timeline and milestones) of the Ystad project. In the following research, it is necessary to establish such an evaluation system to analyze which uncertainty really matters in the decision making and the BwN projects. The cascades of uncertainty may be a possible methodology, but it is not completely compatible with the BwN uncertainty matrix originating from Walker's uncertainty theory.

Finally, the data collection can be more efficient. On the one hand, the research skills of the student, particularly interviewing techniques, can be further improved, from contacting respondents, formulating questions, conducting interviews and transcribing. For instance, the student underestimated the complexity of transcribing so the summaries were sent to the respondents later than expected. Another example is that the student was not fully prepared for the accidents in the interview, such as poor telephone lines and "broken" English of some elder Swedish respondents, which affected the quality of interview. On the other hand, most of the project documents are in Swedish, therefore the translation is not always satisfactory. This made the data collection extremely time-consuming, and provided incomplete information for analysis.

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# Appendix 1. Respondents in the master thesis project

Table S 1 Respondents in the master thesis project

| Name | Position | Organization |
|---|---|---|
| Respondent A | Consultant/Project Manager | SWECO |
| Respondent B | Governmental Official (technical) | SGI |
| Respondent C | (Former) Local Official | Ystad Municipality |
| | Regional Official (political) | Regional Council of Scania |
| Respondent D | Local Official | Ystad Municipality |
| Respondent E | Regional Official (technical) | Regional Council of Scania |
| Respondent F | Regional Official (technical) | County Administrative Board of Scania |
| Respondent G | Project Manager | SGU |
| Respondent H | Regional Official (political) | Regional Council of Scania |
| Respondent I | Consultant/Marine Biologist | Trapezia |
| Respondent J | | |
| Respondent K | Local Administrator (technical) | County Administrative Board of Scania |
| Respondent L | | |
| Respondent M | (Former) Local Director | Ystad Municipality |
| | (Former) Advisor | Land and Environmental Court |
| Respondent N | Researcher | Lund University |
| | Consultant | SWECO |

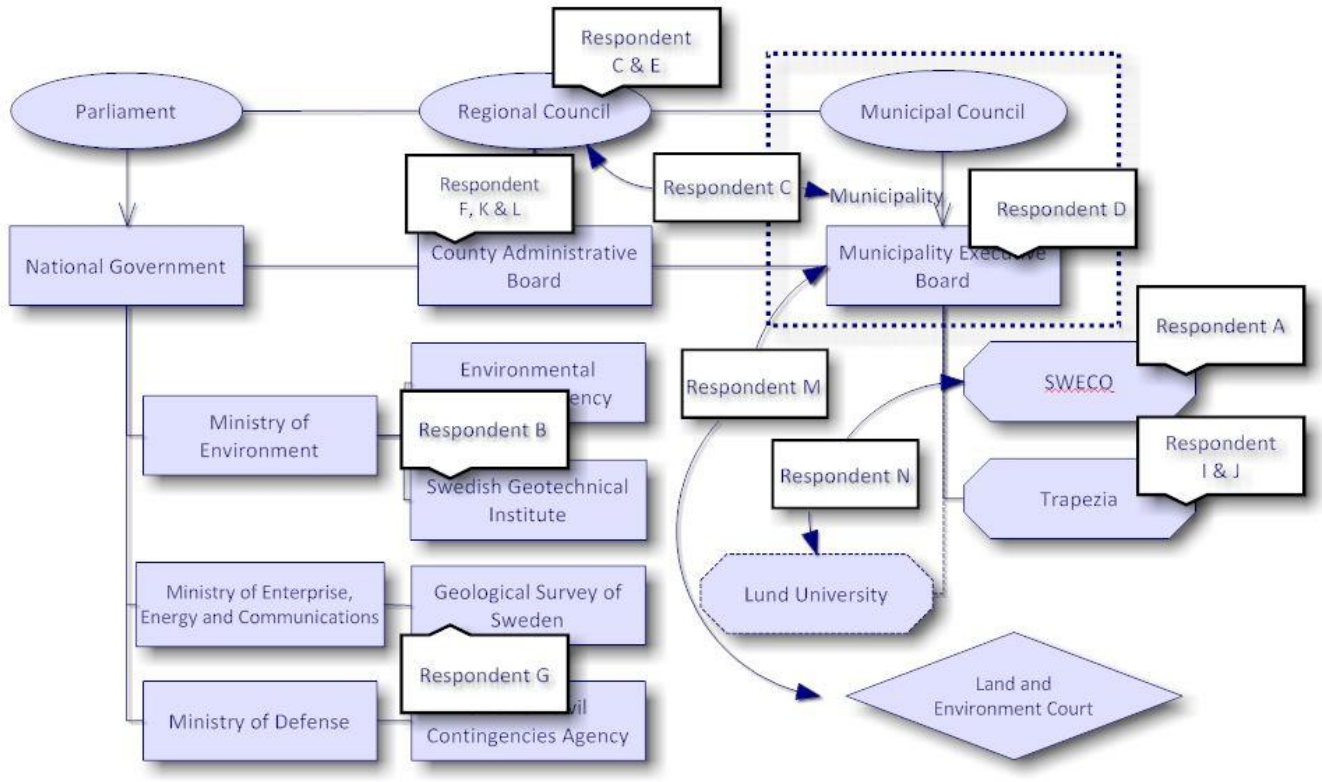


Figure S 1 Respondents' positions in the decision making process of the Ystad project

