Enterprise Ontology of Flood Control Domain

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Specialization in Information Architecture

By

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Enterprise Ontology of Flood Control Domain

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Title
Enterprise Ontology of the Flood Control Domain

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Preface

It is my pleasure to present to you my thesis document today. This is the result of a combination of knowledge that I have received in the past two years of my master studies from two faculties: EEMCS and TPM. It was a very challenging moment for me but due to my own hard work, the support, discussion and feedback from my instructors and my fellow students I was able to come to this end.

I have learnt a lot from this thesis project not only from academic point of view but also from the social point of view. This is mainly because I come from a country (Tanzania) where flooding is seen as a natural disaster that a human being has a limited influence on its happening and hence very limited flood fighting activities; To a country (the Netherlands) which is famous with flood fighting activities both in term of engineering works and information systems.

I would like to express my gratitude to the IBM Global Center of Excellence for Water Management Team in Amsterdam, the Netherlands, especially Bram Havers and Erik Rongen, my IBM mentors who first of all gave me an opportunity to conduct this thesis project at IBM, for the supervision throughout this project while I was at IBM, their time and openness during discussions and during the interviews with various flood control organizations. I would like to thank the whole team for their readiness, openness and invitations to the discussions, presentations and workshops in issues related to the water management issues and flood control activities.

I would also like to thank Prof. Jan Dietz, the main supervisor and chair of this project, for helping me to structure this project. Without his guidance, I would have lost myself in the complexity of the research subject at IBM. I would also like to thank him for his valuable comments on former versions of this thesis documents and his feedback during the entire graduation period. In addition, I want to thank Nitesh Bharosa for his the valuable feedbacks and discussions especially on shaping my thesis document. Further my thanks also go to Prof. Hans Geers and Dr. Marijn Janssen for being members of my thesis committee and for the discussions about this thesis project.

My special thanks also go to all the people outside IBM who allowed me to interview them during the beginning of this project and at the end of the project. It was through them I was able to get an in depth understanding of the domain and been able to continue further with this project.

Last but not least, I would like to thank my family in Tanzania, especially to my father who advised me on how to structure my thesis project and his follow up on the status of my thesis project. And, to my special friends: Charles, Puspa, Thuan, Illias and Yan for your support during my time at the TU Delft and for the discussions and feedbacks about my thesis project.

Diana Benedict Mongula

August, 2009
Delft, the Netherlands
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Summary

Floods are among the most hazardous and destructive natural disasters with the potential to wreak havoc on humans, material assets, cultural wealth and ecological resources. Several countries have used different flood management and control measures both structural (e.g. constructing levees, dams, storm surge barriers) and non structural (e.g. applying spatial measures, developing flood forecasting and early warning systems) to reduce their vulnerability and exposure to floods.

These flood management and control measures can be addressed using the safety chain concept. Originally, the safety chain concept consisted of four links: mitigation, preparation, response and recovery. Now, the safety chain concept is well adopted in different countries with slight adjustments.

Multiple stakeholders and actors are involved in the various links of the safety chain. In many countries, these actors include the government (e.g. national, provincial and local), emergency services (police, fire brigades, medical aid) and the water authorities. However, many more actors are also involved. Due to the involvement of many actors in different activities, it is difficult to compare the construction and operation of Flood Control Domain in different countries.

In line with the above problem, the objective of this thesis project is to develop an enterprise ontology that will show how the Flood Control Domain is constructed and operated by identifying the essential operations performed in the domain, highlighting the interrelationships between these operations and information objects that are relevant for the operations in the domain, and illustrating its use in the Netherlands and the United States.

The literature research resulted in a concise overview of ontology and enterprise ontology. There are various definitions of ontology. In this thesis project, the chosen definition of ontology is: a formal, specification of shared conceptualization. The notion of ontology as applied in this document is the notion of system ontology whose main purpose is to understand the essence of construction and operations of complete systems; more specifically of enterprises. Enterprise ontology can be described as a conceptual model of an enterprise that is coherent, comprehensive, consistent and concise, and that only shows the essence of the operation of an enterprise model, independent from implementation and realization.

The Design and Engineering Methodology for Organizations (DEMO) methodology was selected to develop the enterprise ontology for the Flood Control Domain. DEMO provides a step-by-step procedure that helps to derive the ontology of an enterprise in a systematic way. Following DEMO methodology, the starting point for developing enterprise ontology is the collection of all available documentation about the enterprise. Therefore, a thorough analysis of the Flood Control Domain was conducted through literature reviews, interviews and a case study.

Based on the analysis of the Flood Control Domain, an Explanatory Case describing the domain was provided using the safety chain approach, which is described in five links: the pro-action, prevention, preparation, response and recovery. Based on the Explanatory Case, the Perfoma Analysis was conducted to capture the performa human abilities that concern
the essential productions in an organization. On the basis of the Perfoma Analysis, the transactions, which represent the essential operations in the Flood Control Domain, were identified. These transactions and their specifications were presented in a Transaction Result Table (TRT). Next, the Construction Model of the Flood Control Domain was developed. The Construction Model shows the identified transactions, the initiator(s) and an executor for each of the identified transactions as well as the information links between the actor roles and the information banks. In the next step of this research, the interrelationships between the identified essential operations in the Flood Control Domain were shown. Here, the Process Model of the Flood Control Domain was constructed. In the Process Model, the logical sequence of steps for which a transaction is performed is provided; hence, the interrelationship between the transactions. The Process Model also enables every transaction pattern in the Construction Model to be seen, as well as the specific transaction pattern of the transaction type. Then, the information objects necessary for the organizations in the Flood Control Domain were presented using the State Model, which can be used as a data dictionary of an organization showing the object classes, the fact types, the result types and the existential laws.

In the next phase of the research, the focus was to show how the developed enterprise ontology is used in the Netherlands and the United States. Here, the concern was to show the organizations in the two countries responsible for performing the identified transaction, also regarded as the essential operations, in the Flood Control Domain. In order to do this, the Construction Model was re-drawn whereby the abstract actor roles were replaced with the existing organizations in the Netherlands and the United States.

In the final phase of this research, the thesis results were analyzed. In general, the developed enterprise ontology for the Flood Control Domain seems to be generic since most of the actors who acted as initiators and executor of certain transactions could be mapped to the existing organizations in the Netherlands and the United States. However, some differences were evident in the implementation of flood control operations in the Netherlands and the United States. Such differences could be seen in flood management activities. For instance, while a hierarchical relationship exists between the US Army Corps of Engineers and the local sponsors, such as the levee districts, a horizontal relationship can be seen between Rijkswaterstaat and the water boards in the Netherlands. Moreover, the analysis shows that due to the size of the two countries, the local governments in the United States have more roles and responsibilities as compared to the local governments in the Netherlands. The analysis highlights the differences between the two countries on the use of flood insurance policy. While the flood insurance policy is commonly used and highly emphasized in the United States in order to reduce flood losses, such a policy is not applicable in the Netherlands.

The recommendations for future work include a mapping of the identified transactions to the applications or existing information systems both in the Netherlands and the United States, development of a high level Construction Model of the Flood Control Domain and the initiation of an Action Model. The thesis results should be shared with a large group of people and an ideal enterprise ontology should be developed for the Flood Control Domain that different countries can use to compare themselves with one another.
1. Introduction

1.1 Floods

A flood can broadly be defined as a body of water that rises to overflow land that is not normally submerged (Ward 1978). There are many different types of floods based initially upon the prime causal agent (Table 1).

<table>
<thead>
<tr>
<th>AGENT</th>
<th>DETAILS AND EXAMPLES</th>
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<tbody>
<tr>
<td>Rainfall</td>
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<tr>
<td>Icemelt</td>
<td>Glacial meltwater (rise in air temperature)</td>
</tr>
<tr>
<td></td>
<td>Glacial meltwater (geothermal heat source)</td>
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<tr>
<td>Flooding during freeze-up</td>
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<tr>
<td>Mudfloods</td>
<td>Floods with high sediment content</td>
</tr>
<tr>
<td></td>
<td>Induced by volcanic activity</td>
</tr>
<tr>
<td>Coastal/sea/tidal floods</td>
<td>Storm surge (tropical or temperate induced)</td>
</tr>
</tbody>
</table>

Table 1: Types of floods (Green, Parker et al. November 2000)

Floods are part of the dynamic variation of the hydrological cycle, the basic causes of which are climatological. To this must be coupled the nature of the terrain that generates the runoff (e.g. geology, soil type and vegetation cover), the antecedent conditions, the stream networks characteristics (e.g. storage capacity, channel length) and the channel characteristics (e.g. channel roughness and shape) (Ward 1978). Many of the most catastrophic floods are then associated with the intense rainfalls that result from hurricanes, cyclones and typhoons, particularly when this rainfall occurs on a steep catchment.

Floods are a threat to life, property and other valued resources. Flood disasters are among the world’s most frequent and damaging types of disaster (IFRCRCS 1998). The annual cost to the world economy of flooding and other water-related disasters is between US$50 and US$60 billion. Annually, flooding affects about 520 million people and their livelihoods, claiming about 25,000 lives worldwide (Shady 2006).

There is broad consensus that both the probability and the potential impact of flooding are increasing in many regions across the globe, particularly in delta regions (Kabat et al. 2005). Figure 1 illustrates the increasing frequency of flooding events in the world from the mid-1990s up to present. The series of river floods many countries have experienced in the past decade are often attributed to climate change, and many experts expect the frequency of peak river discharges, hence river floods, to further increase in the future (EnvironmentalAgency 2007). Hurricane Katrina is generally perceived as another strong sign
that the climate is changing more rapidly than many had expected a few years ago (Meijerink and Dicke December 2008)

Figure 1: Timeline results of flooded areas in different areas across the globe (Google)

1.2 The IBM Global Center of Excellence for Water Management

Coastal areas are considered under greater risk of flooding due to rising sea levels and extreme weather episodes associated with the onset of climate change. "With more than 60 percent of the world’s population living in coastal and low-lying delta areas, the need for improved water management systems is an increasing priority," said Sharon Nunes, vice president of IBM Big Green Innovations (Maloney February, 2008).

In response to growing concerns over climate change and its potential impact on low-lying coastal regions, IBM established a Global Center of Excellence for Water Management in Amsterdam, the Netherlands, on February 1, 2008. The Global Center of Excellence for Water Management aims to help IBM’s clients around the world to develop advanced water management systems for low-lying coastal areas and river deltas by drawing on IBM consulting, technology and research expertise.

By working together with the Dutch government and other local agencies, IBM will apply its talent and expertise to address this complex challenge through application of smart technologies and innovative approaches that include 3-D Internet and serious gaming.

Establishing the center in Amsterdam enables IBM to not only utilize (Maloney February, 2008) its own talent and innovation, but also to draw on the high-level skills of local experts and engineers from the Netherlands, a country that possesses world-leading expertise in coastal protection (Maloney February, 2008).

From its establishment, the center will play a key role in delivering the Dutch government’s Flood Control 2015 water innovation program. Under the program, participants from Dutch business, education and government agencies will collaborate with the goal of preventing low-lying delta areas from flooding, hence increasing the safety of the population in these areas.

Among the goals of the IBM Global Center of Excellence for Water Management are:

- Help IBM clients around the world to develop enhanced prediction and protection systems for low-lying coastal areas and river deltas.
- Utilize IBM’s expertise in smart sensors, serious gaming technology and 3D Internet skills to create realistic modeling and simulations.

It is within this center that this thesis project was formulated with the objective described below.
1.3 Problem Statement

The IBM Global Center of Excellence for Water Management team in Amsterdam is interested in obtaining an understanding of the Flood Control Domain in terms of the organizations involved and the operations performed by these organizations, both nationally and internationally. Specifically, the team is interested in comparing the operations performed by flood control organizations in the Netherlands and the United States. Being new in the water management market, this was an important step for IBM to understand the most appropriate clients to target for its business.

However, it was also acknowledged that providing such an understanding of the Flood Control Domain is not an easy task due to the involvement of multiple organizations. In many countries, these organizations include the government (central, provincial and local), emergency services (police, fire brigades, medical aid) and water authorities.

Therefore, the following problem statement was formulated, with the IBM Global Center of Excellence for Water Management team as the problem owner: *it is difficult to compare the construction and operation of the Flood Control Domain in different countries, for instance, in terms of the organizations involved, the essential operations performed, the interrelationship between the operations and the information objects that are relevant for an organization.* It was decided by myself and my supervisors at IBM that this thesis project should be limited to focusing on the comparison between the Netherlands and the United States. And, considering this problem, the following main question was formulated for this Master’s thesis research, under the IBM Global Center of Excellence for Water Management in Amsterdam.