# Appendix 2. Uncertainty matrices of respondents

**Table S 2 Uncertainty matrix of Respondent A**

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| What is the effect of offshore sand extraction on the marine biology and environment in the sand extraction area? | | | | | | | | | | | |
| What is the effect of sand nourishment on the inland biology and environment of Ystad? | | | | | | | | | | | |
| What is the effect of sand nourishment on the sediment dynamics along the coastlines of Ystad? | | | | | | | | | | | |
| What is the effect of sand nourishment on the beach profiles in Ystad? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| What is the cost-effectiveness of the Ystad project? | | | | | | | | | | | |
| What is the cost-effectiveness of other possible alternatives (e.g. relocation)? | | | | | | | | | | | |
| Which sand extraction field does SGU prefer for the Ystad project? | | | | | | | | | | | |
| Which officials does SWECO need to contact to accelerate the permitting process? | | | | | | | | | | | |
| How large areas are vulnerable to sea level rise in Ystad? | | | | | | | | | | | |
| When is Ystad Municipality able to obtain all the permits to the Ystad project? | | | | | | | | | | | |

## Table S 3 Uncertainty matrix of Respondent B

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| What is the effect of sand nourishment on beach profiles in Ystad? | | | | | | | | | | | |
| What is the sediment dynamics along the coastlines of Ystad? | | | | | | | | | | | |
| What is the geological condition of sand extraction area near Sandhammar bank? | | | | | | | | | | | |
| Where is the sand source if other municipalities would like to sand nourishment projects like the Ystad project? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| What are the vulnerable areas and buildings for climate change in Ystad? | | | | | | | | | | | |
| Which ministries and governmental agencies take the administrative responsibilities of coastal erosion in Sweden? | | | | | | | | | | | |

## Table S 4 Uncertainty matrix of Respondent C

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| What is the effect of extreme weather on the nourished beaches in Ystad? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| Which officials in the governmental agencies would like to make the decision of granting permits to Ystad Municipality for the Ystad project? | | | | | | | | | | | |
| Who should take the financial responsibilities of the Ystad project ? | | | | | | | | | | | |
| How many areas and buildings are under the threat of sea level rise in Ystad? | | | | | | | | | | | |
| How do media describe, evaluate and report the Ystad project to the public? | | | | | | | | | | | |

## Table S 5 Uncertainty matrix of Respondent D

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| How much sand resource is available on the Swedish seafloor (for the sand nourishment project in Ystad)? | | | | | | | | | | | |
| What is the effect of offshore sand extraction on the marine biology and environment? | | | | | | | | | | | |
| What is the effect of extreme weather on the nourished beaches ? | | | | | | | | | | | |
| How much will the sea level rise along the coastlines of Scania? | | | | | | | | | | | |
| What is the quality (size/color/fineness) of the dredged sand from the seafloor? | | | | | | | | | | | |
| **Uncertainty about engineering** | | | | | | | | | | | |
| What are the geological scale of the investigation for the permit application of the Ystad project? | | | | | | | | | | | |
| Compared with sand nourishment, is there any alternatives applicable for coastal erosion in Scania? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| When is Ystad Municipality able to obtain all the permits to the Ystad project? | | | | | | | | | | | |
| Which ministries and governmental agencies take the administrative responsibilities of coastal erosion in Sweden? | | | | | | | | | | | |
| Who should take the financial responsibilities of the Ystad project? | | | | | | | | | | | |
| What is the cost-effectiveness of the sand nourishment in Ystad? | | | | | | | | | | | |
| What is the archaeological value of the sand extraction area near Sandhammar bank? | | | | | | | | | | | |
| Is the Ystad project economically attractive for potential Danish contractors? | | | | | | | | | | | |
| How do media describe, evaluate and report the Ystad project to the public? | | | | | | | | | | | |

## Table S 6 Uncertainty matrix of Respondent E

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| What is the sediment dynamics along the coastlines of Scania? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| How many buildings are vulnerable to coastal erosion in Scania? | | | | | | | | | | | |
| What are the attitudes of the officials in the County Administrative Board of Scania towards their cooperation with Regional Council of Scania on regional development in Scania? | | | | | | | | | | | |
| What are the prior issues for regional development in Scania? | | | | | | | | | | | |
| What are the prior issues for coast management in Scania? | | | | | | | | | | | |

## Table S 7 Uncertainty matrix of Respondent F

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| Where is the sand resource if other municipalities would like to have sand nourishment projects like the Ystad project? | | | | | | | | | | | |
| **Uncertainty about engineering** | | | | | | | | | | | |
| Is sand nourishment a long-term solution to coastal erosion? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| How large areas will be affected by sea level rise in the future? | | | | | | | | | | | |
| Which ministries and governmental agencies take the administrative responsibilities of coastal erosion in Sweden? | | | | | | | | | | | |
| How do officials in different units of the County Administrative Board of Scania think about sand nourishment projects? | | | | | | | | | | | |
| Who will be responsible for the next round of permit application for the Ystad project after 2020 in the County Administrative Board of Scania (when Jon Larsen will retire)? | | | | | | | | | | | |

## Table S 8 Uncertainty matrix of Respondent H

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| What is the sediment dynamics along the coastlines of Scania? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| How will other municipalities react if the Ystad project is approved? | | | | | | | | | | | |
| When is Ystad Municipality able to obtain all the permits to the Ystad project? | | | | | | | | | | | |
| Which ministries and governmental agencies take the administrative responsibilities of coastal erosion in Sweden? | | | | | | | | | | | |
| How do the governmental officials follow and interpret the Swedish laws related to coast management? | | | | | | | | | | | |
| What are the attitudes of the officials who take in charge of the permit application of the Ystad project? | | | | | | | | | | | |

## Table S 9 Uncertainty matrix of Respondent I and J

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| What is the effect of sand nourishment on marine environment and biological diversity? | | | | | | | | | | | |
| What is the sediment dynamics along the coastlines of Ystad? | | | | | | | | | | | |
| What is the effect of sand nourishment on dunes and beach profiles? | | | | | | | | | | | |
| Which kind of species exists in the sand extraction area near Sandhammar bank? | | | | | | | | | | | |
| What is the reason of coastal erosion in Ystad? | | | | | | | | | | | |
| **Uncertainty about engineering** | | | | | | | | | | | |
| How does Trapezia detect the biological and environmental changes before and after the Ystad project? | | | | | | | | | | | |
| What is the effect of constant sediment dynamics on detecting the changes of marine environment and biological diversity? | | | | | | | | | | | |
| What is the reference data for the monitoring program of the Ystad project? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| What is the archaeological value of the sand extraction area? | | | | | | | | | | | |
| Which ministries and governmental agencies take the administrative responsibilities of coastal erosion in Sweden? | | | | | | | | | | | |
| How long will Trapezia cooperate with Ystad Municipality on the monitoring program of the Ystad project? | | | | | | | | | | | |

## Table S 10 Uncertainty matrix of Respondent K and L

| Uncertainty | Location | | | | | Level | | | Nature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Context | System | External factors | Policies | Outcomes | Statistical | Scenario | Recognized | Epistemic | Variability | Ambiguity |
| **Uncertainty about nature** | | | | | | | | | | | |
| How much sand resource are available on the Swedish seafloor? | | | | | | | | | | | |
| What is the effect of offshore sand extraction on the marine biology and environment? | | | | | | | | | | | |
| What is the effect of sand nourishment on the inland biology and environment? | | | | | | | | | | | |
| How does offshore sand extraction influence the currents, waves and sediment dynamics? | | | | | | | | | | | |
| What is the mechanism of sediment dynamics along the coastlines in Scania? | | | | | | | | | | | |
| How much will the sea level rise along the coastlines of Scania? | | | | | | | | | | | |
| **Uncertainty about engineering** | | | | | | | | | | | |
| Compared with sand nourishment, is there any alternative applicable for coast management in Scania? | | | | | | | | | | | |
| **Uncertainty about society** | | | | | | | | | | | |
| How many buildings and how large areas are vulnerable to sea level rise in Scania? | | | | | | | | | | | |
| Does coast management have the highest priority for regional development in Scania? | | | | | | | | | | | |
| Which parts of coastlines in Scania have the highest priorities to be protected? | | | | | | | | | | | |
| What parts of coastlines in Scania should be protected by sand nourishment? | | | | | | | | | | | |
| Who should take the financial responsibilities of coast protection projects in Sweden? | | | | | | | | | | | |
| What is the cost-effectiveness of sand nourishment projects? | | | | | | | | | | | |

# Appendix 3. Summaries of interviews

For confidential reasons, the summaries of interviews in the master thesis project are only accessible to the committee members.