*How can you compare the construction and the operation of the Flood Control Domain in the Netherlands and the United States?*

This main question is still too broad and requires further delineation and deduction into more specific sub questions. In the next chapter, we discuss the research design for this project consisting of scope and approach. Chapter 3 of this report discusses the research analysis, mainly with insights gained from literature and interviews about the Flood Control Domain. Chapter 4 is about the enterprise ontology and Chapter 5 is about the DEMO methodology. Chapter 6 will discuss and present the essential operations performed in the Flood Control Domain. Chapter 7 concerns the interrelationship between the identified essential operations in the Flood Control Domain. Chapter 8 will discuss the information objects that are relevant for the operations of the organizations in the Flood Control Domain. Chapter 9 discusses and compares the organizations in the Netherlands and the United States responsible for performing the essential operations in the Flood Control Domain. The analysis of the thesis research will be provided in Chapter 10. Chapter 11 will present the main conclusions for this research, followed by recommendations for further research.
2. Research Design

This chapter presents the formulated research objectives, the scope of the research, and the derived sub questions and approach towards answering these sub questions. Figure 2 illustrates the relationship between the problem statement, research objectives, research questions and research approach. We start with elaborating the sub objectives of the thesis project.

![Figure 2: Relationship between several steps in research design](image)

2.1 Research Objective

As already mentioned in Chapter 1, the main objective of this thesis project is to:

*Develop an enterprise ontology that will show how the Flood Control Domain is constructed and operated by identifying the essential operations performed in the domain, highlighting the interrelationships between these operations and information objects that are relevant for the operations in the domain, and illustrating its use in the Netherlands and the United States.*

This main objective is very generic. Therefore, we have deduced the following sub objectives:

A. Illustrate the use of enterprise ontology for the Flood Control Domain in the Netherlands and the United States.
B. Identify the essential operations performed by organizations in the Flood Control Domain.
C. Show the interrelationship between the essential operations performed by organizations in the Flood Control Domain.
D. Identify information objects that are relevant for the operation of the organizations in the Flood Control Domain.
2.2 Scope

Originally, the IBM Global Center of Excellence for Water Management was interested in understanding the comparison between actors involved in the water management industry and their operations both in the Netherlands and United States. However, since water management includes the management of both water quality and water quantity, we decided to limit our scope to water quantity. Moreover, managing water quantity includes the management of high water, which can lead to flooding and short water, which can lead to drought. Based on this, we further limited this project to high water management; hence, focusing on the Flood Control Domain.

Based on the Flood Control Domain, the scope for this project is divided into:
- Flood type
- Actors
- Operations
- Enterprise ontology notions and the methodology for developing enterprise ontology

The first scope of this thesis project regards to the type of a flood. Table 1 shows different types of floods including both river floods and coastal or sea floods. The concern of this thesis project is mainly the floods that come from the rivers.

The second scope of this thesis project regards to the actors involved in the Flood Control Domain. The term “actor” refers to a social entity, person or organization capable of acting on or exerting influence on a decision. In other words, actors are those parties that have a certain interest in the system and/or have some ability to influence that system, either directly or indirectly (Enserink, Hermans et al. 2008). By reviewing the following sources (Heuer, Flikweert et al. ; Mitchell 2003; Olsthoorn and Tol February 2001; BZK February 2007; BZK January 2007; 2015 July 2008; FloodControl2015 July 2008; Brinke, Saeijs et al. June,2008), the thesis project limited the actors in the Flood Control Domain to organizations that are responsible for flood protection and crisis management.

The third scope of this thesis project regards to the operations performed by the flood control organizations. This scope is limited to the day to day operations performed by the organizations in the Flood Control Domain both during normal situation and during flooding. These operations are categorized based on the safety chain links: pro-action, prevention, preparation, response and recovery.

The fourth scope of this thesis project regards to notion of enterprise ontology and enterprise ontology development methodology. The notion of enterprise ontology will be used to structure the knowledge of the actors and essential operations in the Flood Control Domain. Therefore, an enterprise ontology for the Flood Control Domain will be developed. The Design and Engineering Methodology for Organizations (DEMO) is the chosen methodology for the development of enterprise ontology for the Flood Control Domain. DEMO methodology was agreed between the student and project supervisors from the university and IBM.
Regardless of the potential significance, it was decided not to conduct explicit research on the following issues:

- Construction of new flood control structures (e.g. levees, storm surge barriers, dunes); rather, we are concerned with their day to day management, including operations such as safety assessment, maintenance and improvement.
- Building of information systems and models for improving flood predictions or decision making; rather, we are concerned with using these information systems and models.
- The infrastructure architecture (hardware, software and network components) used by different flood control organizations. However, this document will provide a brief description of the applications and information systems used in the Flood Control Domain in the Netherlands.
- Laws and regulations regarding flood management and crisis management.
- The individual personnel performing the flood control operations; rather, we will generalize specific organizations.
- Cultural differences between the organizations in the Netherlands and the United States.
- Analysis of other enterprise ontology methodologies apart from DEMO.

2.3 Research questions

In the previous sections, we have presented the research objectives and the scope of this thesis project. Accordingly, we have deduced the following research questions derived from the previous chapter for this thesis project:

1. **What are the essential operations performed by organizations in the Flood Control Domain?**
2. **How are the essential operations in the Flood Control Domain interrelated?**
3. **What information objects are relevant for the operation of the organizations in the Flood Control Domain?**
4. **Which organizations are involved in performing the essential operations of the Flood Control Domain in the Netherlands and the United States?**

The first question aims to provide an understanding of the essential operations performed by organizations in the Flood Control Domain, so I will show how the domain is constructed. The aim with this question is to particularly cover the research objective B (identify the essential operations performed by organizations in the Flood Control Domain).

The second question aims to provide an understanding of how the essential operations performed by organizations in the Flood Control Domain as identified in question one are interrelated. Here, I aim to analyze the business processes of the identified essential operations in the Flood Control Domain. This question aims to cover the research objective C (show the interrelationship between the essential operations performed by organizations in the Flood Control Domain).
The third question aims to provide an understanding of the relevant information objects that can assist the flood control organizations to perform the identified essential operations. This question aims to cover the research objective D (identify information objects that are relevant for the operation of the organizations in the Flood Control Domain).

Based on our understanding of essential operations performed in the Flood Control Domain, the fourth question aims to provide an answer to the organizations responsible for performing the identified essential operations both in the Netherlands and United States and a comparison of the identified organizations in both countries. This question aims to cover the research objective A (illustrate the use of enterprise ontology for the Flood Control Domain in the Netherlands and the United States).

2.4 Research Approach

In order to formulate a research strategy, multiple sources on research designs have been consulted (Yin 2003; Ruane 2005; Hevner and Ram March 2004). Considering these consulted sources, (Hevner and Ram March 2004) are the only authors that prescribe an approach specifically for research on information systems. In his document (Hevner and Ram March 2004), the authors suggest a framework called ‘Information Systems Research Framework’ for developing IT artifacts. We therefore chose this approach as we consider using IT artifact(s) to answer the main goal of this thesis project.

This approach suggests that we construct a knowledge base on the “state of the art” of the topic, which in this case is Flood Control Domain. While this knowledge base provides for rigorous research, analysis of the Flood Control Domain determines the need to structure the existing knowledge of the domain. This knowledge can be structured by developing enterprise ontology for the Flood Control Domain. Consequently, the developed enterprise ontology needs to be evaluated by organizations involved in the Flood Control Domain. Hence, this approach suggests three main steps: analysis of the essential operations and actors and information objects in the Flood Control Domain, development of the enterprise ontology for the Flood Control Domain and evaluation of the developed enterprise ontology.

Even though (Hevner and Ram March 2004) provide a clear strategy for the research related to Information Systems discipline, they fail to provide detailed information on the required research methods for each research step. (Yin 2003) suggests determining the appropriate research method by looking at the type of question asked. Depending on the question asked, five general types of research strategies can be used: experiment, survey (interview), archival (literature) analysis, history and case study. Building on the work of several researchers (Verschuren and Doorewaard 1997; Ruane 2005), common research methods used by researchers at the Faculty of Technology, Policy and Management (TPM) at the Technical University of Delft are provided (Enserink, Cunningham et al.): survey (questionnaire, interview), experiment, case study, grounded theory approach, field research, desk research, modeling, gaming and design. The main conditions for using a specific strategy are: (a) the type of research question posed; (b) the extent of control an investigator has over actual behavioral events; and (c) the degree of focus on contemporary events as opposed to historical events. Table 2 presents the research methods for the above questions.
<table>
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<th>Question</th>
<th>Type</th>
<th>Research goal</th>
<th>Method</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>What</td>
<td>Exploration &amp; Explanation</td>
<td>Literature reviews, interviews, case study &amp; conceptual modeling</td>
</tr>
<tr>
<td>2</td>
<td>How</td>
<td>Exploration &amp; Explanation</td>
<td>Literature reviews, interviews, case study &amp; conceptual modeling</td>
</tr>
<tr>
<td>3</td>
<td>What</td>
<td>Exploration &amp; Explanation</td>
<td>Literature review, interviews, case study &amp; conceptual modeling</td>
</tr>
<tr>
<td>4</td>
<td>Which</td>
<td>Evaluation</td>
<td>Literature reviews, interviews, case study</td>
</tr>
</tbody>
</table>

Table 2: Overview of selected research methods

Complementing the approaches of several researchers (Yin 2003; Ruane 2005; Hevner and Ram March 2004) usually means that the systematic, empirical standards of “good” research are often pursued in the name of four basic research goals: exploration, description, explanation and evaluation. Exploratory research is typically conducted in the interest of “getting to know” or increasing our understanding of a research topic. In terms of output, exploratory research often produces qualitative data (evidence presented in words, pictures or some other narrative form) that best captures the research subject’s genuine experiences and understanding. This thesis project facilitates in-depth understanding of the essential operations performed by the organizations in the Flood Control Domain. Descriptive research offers a detailed picture or account of some social phenomena, settings, experiences and groups. It pays close attention to such issues as measurements and sampling, and relies on quantitative research methods. This thesis project will not focus on descriptive research. Explanatory research provides the “why” behind the thesis goal. After conducting exploratory research, the answer to the first three questions (i.e. the essential operations in the Flood Control Domain, the interrelations between the essential operations and information objects) will be provided using DEMO aspect models. An explanation for each developed aspect model will be provided in order to provide the reader with an understanding of how the model was developed. Therefore, we will use a combination of exploratory research and explanatory research for the first three research questions. Finally, evaluation research seeks to test the developed ontological models by illustrating the organizations responsible for performing the identified essential operations in the Flood Control Domain both in the Netherlands and the United States. Evaluation research also seeks to judge the merits or usefulness of the developed enterprise ontology.

As we can see above, more than one research method is used in some of the questions. These methods aim to complement each other. The possibility of using the above research methods together are discussed below:

1. Literature review

Literature review is the base of other research methods used in this thesis project. Studying existing literature familiarized the researcher with the general overview of the Flood Control Domain. Literature reviews also prevent us from rethinking the basics in this field and allow us to focus more on the solutions. Books and different electronic articles gathered from the Internet, the Google Scholar database (http://scholar.google.com/) and Water Management Team Room (a database for IBM’s water management team) were used.
2. **Interviews**

Parallel to the literature review, face-to-face interviews were conducted with some individuals in the Dutch flood control organizations. The interviews were conducted with several purposes. In the beginning of the project, the interviews were aimed at gathering knowledge from the interviews. Hence, the interviews allowed us to gain an in-depth and detailed understanding of the Flood Control Domain, especially in terms of operations or tasks performed by the interviewed organizations. Conducting interviews at the beginning of the project was also aimed at familiarizing the interviewers with this project and to ask for their support later on during the evaluation of this project. Before the end of the project, interviews were conducted to share the results of the project and to get feedback from some individuals in the Dutch flood control organizations.

3. **Case Study**

Case studies are particularly suited to research questions that require detailed understanding of social or organizational processes because of the rich data collected in context. There are three reasons for using the case study strategy (Benbasat, Goldstein et al. September 1987). First, the researcher can study the domain in a natural setting, learn about the state of the art, and generate theories from practice. Second, the case method allows the researcher to answer “how” and “why” questions; that is, to understand the nature and complexity of the processes taking place. Third, a case study method is an appropriate way to research an area in which few previous studies have been carried out. Due to the complexity of the response and recovery activities, a case study strategy will be used as a complement to the research methods mentioned above.

4. **Modeling**

A model can be defined as a simplified representation (abstraction) of reality. Examples of models include system models that are used to provide an insight into the mechanisms of a system or to make an analysis of a possible future situation, statistical models are used to map relations between variables, and decision or deliberation models are used to make choices between alternatives. The first three research questions will be answered using a modeling technique that will be developed using DEMO methodology.
2.5 Research steps

While Table 2 provides an impression of the research methods, Figure 3 presents a more detailed account of the research steps, methods and time schedule. The thesis structure can be interpreted as follows. In the first two months, I conducted literature research to get an understanding of the Flood Control Domain. The following month I conducted interviews with flood control organizations in the Netherlands, as presented in Appendix A. However, the interviews continued while I was busy with other project activities. I devoted half a month to revising and specifying the enterprise ontology notion. Then, I spent half a month describing the DEMO methodology, the theory behind it and the procedures to be taken to derive an ontological model of the Flood Control Domain. Afterwards, I spent a month describing the essential operations in the Flood Control Domain using the DEMO methodology. Here, the essential operations in the Flood Control Domain are presented in the form of a transaction. Then, I spent half a month describing the interrelationship between the identified essential operations (i.e. transactions) in the Flood Control Domain, using the DEMO methodology. Another half a month was spent describing the relevant information objects needed by organizations in the Flood Control Domain, and also using the DEMO methodology. Afterwards, I spent one and a half months illustrating the use of the developed enterprise ontology in the Netherlands and the United States, with time divided into half a month and a month for the two countries, respectively. Then, I spent half a month sharing and discussing the thesis results with flood control experts inside and outside IBM, and getting their feedback. Discussions about the thesis results, feedback and recommendations from the experts are provided in Appendix D. Afterwards, I spent half a month analyzing the thesis results mainly based on the use of the enterprise ontology in the Netherlands and the United States, deriving conclusions and recommendations for future work. The remaining time was spent modifying and finalizing the thesis document. In total, I spent nine months to complete this thesis project.
Figure 3: Thesis Structure
2.6 The deliverables

The main deliverable of this thesis project is the thesis document. The content of the thesis document will provide detailed explanations of the following topics (see Figure 4):

- Enterprise ontology
- DEMO theory and methodology
- The essential operations in the Flood Control Domain in the form of Transaction Result Table (TRT) and the Construction Model
- The interrelationship between the identified essential operations in the Flood Control Domain in the form of the Process Model
- The relevant information objects required for the operations of the organization in the Flood Control Domain in the form of the State Model
- The use of enterprise ontology in the Netherlands and the United States. And the analysis of the use of enterprise ontology in the two countries.
- Conclusions and recommendations for further work

Figure 4: Thesis Deliverables
2.7 Relevance of the research

This thesis project is relevant both to the societal world and to the scientific world. For the societal world, the thesis project is relevant as it aims to share the conceptualization of the Flood Control Domain in terms of essential operations performed in the domain, the interrelationships between the identified operations and the information objects needed to perform the identified essential operations. Also, through the conceptual picture of the Flood Control Domain, the organizations involved in the domain in the Netherlands and the United States will be shown. Being able to understand the organizations involved, the operations performed by different organizations and the information needed by other organizations will facilitate quick and easy communication between multiple organizations involved in the domain. For instance, during a flood crisis, the conceptual model of the Flood Control Domain can be used to improve inter-agency communication and collaboration, and hence assist in bringing about an effective response to the flooding disaster.

Apart from the social relevance, the thesis project is also relevant to the scientific world. The thesis is especially relevant in the field of computer science as the background of the thesis project is in the field of ontology. Considering its relevancy to the scientific world, it is somewhat surprising that no such research has been conducted so far. The previous table (see Table 3) shows the list of alternatives found by a quick search that could have been potentially related to this work. However, the main difference between this thesis project and the listed alternatives is its specific concern for the Flood Control Domain. The thesis project also aims to describe the Flood Control Domain using the safety chain approach, which will be described in the next chapter; hence, making it different from the listed alternatives.

<table>
<thead>
<tr>
<th>References</th>
<th>Purpose</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Tekes June 2008)</td>
<td>Developing core ontology of crisis management is necessary:</td>
<td>• The scope of the project was meant for any kind of a crisis, not just a flooding crisis</td>
</tr>
<tr>
<td></td>
<td>• For integration of domain-specific ontologies</td>
<td>• The project was not based on DEMO methodology</td>
</tr>
<tr>
<td></td>
<td>• For supporting document management and data transfer between various groups.</td>
<td></td>
</tr>
<tr>
<td>(Ordance Survey)</td>
<td>Developing flood defense ontology to classify the meaning of flood defense to enable the querying of Ordnance Survey data to find all features in the landscape that can hold back flood water or reduce its flow. The ontology is expected to return features like retaining walls and earth embankments in addition to commonly known flood defenses like flood walls, sluices and weirs</td>
<td>• The scope of the project limited only to “flood defense”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The project was not based on DEMO methodology</td>
</tr>
</tbody>
</table>
(Rijkswaterstaat 2007) Developing the Construction Model for the Crisis Management using DEMO methodology. The methodology used is similar to the methodology used in this project. However, the following differences exist:
- The scope of the project was meant for all Crisis Management situations, not just for flooding
- Not all the safety chain links were used as concepts.
- Other DEMO aspect models were not shown

Table 3: Prior art
3. Research Analysis

This chapter presents the analysis of the Flood Control Domain, which was conducted earlier in this project. This analysis was done in order for students to acquire an understanding of the Flood Control Domain before continuing with the rest of the project. Therefore, even though this chapter doesn’t explicitly provide answers to any of the research questions listed in Section 2.3 of Chapter 2, it has given me the confidence to answer the research questions in the coming chapters. Among the issues discussed in this chapter are flood risk and flood risk management, the safety chain, flood control actors and a list of organizations that were interviewed together.

3.1 Flood risk

Flooding risks result from a flood hazard in an area that is considered vulnerable. The vulnerability of an area depends on the number of people, the economic value (invested capital and earning power) and/or ecological values. Without a vulnerable society or ecosystem, a flood may be regarded as a natural phenomenon that cannot be qualified in a normative way as posing “a risk.” Therefore, the concept of flood risk embraces the concepts of flood hazard and vulnerability; often, it is expressed as a function of the two (the product, to be precise). In the Netherlands, however, it is common practice to define flood risk as flood probability times flood damage. The formula for flood risk can be provided (VenW ; Klijn, Van Buuren et al. 2004; Meijerink and Dicke December 2008) as:

\[ R_f = H_f \times V = P_f \times D_f \]

\(R_f \) = flood risk; \(H_f\) = flood hazard; \(V\) = vulnerability; \(P_f\) = flood probability; \(D_f\) = flood damage; with both \(H_f\) and \(D_f\) depending on flooding depth.

Densely populated areas around the world tend to be located near delta areas, rivers, coasts and lakes. These are areas of great economic value that attract a high rate of development, but they also come with high flood risk (Mitchell 2003). The attractiveness of coastal areas has resulted in disproportionately rapid expansion of economic activity, settlements, urban centers and tourist resorts. Migration of people to coastal regions is common in both developed and developing nations. As already mentioned, these areas occupy more than 60 percent of the world’s population.

Rapid urbanization has many consequences, such as enlargement of natural coastal inlets and dredging of waterways for navigation, port facilities, and pipelines exacerbate saltwater intrusion into surface and ground waters. The vulnerability of the coastal and low-lying delta areas and flood damage in these areas has increased due to the rapid urbanization. Increasing shoreline retreat and risk of flooding of coastal cities in Thailand (Durongdej, 2001; Saito, 2001), India (Mohanty, 2000), Vietnam (Thanh et al., 2004) and the United States (Scavia et al., 2002) have been attributed to degradation of coastal ecosystems by human activities, illustrating a widespread trend.

3.2 Flood risk management
Several flood management strategies and measures can be used to control and reduce the risk of flooding in an area. The strategies aim to reduce the flood risk, which is defined above as the product of flood hazard and vulnerability or flood probability times flood damage. Drawing on previous research (Oosterberg, Van Drimmelen et al. 2005), Table 4 makes a distinction between three different strategies of flood risk management: hazard reduction, vulnerability reduction and exposure reduction.

The aim of hazard reduction or a reduction of the probability of flooding is “to keep floods away from urban areas.” Traditionally, water managers have coped with floods by constructing dams, dykes, levees, storm surge barriers and other civil engineering works. While these structural measures may reduce damage for smaller floods, they may also overtop or breach in extreme flood events and subsequently create more flood damage than would have occurred without the levees. Examples can be seen from the 2005 flooding of New Orleans in the aftermath of Hurricane Katrina when the levees protecting the city were overtopped and breached and 8 percent of the city was flooded. The flooding took the lives of approximately 1,464 people and caused damages estimated to be in excess of $200 billion (Dolfman, Wasser et al. June 2007). The awareness amongst experts and policy makers of climate change and the increasing flood risks have led to the development of new modes of flood protection, which many consider nothing less than a paradigm shift in water management. Whereas policies used to be aimed at fighting the water by means of “hard engineering,” new policies try “to work with nature” or “to live with the water.” These policies are characterized by soft engineering or non-structural approaches. An example of these approaches is a spatial planning project called “room for river” conducted by the Dutch government to create more space for the main Dutch rivers (Van den Brink & Meijerink, 2005). In many countries such as the United States, the United Kingdom and France, the insurability of real estate in flood-prone areas is also linked directly to the probability of flooding. Spatial developments can thus be directed.

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Reduce Probability of flooding Hazard reduction (“Keep floods away from urban areas”)</th>
<th>Reduce Impact of flooding Vulnerability reduction (“Prepare urban areas for floods”)</th>
<th>Exposure reduction (“Keep urban areas away from floods”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures</td>
<td>Technical: Dams, dykes, storm surge barriers Spatial: Space for water</td>
<td>Early warning and evacuation Adjustments to real estate and infrastructure</td>
<td>Inhibiting flood plain occupancy Re-locating houses/ de-urbanization</td>
</tr>
</tbody>
</table>

Table 4: Strategies of flood risk management, modified after by (Oosterberg, Van Drimmelen et al. 2005)

In addition to reducing flood probability by taking technical or spatial measures, policies may be implemented aimed at reducing flood vulnerability; for example, by developing early warning systems. Advanced warnings for floods can mean the difference between life and death, as well as curtailing economic losses. Some studies suggest that as little as one hour of lead-time could result in a 10-percent reduction in flood damages (EASPE May 2002). Other techniques that can be used to reduce the vulnerability or flood damage include careful planning of evacuation routes, or by making adjustments to houses and infrastructure. By doing so, urban areas are better prepared for flooding.
Finally, policies may be implemented aimed at reducing the exposure to flooding; for example, by relocating properties or by inhibiting new developments in flood prone areas.

### 3.3 Safety Chain Approach

The flood risk management measures mentioned above can be addressed using the safety chain concept. The concept was originally developed by the Federal Emergency Management Agency (FEMA) as an approach to address safety and security concerns. The original safety chain approach can be seen to consist of four links: mitigation, preparation, response and recovery (FEMA 2003). Now, the safety chain concept is well adopted in different countries (Brinke, Saeijs et al. 2008) and is addressed in various literatures (Helsloot; Heuer, Flikweert et al.; Interreg; Bierens 2006; Brinke, Saeijs et al. June,2008; Laanen October 2005).

In the Netherlands, the safety chain concept was introduced in 1993 (Interior 1993) with slight adjustments since; instead of the mitigation link, two more links, pro-action and prevention, have been added, but the other links have stayed the same. The safety chain links are defined in Table 5 and illustrated in Figure 5.

![Figure 5: Safety Chain Approach](image)

<table>
<thead>
<tr>
<th>Link</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pro-action</td>
<td>Eliminating structural causes of accidents and disasters to prevent them from happening in the first place (e.g. prohibit building in flood prone areas)</td>
</tr>
<tr>
<td>Prevention</td>
<td>Taking measures beforehand aimed at preventing accident and disasters, and limiting consequences in case such events do occur (e.g. building levees)</td>
</tr>
<tr>
<td>Preparation</td>
<td>Taking measures to ensure sufficient preparation to deal with accident and disasters in case they happen (e.g. contingency planning, training, early warning, initiating flood fighting efforts)</td>
</tr>
<tr>
<td>Response</td>
<td>Actually dealing with accidents and disasters (e.g. response teams)</td>
</tr>
<tr>
<td>Recovery</td>
<td>All activities that lead to rapid recovery from consequences of accidents and disasters and ensuring that all affected can return to “normal” and recover their equilibrium.</td>
</tr>
</tbody>
</table>

Table 5: Definitions of the successive links in the Safety Chain (Brinke, Saeijs et al. June,2008)
3.4 Flood control actors

Based on the safety chain concept, several organizations can be seen to play a role in flood control activities. These actors can be represented by organizations with roles and responsibilities in water management and disaster management. A quick research of organizations responsible for flood control activities was conducted both in the Netherlands and United States. In the Netherlands, these organizations include:

- Pro-action: actors involved in this link include the national, provincial and local governments as well as the water boards.

- Prevention link: the main actors are the water boards and the Ministry of Transport, Public Works and Water Management together with its divisions, especially Rijkswaterstaat.

- Preparation: the primary actors responsible for specifying activities in this link are the municipalities. The provinces have regulatory authority over the municipalities. The Queen’s Commissioner (in the provinces) ensures administrative coordination with and between municipalities, state services and other authorities and bodies. At national level, the Ministry of the Interior and Kingdom Relations plays a coordinating role.

- Response: according to the Disaster and Major Accidents Act, the municipal mayors are in supreme command and, as a result, municipalities play a central role in the response link. Disaster control is initially carried out by the emergency services (police, fire brigades, medical aid). However, when the situation becomes more serious or transcends the boundaries of one municipality, provincial or even national authorities (especially the Ministry of Home Affairs) may decide to coordinate or otherwise intervene.

- Recovery: all government authorities will play a role in recovery. However, an important role in the recovery link is reserved for the State within its financial capabilities.

In United States, these organizations include:

- Pro-action: local governments are responsible for land use and zoning decisions that direct floodplain and coastal development; however, numerous federal and state policies and programs influence local and individual decision making. Apart from land use regulations and zoning, the National Flood Insurance Program (NFIP), managed by the Federal Emergency Management Agency (FEMA), is commonly used as a non-structural approach towards flood damage reduction.

- Prevention: the US Army Corps of Engineers (USACE) is the federal agency responsible for civil works projects for water resources development, including flood control. Although the USACE is mostly engaged in the construction of flood control structures, the responsibility for the operation, maintenance, repair, replacement, and rehabilitation of the levees after construction of the projects is mainly left to the local levee districts.
- **Preparation**: governments at all levels (federal, state and local) are responsible for disaster preparation. At national level, FEMA plays the most prominent role in disaster preparedness.

- **Response**: disaster response is generally handled by local authorities and local emergency personnel, including the police, fire, public health and emergency management personnel.

  Under the Stafford Act, a state governor may request that the President of the United States declare an emergency or a major disaster. A governor’s request is based on “a finding that the disaster is of such severity and magnitude that effective response is beyond the capabilities of the state and affected local governments and that federal assistance is necessary. When the federal assistance is requested and approved, FEMA, which is part of the Department of Homeland Security, coordinates response activities.

- **Recovery**: at federal level, once a major disaster is declared, FEMA plays an active role in assisting communities and individuals to recover. FEMA administers the president’s Disaster Relief Fund and disaster aid programs of other participating federal departments and agencies.

As previously mentioned, the above examples only show some of the organizations involved in the Flood Control Domain. However, more organizations can be involved in the domain. In addition, the examples don’t explicitly specify the essential operations performed by those organizations in different links of the safety chain approach. Researching the organizations involved in the Flood Control Domain and identifying explicit essential operations performed by these organizations are among the questions that this thesis project is trying to answer.

In order to get answers to these questions and to all the research questions listed in Section 2.3 of Chapter 2, three research methods were used at this stage: literature reviews, interviews and a case study.

### 3.5 Interviews

Several experts were approached during face-to-face interviews, including the Global Centre of Advanced Water Management team and other experts outside IBM, both within the Netherlands. The interviews were focused on specific questions. However, open discussions evolved during the interviews process since some of the questions couldn’t be answered by the interviewees. And the interviewees instead gave recommendations to specific people to whom I could get the missing information. The individuals from external organizations that were interviewed and the questions that were asked during the interviews are provided below. More information about the interviews is provided in Appendix A.
The list of questions that were asked during the interviews is provided below. The questions were categorized under two headings. The first set of questions was aimed at understanding the interviewees’ role and responsibilities and about their department. The second set of questions was aimed at understanding organization for which the interviewees’ work in general. These questions are:

**Personal Related Question**
1. What is your role and responsibility in the Flood Control Domain?
2. Which department are you in?
3. What are the top three priorities of your department regarding flood control?

**Organization Related Question**
1. In which phase is your organization involved: pro-action, prevention, preparation, response or recovery?
2. How is your organization involved in the above phase(s)?
3. How is your organization structured regarding flood control?
   1. How is the organization structured now?
   2. How is the organization structured during flooding?
4. What other organization(s) does your organization collaborate with to fulfill its functions?

Through my discussion with the experts, I understood that my thesis project was trying to cover a very complex domain, especially when flood response is concerned. Realizing this, I also used a case study strategy to study the Flood Control Domain as a complement to the interviews and the literature review.

### 3.6 The case study

The case study that is used in this project is a series of two documents:
The first document describes a flood scenario that can result into a need of national coordination of crisis situation. This policy scenario sets out the ways in which then national government will take practical measures to tackle high water and flooding. Its objective of is to describe an approach which will enable the parties involved both administratively and operationally to respond optimally to the (imminent) flood, thereby containing and/or managing the consequences of the flooding as effectively as possible. The actions of the national government are steered by the type of flood scenario confronting the Netherlands and the issues (dilemmas, bottlenecks) that this generates. These actions are categorized in the following phases:

- **Phase 0**: Normal control situation
- **Phase 1**: Crisis control: dealt with regionally
- **Phase 2**: National coordination of crisis situation in the water sector
- **Phase 3**: (imminent) flooding as a result of high water
  - **Phase 3a**: From official alert to decision to evacuate area completely, partially, or not at all
  - **Phase 3b**: Evacuation phase: period between decision on whether or not to evacuate and moment of flooding
  - **Phase 3c**: Acute phase
  - **Phase 3d**: Stabilization phase
  - **Phase 3t**: Return

The above coordination phases run parallel to the coordination phases currently applied within the water sector, with which this scenario links up with the Ministry of Transport, Public Works and Water Management (VenW) scenarios. An example of a scenario for a river flooding with used within the water sector is provided in Appendix B. The activities in phase 1 and 2 mainly involve the water sector. Although the activities in these phases are implemented within the water management domain, the general sector is nonetheless alerted in accordance with national arrangements (warning system). Announcing phase 3 means that there is a national crisis. In that case, the situation calls for national direction.

With the scale of the crisis and of the social disruption that ensues, these processes call for national coordination. The same applies to the mobilization of the – scarce – crisis control resources. The National Operational High Water and Flooding Strategy optimally coordinate the demand and supply of these resources. This Strategy is described in the second document mentioned above. The Strategy supports the safety regions and the National Operational Coordination Centre (Landelijk Operationeel Coördinatiecentrum or LOCC in dealing with all assistance needs in a proactive and structured fashion. Together, the Policy Scenario and the Operational Strategy focus on the administrative and operational approach to (imminent) floods.
3.7 Conclusion

The analysis of the Flood Control Domain which was conducted using three research methods: interviews, the case study, and literature reviews, gave me a vision on how the Flood Control Domain is constructed and operated. The safety chain concept provides a general structure on how the Flood Control Domain could be described in a simple and understandable way. The organizations involved in the domain and their activities can be described using the safety chain concept. The safety chain concept will be seen several times in this document.

The information gathered during the analysis phase will be used to constructing the enterprise ontology for the Flood Control Domain. Before showing how the enterprise ontology for the Flood Control Domain is constructed, I will first explain the notion of enterprise ontology in the next chapter. Afterwards, the methodology for developing an enterprise ontology will be discussed.
4. Enterprise Ontology

After the analysis of the Flood Control Domain in the previous chapter, the next step is to show how the domain is constructed in terms of operations, actors and information objects. In order to show such a construction, the enterprise ontology for the Flood Control Domain will be developed. But before this can be done, the notion of enterprise ontology will be introduced in this chapter. The chapter will also discuss the terms enterprise and ontology, the reason for the need of enterprise ontology, people within an organization who might need enterprise ontology and a short introduction of how enterprise ontology can be developed.

4.1 Defining an enterprise

First, it is important to clarify that the notion of “enterprise” here can be interpreted as an overall term to identify a company, organization, business or governmental institution. The literature provides many definitions for an enterprise. An enterprise can be considered as a “consciously coordinated social entity, with a relatively identifiable boundary, that functions on a relatively continuous basis to achieve a common goal or a set of goals” (Robbins 1990). Another definition reads: “organizations are social units (or human groupings) deliberately constructed and reconstructed to seek specific goals” (Lammers 1987; Hoogervorst 2008).

Despite some differences, all definitions point to a number of specific characteristics (Hoogervorst 2008):

- An enterprise is a social entity — this means that, despite technological resources of support, human beings are ultimately responsible for realizing enterprise goals.
- An enterprise is goal oriented — referring to this characteristic, one might also speak of the function of the enterprise. As a consequence of the goal orientation of the social entity, certain interaction patterns necessarily exist between human beings (actors) within the enterprise, dealing with coordination, cooperation and collaboration in view of the enterprise goal.
- An enterprise is consciously and intentionally created or designed — the intentional character points to being purposefully organized: the arrangement of things such that the enterprise purpose is realized. One might say that being organized points to a certain order, which is manifest in the enterprise design. It seems plausible that (generally) enterprise order does not occur incidentally, which is precisely the reason for speaking about the intentional character of enterprises.
- An enterprise is linked to the external environment — the enterprise delivers its function to entities in the environment, and on the other hand, takes energy, resources and information from the environment.

The above-mentioned characteristics are summarized in the following definition: “Organizations are (1) social entities that (2) are goal directed (3) are designed as deliberately structured and coordinated activity systems, and (4) are linked to the external environment” (Daft 2001).

Considering its characteristics, an enterprise can be viewed from two fundamentally different perspectives:

- The functional (black-box) perspective — the central question in the functional perspective regards what an enterprise is required to deliver to the environment,
such as products and services. The functional perspective also identifies the business functions of an enterprise without regarding how those business functions are realized.

- The constructional (white-box) perspective — this perspective, on the other hand, regards the question of how an enterprise is to be designed and built. It specifies how the organization is structured to realize the business functions, and the information and technology needed to produce the products and services.

Depending on the resources and capabilities, an enterprise can provide all its services and products to the environment by itself or through collaboration with other enterprises. In e-business, for instance, significant benefits can be achieved by integrating the whole supply chain (Lee and Whang November 2001), which can involve manufactures, partners, suppliers, consumers, logistic providers and financial institutions. The same can be seen within the Flood Control Domain since multiple actors are involved in different links of the safety chain in order to reduce flood hazard and vulnerability.

4.2 Defining an ontology & enterprise ontology

In this section, I will describe the terms ontology and enterprise ontology. The original Greek word, from which the English word “ontology” stems, means study or knowledge of what is or exists. This definition has also been preserved in the philosophical branch, where ontology is referred to as the study of what kind of things that exist (Chandrasekaran, Josephson et al. 1999).

In its modern use, ontology has preserved its original meaning, but it also has a definitive practical goal. It serves to provide a basis for the common understanding of some areas of interest among a community of people who may not know each other at all, and who may have very different cultural backgrounds. Various definitions of the modern notion of ontology have been put forward (Flouris, Plexousakis et al.; Gruber 1995; Chandrasekaran, Josephson et al. 1999; Dietz 2006). In this thesis project, I have chosen a widely adopted definition of ontology (Gruber 1995; Dietz 2006), where ontology is defined as: a formal specification of shared conceptualization. Such a definition shares the core properties of ontology, which can be explained as follows (Dietz 2006):

- Conceptualization – ontology is something in our mind. Hence, it is considered as a mental picture that needs to be checked and adapted in communication.
- Sharing – such a conceptualization is supposed to be shared
- Explicit – ontology needs to be fully and clearly expressed/defined in such a way as it leaves no room for misunderstanding
- Formal – ontology needs to be specified in a formal way. This means natural language can’t be used to define ontology as its inherent ambiguity and impreciseness.

The notion of ontology as applied by (Gruber 1995), but it is also (Guarino 1998; Spyns, Meersman et al. 2002; Choi, Cho et al. February 2006) what we call a world ontology. Common examples of such ontology are the world of traveling or the world of cooking and dining. The focus is on defining the core elements in such a world and their interrelationships in a most clear and extensive way. The notion of ontology as applied in this document is the notion of system ontology. Our goal is to understand the essence of construction and operations of complete systems; more specifically, of enterprises. Therefore, we can call this notion enterprise ontology.
Enterprise ontology provides a basic, systematic and integral understanding of how enterprises work. In order to provide such an understanding, a conceptual model of the enterprise is needed that is coherent, comprehensive, consistent and concise, and that only shows the essence of the operation of an enterprise model (Dietz 2006). Coherent means that the distinguished aspect models constitute a logical and truly integral whole; comprehensive means that all relevant issues are considered; consistent means that the aspect models are free from contradictions or irregularities; and concise means that no superfluous matters are contained in it. The most important property, however, is that this conceptual model is essential, that it shows only the essence of the enterprise, its deep structure; abstract from all realization and implementation issues.

Therefore, I can say that the enterprise ontology approach aims to comprehend and design the enterprise in its essential form, totally independent and abstract from its actual or possible implementation [Dietz 2006]. And, it focuses mainly on the essence operations of an enterprise.

4.3 Why do we need enterprise ontology?

A major motivation for developing and applying the notion of ontology in general is that the world is in great need of transparency with regard to the operation of all the systems we work with daily (Dietz 2006). The main goal of enterprise ontology (Dietz 2006) is to offer a new understanding of enterprises, such that one is able to look through the distracting and confusing actual appearance of an enterprise right into its deep essence, like an X-ray machine can let you look through the skin and the tissues of the body right into the skeleton.

As already mentioned, ontology serves to provide a basis for the common or shared understanding of some areas of interest among a community of people who may not know each other at all, and who may have very different cultural backgrounds. So, providing a shared understanding can be seen as another reason for having enterprise ontology within an enterprise or a domain.

4.4 Who needs enterprise ontology?

The understanding of enterprise ontology is not limited to a group of individuals within an enterprise, but it is important for everyone from the managers to the clients. The managers, for instance, need to understand the ontological essence of their enterprise because they are held accountable. Developers need to understand the construction and operation of the organization, independent of its implementation. Moreover, the ontology of an enterprise shows the roles fulfilled by the employees. Furthermore, through enterprise ontology, the operations of an enterprise become transparent to the clients of an enterprise.

4.5 How can enterprise ontology be developed?

The Design and Engineering Methodology for Organizations (DEMO) methodology provides a step-by-step procedure that helps to derive the ontology of an enterprise in a systematic way. The methodology is developed by Professor Jan L.G.Dietz of Delft Technical University Delft (Dietz 2006). The next section will describe in detail about the DEMO methodology.
5. DEMO (Design & Engineering Methodology for Organizations)

The modeling of an enterprise is generally a tough job because the available descriptions of its operations tend to be voluminous and, at the same time, incomprehensive and consistent. Therefore, it is imperative to develop an enterprise ontology in a systematic way. In this chapter, three things are presented and discussed that can assist during the development of the enterprise ontology for the Flood Control Domain. The first is the theory behind the DEMO methodology. The second is the set of aspect models in which the ontological knowledge of (the organization of) an enterprise is expressed, such that this knowledge is easily accessible and manageable. The third is the method/procedure for the development of the ontological aspect models of an enterprise.

5.1 The Theory

The theory behind DEMO methodology will be explained using four distinct axioms: the Operation Axiom, the Transaction Axiom, the Composition Axiom and the Distinction Axiom. These axioms will be applied when developing the enterprise ontology for the Flood Control Domain, which will be presented in the form of a conceptual model. The four axioms described in DEMO methodology are discussed as follows.

5.1.1 The Operation Axiom

The operation axiom states that the operation of an enterprise is constituted by the activities of actor roles. In doing so, these subjects perform two kinds of acts: production acts and coordination acts. These acts have definitive results: production facts and coordination facts respectively.

By performing production acts (P-acts) the subjects contribute to bringing about the goods and/or services that are delivered to the environment of the enterprise. The realization of a production act is inherently either material or immaterial. Examples of material acts are implementing a land use change plan and maintenance of a flood defense. Examples of immaterial acts are the decision to evacuate people from a certain area because of a flood threat and approval to grant a claim or compensation for flood damage.

By performing coordination acts (C-acts) subjects enter into and comply with commitments towards each other regarding the performance of production acts. Therefore, enterprise performance is ultimately the result of social interaction between human actors who enter into, and comply with, commitments. Human beings enter into and comply with commitments by presenting their intentions or confirming their intentions to the other human beings. Coordination acts include intentions such as: request, promise, state and accept. These acts can be seen by an example below:

(1) Actor A requests actor B for a certain product,
(2) Actor B promises to give the product to actor A,
(3) Actor B states that the request is fulfilled, and finally
(4) Actor A accepts that the fulfillment is satisfactory.
A subject in fulfillment of an actor role is called an actor. So, actors are the (active) elements of an enterprise. They are also the only active elements that will be considered, which means we disregard all kinds of artificial (mechanical or electronic) systems.

5.1.2 The Transaction Axiom

In the previous section, it was seen that an enterprise is a system of actors who perform two kinds of acts: production acts and coordination acts. The transaction axiom defines the relationship between these acts; whereby a transaction can be defined as a universal pattern in which coordination acts are performed, always involve two actor roles and are aimed at achieving a particular result.

A transaction consists of three phases: the order phase (O-phase), the execution phase (E-phase) and the result phase (R-phase), (see Figure 6). One of the two actor roles is called the initiator (e.g. a customer) and the other is called the executor of a transaction (e.g. a producer). In the order phase, the initiator and the executor work to reach an agreement about the intended transaction (i.e. the production fact that the executor is going to create as well as the time of creation). In the execution phase, this production fact is actually brought about by the executor. In the result phase, the initiator and the executor work to reach an agreement about the production fact that is actually produced, as well as the actual time of creation.

These phases of transactions can be seen by an example below. It is about the request for a product from a customer (C) to a shopkeeper (S):

1. C: I would like to have such a product: <request>
2. S: Very well, madam: <promise>
3. (Actual delivery of a product)
4. S: Here you are madam: <state>
5. C: Thanks: <accept>

Line 1 and 2 constitute the order phase of the transaction: line 1 contains the request from the customer to the shopkeeper about a particular product in the shop. Line 2 is the promise of the shopkeeper to the customer to produce the requested product. Line 3 constitutes the execution phase, it refers to the production act and fact. Line 4 and 5 constitute the result phase of the transaction; line 4 contains the statement that the customer can have the requested product, and line 5 is the corresponding acceptance of the product by the client. These five lines constitute a transaction.

The example of buying a product from a shop above follows completely the basic pattern of a transaction, as exhibited in Figure 6. An open or white box represents Coordination–act type and an open or white disk represents Coordination–fact type. A gray box represents a Production–act type and a gray diamond a Production–fact type. The initial Coordination–act is drawn with a bold line, as is the terminal Coordination–fact. The three transaction phases are indicated. Every act and fact belongs to one of the. The gray-colored frames, denoted by “initiator” and “executor” represent the responsibility areas of the two actor roles.
The example above shows the basic transaction pattern whereby the initiator and executor keep agreeing on each other’s act. However, in reality disagreements between these two actor roles can occur. For instance, instead of promising, one may respond to a request by declining it. For instance, this can happen when the product requested by the customer is out of stock. And, instead of accepting, one may respond to a statement by rejecting it. For instance, this may happen when the customer is not satisfied with the quality of the product. Therefore a standard transaction pattern extends the basic transaction pattern with the disagreement patterns.

5.1.3 The Composition Axiom

From the previous section, it was seen that the result of a successful transaction is the creation of a production fact (P-fact). Conversely, every original new fact in the production-world is brought about as the result of a successful transaction. This section addresses how the transactions are interrelated. As an example, I will use the manufacturing of a bicycle. As everyone knows, manufacturing a bicycle is not one (atomic) act, like switching of your desk lamp. Instead, it is an assembly of a number of parts. A bicycle can be seen as a tree structure of parts, both atomic parts and subassemblies parts, as exhibited in Figure 7. Like a definition of an atom, an atomic part cannot be disassembled: examples are a bolt and a nut. Most parts of the bicycles like the lamps and the chains are subassemblies.
The tree is broken down from left to right, so e.g. part P2 is a component of part P1, and part P5 is a component of part P2. The number of instances of a part that are contained as components in another part is indicated by k..n, where k stands for the minimum number and n for the maximum number. The default value is 1..1; by convention, this value is not indicated in the component structure. So, the figure tells us that a bicycle is an assembly of (exactly) two wheels, one frame, one handlebar and one cycle chain (note: the dashed continuation of the first level decomposition means that there may be more components). Next the wheel is an assembly of one rim, one hum and 40 to 60 spokes.

As stated before, the creation of every part is the outcome of a successful transaction, for instance manufacturing a bicycle. Clearly, the logical sequence of the component structure of the bicycle, as shown in Figure 7, puts the restriction on the sequence in which all these transactions are carried through. For example, to complete the production of the bicycle assembly (P1), the parts P2, P3, P4 etc., have to be produced first. Similarly, in order to complete the production of P2, the production of P5, P6 and P7 has to be completed first. The general question then is how the transactions in which an assembly is produced is related to each of the transactions in which a component is produced or acquired. The answer is shown in Figure 8. It is derived from the basic transaction pattern in Figure 6.

In the state promise of T1, the executor (A1) performs two acts. One is the execution of the production act (the gray box) and the other is the request for a T2, of which the executor is actor role A2. This ensures that within every transaction T1, a transaction T2 is started. The dashed arrow from the state accepted of T2 to the execution act of T1 means that the execution of T1 has to wait for the completion of T2. Through this construction, T2 becomes an enclosed transaction of T1. The figure shows the basic enclosing structure. Of course, many more transactions may be initiated from within T1. Continuing T1 would have to wait then for each of them to be completed. Transaction T1 itself is initiated externally, which is indicated in the figure by an arrow with a dot on the other end of the shaft. By externally it means that the initiator is an actor role in the environment of the organization under the consideration.
Apart from being initiated as an enclosed transaction or an external transaction, a transaction can be initiated by means of self-activation. Figure 9 exhibits the general structure of self-activation. For the state requested of T1, two acts are performed. One is the promise of T1, performed by the executor of T1 (A1). The other is the request for a next T1, performed by the initiator of T1 (A0). This self-activation is the generic solution for periodic activities, as for all control activities. Suppose, for example, that in the bicycle manufacturing company the stock control of purchased parts is done every month. Then T1 would be the stock control transaction, and T2 the purchase transaction.
The two Figures 8 and 9 constitute the composition axiom which can be expressed that every transaction is enclosed in some other transaction, or is a customer transaction of the organization under the consideration or is a self-activation transaction.

5.1.4 The Distinction Axiom

The distinction axiom states that there are three distinct human abilities playing a role in the operation of actors, called performa, informa and forma. The three human abilities are summarized in Figure 10. These abilities regard communicating, creating things, reasoning and information processing.

The forma (Latin for “form”) ability concerns the form aspect of communication and information. The informa ability concerns the content aspects of communication and information (Latin for “what is in the form”). The performa ability concerns the bringing about of new, original things, directly or indirectly by communication. We are talking now about engaging into commitments and about decisions, judgments etc. The performa abilities are considered as essential abilities for doing business of any kind.

![Figure 10: The three human abilities(Dietz 2006)](image-url)
5.2 The Distinct Aspect Models

Figure 11 exhibits the four aspect models that are distinguished in the DEMO methodology.

![Figure 11: The ontological aspect DEMO models (Dietz 2006)](image)

5.2.1 The Construction Model (CM)

The Construction Model (CM) specifies transactions types and the associated actor roles, as well as information links between actor roles and information banks (a collective name for coordination banks and production banks). In short, the CM specifies the construction of the organization. In relation to the theory provided in section 5.1, the Construction Model (CM) combines the Operation Axiom discussed in section 5.1.1 and the Transaction Axiom discussed in section 5.1.2.

Two models make up the Construction model (CM): the Interaction model (IAM) and Interstriction Model (ISM). In light of the transaction pattern described earlier, executing a transaction implies carrying out coordination and production activities. Within the Interaction Model, the result of every transaction is specified precisely. Otherwise said, the production fact created is precisely specified and summarized in a transaction-result table (TRT). An example of the how the Transaction Result Table is provided in Table 7.
<table>
<thead>
<tr>
<th>Transaction Type</th>
<th>Result Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>T11  Check flood defense safety assessment</td>
<td>R11 Flood defense assessment for period P has been checked</td>
</tr>
<tr>
<td>T12  Establish flood defense safety assessment</td>
<td>R12 Standard for flood defense safety assessment SA has been established</td>
</tr>
<tr>
<td>T13  Conduct flood defense safety assessment</td>
<td>R13 Flood defense safety assessment SA has been conducted</td>
</tr>
<tr>
<td>T14  Evaluate flood defense safety assessment</td>
<td>R14 Flood defense safety assessment SA has been evaluated</td>
</tr>
</tbody>
</table>

Table 7: An example of a Transaction Result Table

All the identified transactions, the actors and information links will be presented in the Interstriction model. The Interstriction Model will be expressed using the Organization Construction Diagram (OCD). An example on how the Organization Construction Diagram is exhibited is provided in Figure 12.

The example above shows that, an actor role A11 that initiates and executes a transaction T11 is a self-activating actor role. An actor role A11 also initiates transactions T12, T13 and T14. Together transactions T11, T12, T13 and T14 constitute of a result structure. This means that every time a transaction T11 is initiated, transactions T12, T013 and T14 have to be performed and for the completion of a transaction T11, transactions T12, T13 and T14 have to be completed first. An actor role A13 needs that data that has been gathered during an assessment and safety assessment checklist that, deduced from CPB08 and CPB09 respectively.
5.2.1 The Process Model (PM)

The Process model (PM) contains, for every transaction type in the Construction Model, the specific transaction pattern of the transaction type. The Process model also shows the interrelationship between different transactions; hence the logical sequence of steps for which a transaction is performed. In relation to the theory provided in section 5.1, the Process Model describes the Composition Axiom theory which is discussed in section 5.1.3. The Process Model is expressed in a Process Structure Diagram (PSD). An example of how the Process Model is constructed is presented in Figure 13.

The figure above shows the business process regarding the safety assessment of the primary flood defenses that is conducted every five years in the Netherlands. It starts with an actor role A11 dealing with an agendum T11/rq. As the result of dealing with the C-result T11/rq,
an actor role A11 performs two actions. First, A11 performs a new request (T11/rq), with the requested occurrence time of the P-result that is 5 years from now. Second, A11 performs the promise (T11/pm). And, as the result of dealing with the agendum T11/pm, A11 performs four acts: T12/rq, T13/rq, T14/rq and T11/ex. However there is a conditional link from T12/ac to T13/rq. The meaning for this conditional link is that dealing with C-result T13/rq has to wait until the C-result T12/ac has been done. Its practical meaning is that the safety assessment of flood defense is conducted when the safety assessment standards has been received. Similarly, dealing with C-result T14/rq has to wait until the C-result T13/ac has been done. This means an evaluation of flood defense safety assessment is done when the safety assessment is completed. Likewise, the completion of a transaction T11 is a wait condition for the T14/ex step. So, the checking of flood defense safety assessment in a particular 5 year period is said to be performed when evaluation report of the safety of the flood defenses is provided. The minimal and maximal cardinality of casual links is 1, unless otherwise specified. Lastly, the responsibility areas encompass all acts that the indicated actor role is allowed to perform.

## 5.2.2 The State Model (SM)

State Model specifies information items that are relevant for the operation of an organization. It specifies the state space (i.e. the state of allowed or lawful states) of the production world (i.e. set of production facts) in terms of: object classes, fact types and result types as well as the pertaining existential laws. The State Model is expressed in an Object Fact Diagram (OFD) and Object Property List (OPL). The Object Fact Diagram shows the object classes, the result types and the pertaining existential rules. Figure 14 shows an example of how the State Model is constructed using the Object Fact Diagram (OFD).

![Figure 14: An example of the Object Fact Diagram (OFD)](image)
The figure above shows one object class SAFETY ASSESSMENT whose instances are created by an example provided. There are two external object classes: FLOOD DEFENSE and PERIOD. So, one has to consider these object classes as given. For instance, there exists a particular flood defense, whose safety has to be assessed periodically. The figure above also shows the relationship between two objects: SAFETY ASSESSMENT and FLOOD DEFENSE. This relationship can be formulated as: regards (SA, FD). In practical way it can be read as: safety assessment SA regards a flood defense FD. On top of the object classes are the declared result types. These results types are defined in the Transaction Result Table 6.

The figure above shows two existential laws:

- **Dependency law** - this law states that for every safety assessment SA there must be a flood defense FD such that assesses (SA, FD) holds.
- **Unicity law** – this law states every safety assessment SA for a particular flood defense is unique. Although the same flood defense may be assessed several times but the gathered data for and the results of the safety assessment that is conducted today is unique from the safety assessment that is conducted at another time.

The State Model is also expressed using the Object Property list (OPL). The Object Property List shows the fact types that are pure mathematical functions, and of which the range is a set of values. That set of values, normally ordered, is called a scale. The scale types we distinguish are: categorial or nominal, ordinal, interval, ratio, and absolute. These scales are described as:

- **Categorial (C)**: A scale that measures data by name only. For example, religious affiliation (measured as Jewish, Christian, Buddhist, and so forth), political affiliation (measured as Democratic, Republican, Libertarian, and so forth), or style of automobile (measured as sedan, sports car, station wagon, van, and so forth). A categorial scale can be sometimes referred to as a nominal scale.

- **Ordinal (O)**: Measures by rank order only. Other than rough order, no precise measurement is possible. For example, medical condition (measured as satisfactory, fair, poor, guarded, serious, and critical); social-economic status (measured as lower class, lower-middle class, middle class, upper-middle class, upper class); or military officer rank (measured as lieutenant, captain, major, lieutenant colonel, colonel, general). Such rankings are not absolute but rather “relative” to each other: Major is higher than captain, but we cannot measure the exact difference in numerical terms.

- **Interval (I)**: Measures by using equal intervals. Here you can compare differences between pairs of values. The Fahrenheit temperature scale, measured in degrees, is an interval scale, as is the centigrade scale. The temperature difference between 50 and 60 degrees centigrade (10 degrees) equals the temperature difference between 80 and 90 degrees centigrade (10 degrees). Note that the 0 in each of these scales is arbitrarily placed, which makes the interval scale different from ratio.

- **Ratio (R)**: Similar to an interval scale, a ratio scale includes a 0 measurement that signifies the point at which the characteristic being measured vanishes (absolute 0). For example, income (measured in dollars, with 0 equal to no income at all), years of formal education, items sold, and so forth, are all ratio scales.
• **Absolute (A):** commonly use in all cases of counting. It has fixed measurement units for instance amount of money, number of days.

Based on the explanations above Table 8 presents an example of the Object Property

<table>
<thead>
<tr>
<th>Property type</th>
<th>Object Class</th>
<th>Range</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>assessment_date</td>
<td>SAFETY ASSESSMENT</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td># assessments (*)</td>
<td>SAFETY ASSESSMENT</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>assessed_section</td>
<td>SAFETY ASSESSMENT</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>assessment_method</td>
<td>SAFETY ASSESSMENT</td>
<td>METHOD TYPE</td>
<td>C</td>
</tr>
<tr>
<td>assessment_result _category</td>
<td>SAFETY ASSESSMENT</td>
<td>(MEETS, NO JUDGEMENT, DOES NOT MEET)</td>
<td>O</td>
</tr>
<tr>
<td>design_level</td>
<td>FLOOD DEFENSE</td>
<td>HEIGHT ABOVE SEA LEVEL</td>
<td>R</td>
</tr>
<tr>
<td>crest_level</td>
<td>FLOOD DEFENSE</td>
<td>HEIGHT ABOVE SEA LEVEL</td>
<td>R</td>
</tr>
<tr>
<td>soil_type</td>
<td>FLOOD DEFENSE</td>
<td>SOIL TYPE</td>
<td>C</td>
</tr>
<tr>
<td>flood_defense_category</td>
<td>FLOOD DEFENSE</td>
<td>(PRIMARY, SECONDARY)</td>
<td>C</td>
</tr>
<tr>
<td>flood_defense_ construction_year</td>
<td>FLOOD DEFENSE</td>
<td>YEAR</td>
<td>I</td>
</tr>
</tbody>
</table>

*Table 8: An example of a Transaction Result Table*

There is a derived property that is indicated by an asterisk between brackets. Its derivation rule can be as follows:

# assessments = < sum total assessments during safety assessment period>

5.2.3 The Action Model (AM)

The Action Model (AM) specifies action rules that serve as guidelines for the actors in dealing with their agenda. It contains one or more rules for every agenda type. The Action Model is the most detailed and comprehensive aspect model. It is also atomic on the ontological level. The action rules specified in the Action model serves as guidelines for an actor hence these rules are grouped according to the identified actor roles.

A pseudo-algorithmic language is used for specifying the action rules of an organization which can be explained as follows. An action rule is enclosed by an on-no bracket pair. The on clause, as it is called formally, specifies the agenda that is being dealt with (in the first lines), and what actions have to be taken for dealing with it (in the other lines). Conditional responses (choices) are represented by an if clause, enclosed in an if-fi bracket pair. If there is more than one choice, the second and following ones are presented by a diamond symbol. Every choice consists of a condition which is checked to be true followed by an arrow symbol, followed by the action(s) to take. Repeated actions are specified by means of a do clause, enclosed in a do-do bracket pair. Sometimes it is not possible to specify a rule (completely) formally. In such cases, informal expressions are allowed; they are always put between the meta-brackets < and >.
An example of the action rules for an actor role A11, identified in the Organization Construction Diagram (OCD) in Figure 11 and in the Process Structure Diagram (PSD) in Figure 12, is formed below.

**Action rules for actor role A01**

```plaintext
on requested T01 (SA)
  request T01(next (SA)) with
  requested_creation_time of ex(T09) = Now + 5 years
  promise T09 (SA)
no
```

Self-activation of actor role A01 is realized by starting a new T01 at the time of dealing with the request of the current one. We use a simple function, next, to provide us with the next time period. The requested creation time of the P-event is set to now plus five years.

```plaintext
on promised T01 (SA)
  request T02 (safety_assessment_standard (SA))
  request T03(SA)
  request T04(SA)
on
```

After self-accepting that the safety assessment will be checked, the safety assessment standard is requested that can be used when the safety assessment is carried out. At the same time, a request is made to the individuals responsible for carrying out the safety assessment and to a person responsible for the evaluation of the safety assessment.

```plaintext
on stated T02 (SA)
  if <safety assessment standards are acceptable > accept T02 (SA)
  ◊ not < safety assessment standards are acceptable> reject T02 (SA)
fi
```

```plaintext
on stated T03 (SA)
  if <safety assessment is accepted > accept T03 (SA)
  ◊ not < safety assessment is accepted > reject T03 (SA)
fi
```

```plaintext
on stated T04 (SA)
  if <safety assessment evaluation is accepted > accept T04 (SA)
  ◊ not < safety assessment evaluation is accepted > reject T04 (SA)
fi
```

The example above shows the action rules only for actor role A01. The Action Model is supposed to show the action rules for all the actor roles and this is why the Action Model is considered to be the most detailed and comprehensive aspect model.
5.3 Scope of the enterprise ontology for the Flood Control Domain

The enterprise ontology for the Flood Control Domain will be developed using DEMO methodology hence presented in form of a conceptual models. In order to do present the enterprise ontology, only three DEMO aspect models will be used the Construction Model, the Process Model and the State Model as can be seen in Figure 15. These models will be used to answer the research questions 1, 2 and 3 respectively.

![Diagram of Conceptual Models](image)

**Figure 15: An example of the Object Fact Diagram (OFD)**

DEMO provides a general method that can be used to assist the developers in developing enterprise ontology of an organization. These steps are provided in the section below.

5.4 Procedures for enterprise ontology development

The general elicitation method to acquire the basis for a correct and complete set of aspect models of an enterprise ontology consist of three analysis and three synthesis steps. These steps support the way of working that one can use to derive an ontological model of an organization. The starting point is all available documentation about the enterprise.

1. The Performa- Informa- Forma Analysis: in this step all available pieces of knowledge are distinguished according are divided in three set (i.e. forma, informa and performa), as explained in the distinction axiom (Section 5.1.4). This is not always an easy job, since in natural language descriptions words and sentences may belong to more than one of these sets.

2. The Coordination-Actors- Production Analysis: this step distinguishes the actor roles and the two kinds of operations performed by the actor roles: the coordination acts and production acts, according to the operation axiom (Section 5.1.1).

3. The Transaction Pattern Synthesis: In this step the production acts and coordination acts belonging to one transaction are clustered into transaction types, according to the transaction axiom (Section 5.1.2). Next, for every transaction type, the result type is correctly formulated. The Transaction Result Table can now be produced.
4. The Result Structure Analysis: according to the composition axiom (Section 5.1.3), every transaction a transaction can be initiated by a user in the environment, or can be enclosed in another transaction, or can be a self-activation transaction. Generally, the (internal) executor of a transaction can be the initiator or one or more other transactions types, and so on. The results of these cascaded transactions can be viewed as components of the end results.

5. The Construction Synthesis: at this step for every transaction type, initiating actor role(s) and executing actor role are identified, based on the transaction axiom. This is the first step in producing the Construction Model.

6. The Organization Synthesis: in this step a definitive choice has to be made as to what part of the construction will be taken as the organization to be studied and what part will become its environment.

In general, the steps above are meant to aid the enterprise ontology developer in building the enterprise ontology of an organization; one may freely iterate through the six steps, and even skip a step. The next chapter will illustrate how some of the steps of this procedure, will be used to develop the enterprise ontology for the Flood Control Domain.

5.5 Conclusion

Based on the explanations above, DEMO can be seen as a suitable methodology for developing enterprise ontology of an organization. This can be seen through the theory behind the methodology that provides a strong foundation when constructing a conceptual model of an organization using the four distinct aspect models: the Construction Model, the Process Model, the Action Model and the State Model. Moreover, the steps provided in DEMO methodology makes it easy for the enterprise ontology developer in any organization or a certain domain to develop enterprise ontology for a specific organization or a domain, respectively.

Based on this understanding of DEMO methodology, the next chapters will show how the enterprise ontology for the Flood Control Domain is constructed and hence provide answers to the first three research questions. The answers to the first, the second and the third research questions will be provided in Chapter 6, Chapter 7 and Chapter 8, respectively.
6. Essential operations of the Flood Control Domain

From the previous chapter, we have learned that the enterprise ontology of an organization or a domain can be developed in a systematic way using DEMO methodology. As already mentioned, the enterprise ontology of an organization is a conceptual model of how the organization is constructed. Such a conceptual model shows the essential operations that are performed by the organization under consideration. Showing the essential operations performed by organizations in the Flood Control Domain is the aim of this chapter. Therefore, this chapter will provide the answer for the first research question: “what are the essential operations performed by organizations in the Flood Control Domain?”

In order to provide the answer to the question above, three things are presented and discussed in this chapter. The first is Performa Analysis where the performa human abilities will be captured from an Explanatory Case that is provided in Appendix C. The second is the Transaction Pattern Analysis where transactions and their results will be specified using the Transaction Result Table (TRT). The identified transactions can be regarded as the essential operations performed by the organizations within the Flood Control Domain. These operations, the fulfilling actor roles and data needed by the actor roles will be modeled using the Construction Model. Therefore, the Construction Model is a conceptual model of how the Flood Control Domain is constructed, in terms of actor roles, transactions and data are used by the actor roles. Finally, after discussing the Construction Model of the Flood Control Domain, its practical relevancy is discussed.

6.1 The Performa Analysis

Although three human abilities are distinguished according to the distinction axiom, my concern in this section is only the performa abilities. According to (Dietz and Hoogervorst 2008), the first step in arriving at the ontological model of an organization consists of taking only into account the performa ability in both coordination and production. Therefore, based on an Explanatory Case provided in Appendix C, the Performa Analysis is conducted below. The performa human abilities are highlighted in red.

6.1.1 Pro-action

According to the interview conducted with the Dommel Water board, the water boards are required every 6 years to provide a report of the possible future flooded areas and about their spatial plans. In order to provide such a report, they perform flood analysis. The result of flood analysis is a report, which can aid in the formation of a map, showing the possibility of flooding in certain areas, for instance in the coming 100 years. Among the data that the water boards need to perform flood analysis include the following: the average rainfall data obtained from the Royal Dutch Meteo Institute (KNMI), elevation data which obtained from Rijkswaterstaat and the internal data that comes from the water boards themselves such as different flooding scenarios.

Based on flood analysis, the Water boards develop spatial plans. Spatial plans are one of the measures that can be taken to reduce the risk of flooding and protect water resources. Spatial measures address land use, and exclude the construction of built-up areas in sensitive
locations and changes in land use so that the area can also be used as an artificial water basin, etc., when necessary. For making spatial plans, the water boards also gets inputs from the European Commission located in Brussels and from the Ministry on the policy issues that should be taken into account.

The water boards send their reports to the municipalities and the provinces. These authorities use the water board’s reports to make land use plans. Land use authorities: the municipalities, the provinces or the national government can initiate land-use change, for example, the development of urban areas, infrastructures, or natural environments. In order to implement land use change, the initiator has to develop a land use plan. Among the things needed to assess a land-use plan is the Water Assessment Test (WAT). The WAT is a general framework for assessing land-use proposals. The WAT framework consists of a checklist and a clarification of the roles of the actors involved. The framework includes all relevant water management aspects (flood protection, water quality and depletion). A WAT has three types of actors: the initiator, the advisor and the reviewer (Voogd 2006).

The initiator is the land-use authority that wishes to implement a land-use change, for example, the development of urban areas, infrastructures, or natural environments. This can be a local, regional or national authority. As already mentioned, this can be the municipality, the province or the national government. However, the initiator can also be a private organization. In such cases, the responsible public authority (municipal, provincial or national) performs the WAT.

The advisor is the water authority with jurisdiction: the water board, groundwater authority or national Rijkswaterstaat. The water authority assists the land use authority in conducting the water assessment test. If water management priorities (collect, store, and discharge) cannot be realized, explanations must be provided and compensatory measures taken. The water authority proposes mitigation and compensation measures that can be taken. The water authority then advises the land use authority on how the water management aspects can be incorporated. However, it is the responsibility of the land use authority to decide whether to incorporate the proposed mitigation and compensation measures.

The land use decision then has to be reviewed according to urban and regional planning legislation. For example, the provincial authority reviews land-use decisions taken by municipal authorities. Finally, the land use authority can implement the land use plan.

6.1.2 Prevention

Without flood defenses such as dikes and dunes, more than half of the Netherlands would be regularly inundated. So, the extensive system of flood defenses is essential to the safety and habitability of the country and an absolute precondition for healthy economic development.

There are two main categories of flood defenses in the country: primary and secondary flood defenses. All flood defenses structures along the major rivers of the Netherlands and the area around Lake IJsselmeer (including Lake Markermeer) and the delta are part of the primary flood defense system. The total length of these primary flood defenses is over 4,000 km, consisting of dikes, dams and dunes; they include over 800 structures such as pumping stations, navigation locks and quay walls. These defenses are managed 90% by the water boards and 10% by Rijkswaterstaat (Bake and Wolters).
All other flood defense structures are generally identified as regional or secondary flood defense structures (Rijkswaterstaat 2006). There are 14,000 km of secondary flood defense structures, including regional river dikes (for the smaller rivers), storage basin dikes, dikes/flood defense structures used to separate areas with different functions (compartment dikes), polder dikes and dikes/flood defense structures dividing differences in ordnance datum, all of which are managed by the Water boards (Rijkswaterstaat 2006).

These flood defenses have been constructed according to specific standards. For instance, the safety standard for the primary flood defenses ranges between 1/250 per year (upriver) and 1/10,000 (coast) per year (Rijkswaterstaat 2006). This safety standard is defined as the probability of exceedence of the hydraulic conditions.

In order to achieve the same level of protection against flooding, the flood defenses need to be maintained in the future. The Water Embankment Act requires the water boards and Rijkswaterstaat to report on the safety assessment of primary flood defense every 5 years. The safety standard that includes guidelines (VTV) and hydraulic boundary conditions (HR) for safety assessment is established by the Directorate General Water within the Ministry of Transport, Public Works and Water Management. The water boards and Rijkswaterstaat conduct the safety assessment. During the assessment, they check whether the strength of the flood defenses meets the statutory safety standards (Bake and Wolters). The assessment of a flood defense can lead to three categories: the flood defense “meets” the standard, the flood defense “does not meet” the standard, or because of insufficient information “no judgment” can be made.

The water boards and Rijkswaterstaat send their assessment reports to the provincial authorities that make an assessment, which is then attached to the reports and submitted to the Minister of Transport, Public Works and Water Management. Based on its independent position, the Transport and Water Management Inspectorate evaluates whether the assessment or management has been conducted in accordance with the regulations (this is known as official judgment). The results are summarized to create a national picture and analysis is provided together with its findings and conclusions. The Transport and Water Management Inspectorate submits this report to the Minister of Transport, Public Works and Water Management. Based on the summary, the minister informs Parliament about the state of all the primary flood defenses in the country and draws up a program of improvement, known as the Flood Protection Programme, based on the results (Inspectorate September 2006).

During the safety assessment period, preventive maintenance can be performed when the condition of flood defense seems to be threatening. Such maintenance can be called “variable maintenance,” as it is performed after the safety assessment when the condition of flood defense is identified to be threatening. However, there might be a fixed maintenance, performed in particular time interval to ensure good condition of flood defenses. For the maintenance to be implemented, a maintenance plan has to be developed. Such a plan includes things like an area that will be maintained, the equipment that will be used, personnel, maintenance period and maintenance cost. The maintenance plan needs to be approved before the maintenance is implemented.

As already mentioned, an improvement program is drawn based on the safety assessment results. In order to conduct an improvement program, an improvement plan has to be established. This plan can be established by the flood defense manager, the water board or Rijkswaterstaat. The improvement plan contains the necessary project provisions as well as
mitigating and compensating measures for damage done. Moreover, the plan clarifies which measures will be taken to promote the values of landscape, nature, and cultural heritage, the so-called LNC-values (Olsthoorn and Tol February 2001). The established plan has to be approved by the province involved (Olsthoorn and Tol February 2001) before the improvement is implemented. The flood defense improvement implementation has to be inspected to check whether the improvement is done according to the established and approved plan. The flood defense inspection role is the responsibility of the Transport and Water Management Inspectorate.

6.1.3 Preparation

Flooding in the Netherlands is fortunately rather uncommon. This means that the practical knowledge of how to deal with threats of extreme floods and actual flooding is limited. To raise preparedness among all parties involved in flood response and recovery, flood disaster plans or high-water plans are prepared. In addition to the flood disaster plans, training is organized within individual groups with a role in the decision-making chain to practice skills related to their individual task.

The government authorities (i.e. municipality, region and province) are responsible for the preparation and updating of flood disaster plan or high-water plan. Such plans need to be checked periodically for reviews.

A good example of a region in the Netherlands with such a plan is the region of Nijmegen (Bezuyen, MPA et al. Winter 1998). Because of the possibility of floods and the threat of a dike breach, a disaster plan was developed for the region of Nijmegen in the early 1980s. After the flood of 1993 from the river Meuse and the fact that there appeared to be real threat of weakening and breaching of the dikes along the river Waal, the board of mayors from the region decided to update the plan. At the end of 1994, this model was accepted and sent to other regions in the province. Although the other regions had not formally accepted this plan before the 1995 flood occurred, most of the regions could use it as a guideline for their response to the flood. Among the issues dealt in this plan include the following: inundation scenarios, evacuation planning for persons, evacuation planning for animals, communication plan and information for the population. Because the region was well-prepared, it was possible to evacuate about 60,000 people in the region of Nijmegen. The successful evacuation of Nijmegen gave confidence to the other regions that an evacuation of a large number of people was possible.

Apart from the regional flood disaster plans, the National High Water and Flooding Emergency Response Plan has been developed recently (BZK January 2007). Such a plan was deemed to be necessary in the event of high water. The (impending) disaster will strike multiple regions simultaneously, and regions that are not hit will also be involved in coming to the aid of the affected regions and in the care of people evacuated from the regions. Here, the preparations confined to municipal or regional level are insufficient.

As already mentioned, training is also used to raise preparedness among parties involved in flood response and recovery. By implementing multidisciplinary training courses and large-scale exercises, the government is ensuring that relief workers can acquire the right kind of knowledge and skills for potential disasters, so that when needed, they can carry out their tasks efficiently and effectively. Training is also used to test the established flood disaster
plans or the high-water plan. Tests will always be needed to establish whether the established plans work, which is why exercises are the final step in effective preparations.

For example, in November 2008, large-scale training was conducted in the Netherlands that involved many stakeholders in the water domain and safety domain. The Flooding Taskforce Management (TMO) was in charge of organizing the large-scale flooding exercise in November 2008. Large-scale training sessions are infrequently conducted, as compared to small-scale training sessions. Due to the importance of training for disasters in the Netherlands, several training institutions recently combined forces and founded a consortium to provide training courses to anyone involved in disaster control or crisis management. This consortium includes Bestuursacademie Nederland (BAN), Crisis Onderzoek Team (COT) of the University of Leiden, Nederlands Bureau Brandweerexamen (NBBe), Nederlands Instituut voor Brandweer en Rampenbestrijding (Nibra), Politie Instituut Openbare orde en Veiligheid (PIOV), and Stichting Opleiding en Scholing Ambulance Hulpverlening (SOSA)(Interior Affairs).

After the training has been conducted, an evaluation regarding measures and the whole flooding process has to be performed. The evaluation is important since during training or a real flood crisis, a new scenario may unfold that was not in the flood disaster plan. As a result, it may take a long time to figure out who could resolve issues presented during such a scenario and how those issues could be resolved. If necessary, and when it is foreseen that such a scenario can happen again in the future, the manager of the flood disaster plan may decide to update the existing flood disaster plan to include the new scenario.

6.1.4 Response

The response phase deals with operations that are directed at managing, containing and combating the consequences of an imminent flood (also referred to as high water) even before the actual flood has occurred. High water occurs when the water rises above a specific pre-defined level; the water defenses have not yet been breached. Although in this situation the disaster has not (yet) taken place, it is considered a crisis situation and large-scale action is taken: full crisis control measures are mobilized (pre-crisis response). This situation thus differs from that of many other types of emergencies (post-crisis response). High water can, but not necessarily, be followed by flooding. In this phase, we will consider actions that are taken not only during the actual flood, but also during an imminent flood.

Therefore, we can say that the response phase starts when a flooding event is predicted through flood forecasting activity. The Inland Information Centre within RIZA, Rijkswaterstaat Regional Departments and the water boards are responsible for daily water level measurement and water level forecasting at the national, regional and local levels, respectively. Under normal conditions, water level forecasting is done every morning, mainly for the benefit of navigation. In times of flood, forecasts are made at least twice a day, again for navigation but also for river management authorities, crisis organizations and population (Sprokkereef 2001).

Among the data needed for flood forecasting is the data about water level measurements and weather forecasts. The water level measurements are collected every 10 minutes by the Geo-Information Department. The Royal Netherlands Meteorological Institute (KNMI) provides weather forecasts on an hourly basis to government agencies, commercial weather bureaus, broadcasters and media (SGI). Flood forecasting organizations mentioned above use
a high-water scaling up procedure as a guideline to initiate crisis actions. This procedure shows what actions can be taken when a certain water level is reached and/or expected to increase. A scaling diagram with regard to river flooding is provided, and the flooding scenario is provided in appendix B.

After a flooding event is predicted, the forecasting authorities warn water management authorities and/or crisis organizations according to the high-water scaling level. Operational high-water management is among the activities that are initiated early when a flooding event is predicted. The water boards and Rijkswaterstaat are responsible for the operational high-water management. They can propose several operational high-water management measures such as pumping out of water, deciding to flood a certain retention area, etc. The effects of the proposed measures are analyzed in advance before they are selected as the right measures that will be implemented.

Another activity that is also initiated during the early stages of a flooding event is the periodic monitoring or inspection of flood defense such as dikes. The information about the condition of dikes is important for initiating actions like evacuation. It is the role of the water boards to provide the information about the condition of the dykes to other crisis organizations. To do that, the dyke guards are called to inspect the conditions of the dykes. Based on the inspection, or because of known condition of the dyke, the water boards can initiate temporary dyke reinforcement measures such as sandbagging. Because a lot of manpower is needed to perform sandbagging activity, the water boards request additional help from the local people and the army.

During a flood crisis, operational effort needs to be coordinated. At the national level, LOCC is responsible for the efficient, coordination of manpower, resources and expertise (the fire service, police, emergency medical aid (offered by the GHOR) and Ministry of Defense) if there is a threat or acute serious crises. Regionally, the coordination of operation efforts is the responsibility of the Regional Operation Team (ROT). Therefore, in case a flood crisis is coordinated nationally, it is the responsibility of LOCC to ensure the availability of operational resources. To achieve that purpose, LOCC periodically analyzes operational resources by checking what resources are available, where these resources are and how many resources are needed. In case of insufficient operational resources, LOCC drafts an advice report requesting additional resources. The decision for additional resources is taken at the Inter Ministerial Policy team meeting (BZK January 2007).

Once a flooding is predicted, people need to know about the possible flooded areas and the time of the flooding. This information is provided locally by the water boards. At the national level, the National Flood Threat Coordinating Commission (LCO) becomes responsible. LCO is activated and managed by the Departmental Coordination Centre within the Ministry of Transport, Public Works and Water Management. The water boards and LCO perform an analysis for the possible flooding areas and flood break time. In order to perform the analysis, a combination of information is required including the water level measurements, weather forecast, flood forecast and the condition of the threatened water defenses. Based on their analysis, the LCO advises the Inter Ministerial Policy Team and the Ministerial Policy Team of the chance that the threatened area will actually be flooded, the size of the (potential) flood area and the time left before the flood breaks (BZK January 2007).

In addition to the prediction of possible flooded areas and flooding time, the effects of flooding in terms of casualties and economic damage in the predicted areas need to be analyzed in advance. This information is important to initiate actions that aim to reduce
flooding effects such as evacuation. The municipalities perform both the causality analysis and economic damage analysis.

Due to the possibility of flooding, evacuation preparations are initiated. On one hand, some authorities are responsible for the preparations of evacuation implementation. In doing so, they develop an evacuation plan and prepare resources needed for the evacuation purpose. Among the things included in the evacuation plan are the required evacuation time, the exit points and evacuation routes that people can take to evacuate from the flooded area. An evacuation plan and evacuation process discussed here is a general one. However, specific evacuation plans must be integrated together. For instance, these plans may be specific for population in a threatened area without a need of assistance, the population in a threatened area with the need of assistance (e.g. the nursing homes, the patients in hospitals), prisoners and animals.

On the other hand, some authorities are responsible for checking whether an evacuation has to be done. In doing so, an evacuation decision-making process is initiated. At the national level, if a disaster affects more than one province or country, the Minister of Interior Affairs decides on evacuation. If a disaster affects a single province, the Queen’s Commissioner can decide to evacuate the population. Regionally, if flooding affects more than one municipality, the appointed coordinating Mayor within a region can decide on evacuation. Locally, when a single municipality is affected, moreover, and this is very rare for a flooding disaster type in the Netherlands, the Mayor of the municipality could decide on the evacuation.

Let’s consider a flooding crisis coordinated at the national level. Therefore, the evacuation decision is made by the Ministry of Interior Affairs. He does this after consulting with the regional authorities and Queen’s Commissioners and discussing the decision in the Ministerial Policy Team meeting. Among important information needed for evacuation decision making is the available time (i.e. the time from the moment of the warning to the anticipated moment of flooding) and the required time (i.e. the time required to evacuate all inhabitants from the disaster area). Depending on the way in which these timeframes interrelate, the Minister of Interior Affairs will decide whether or not to evacuate wholly or partially on the ground of the Population Evacuation Act (BZK January 2007).

Once an evacuation has been decided, some relief activities will focus on implementing the evacuation, some relief activities will focus on measures to manage or cordon off the area (prevent further disaster after the flood), while other relief activities in the non-threatened regions/provinces will focus on setting up shelters, implementing shelter care measures and registering evacuated victims. LOCC coordinates all these activities. In doing so, LOCC mobilizes the necessary operational resources required for carrying out these activities.

Moreover, traffic control measures need to be implemented in case a large-scale evacuation is implemented. Without implementing traffic control measures, it may be impossible to evacuate a large population within a certain time limit.

6.1.1 Recovery

As already mentioned, the recovery activities ensure that the affected population can return to its normal routines. Recovery operations should commence as early as possible during flood response operations. Therefore, it is important to note that the links in the safety chain approach are not sequential. They can be regarded as aspects of management, not phases.
While in evacuated shelters, people register for damage settlement and the damage claims are organized. This registration is done by the Central Damage Registration and Reporting Point (CRAS) team. The state government is responsible for the claim payments (BZK January 2007).

Another concern during this period is the restoration of flood defenses to normal operations. In doing so, the repair of failed flood defenses is initiated. Each repair has to be planned. Among the things that are included in the repair plan are resources that will be used and the cost of repair. The developed repair plan has to be approved before the repair work is implemented.

Moreover, other authorities research when people can return. The water board councils and LCO perform the return analysis. Based on their analysis, LCO provides advice to the Ministerial Policy, which then decides on scaling down crisis activities in consultation with the highest administrative parties. Based on the LCO’s advice, the Ministry of Interior Affairs can decide whether to return evacuated victims to their original homes; LOCC coordinates the return. In doing so, LOCC mobilizes operational resources needed for implementing the return activity.

Finally, the whole flood crisis has to be evaluated, regarding measures taken. An evaluation document will provide an insight and can be used to provide lessons to all the organizations that were involved during the crisis. Such lessons can be used to update existing flood scenarios as well as the flood disaster plan or high-water plan.

6.2 The Transaction Pattern Synthesis

The Performa Analysis conducted in section 6.1 identified the ontological human abilities. In this section, the identified ontological abilities will be formulated as transactions and shown in the Transaction Result Table (TRT). For easy understanding and readability, the identified transactions are presented according to the five safety chain links as seen in the Transaction Result Tables (TRT) below.

<table>
<thead>
<tr>
<th>TRANSACTION TYPE</th>
<th>RESULT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T01 Flood analysis check</td>
<td>R01 Flood analysis check for period P has been done</td>
</tr>
<tr>
<td>T02 Perform flood analysis</td>
<td>R02 Flood analysis FA has been performed</td>
</tr>
<tr>
<td>T03 Develop flood control spatial plan</td>
<td>R03 Flood control spatial plan SP has been developed</td>
</tr>
<tr>
<td>T04 Determine land use change</td>
<td>R04 Land use change for period P has been determined</td>
</tr>
<tr>
<td>T05 Develop land use change plan</td>
<td>R05 Land use change plan LP has been developed</td>
</tr>
<tr>
<td>T06 Advise water management related aspect</td>
<td>R06 Advice for water management aspect regarding land use change plan LP has been provided</td>
</tr>
<tr>
<td>T07 Assess water management aspect</td>
<td>R07 Water management related aspect regarding land use change plan LP has been assessed</td>
</tr>
</tbody>
</table>

58
T08 Propose water management compensation – mitigation measure

R08 Water management compensation mitigation measure regarding land use change plan LP has been proposed

T09 Review land use change plan

R09 Review for land use change plan LP has been done

T10 Implement land use change plan

R10 Land use change plan LP has been implemented

<table>
<thead>
<tr>
<th>TRANSACTION TYPE</th>
<th>RESULT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T11 Check flood defense safety assessment</td>
<td>R11 Flood defense assessment for period P has been checked</td>
</tr>
<tr>
<td>T12 Establish flood defense safety assessment standard</td>
<td>R12 Standard for flood defense safety assessment SA has been established</td>
</tr>
<tr>
<td>T13 Conduct flood defense safety assessment</td>
<td>R13 Flood defense safety assessment SA has been conducted</td>
</tr>
<tr>
<td>T14 Evaluate flood defense safety assessment</td>
<td>R14 Flood defense safety assessment SA has been evaluated</td>
</tr>
<tr>
<td>T15 Flood defense maintenance control</td>
<td>R15 Flood defense maintenance control for period P has been done</td>
</tr>
<tr>
<td>T16 Develop flood defense maintenance plan</td>
<td>R16 Plan for flood defense maintenance M has been developed</td>
</tr>
<tr>
<td>T17 Approve flood defense maintenance plan</td>
<td>R17 Plan for flood defense maintenance M has been approved</td>
</tr>
<tr>
<td>T18 Execute flood defense maintenance</td>
<td>R18 Flood defense maintenance M has been executed</td>
</tr>
<tr>
<td>T19 Flood defense improvement check</td>
<td>R19 Flood defense improvement for period P has been checked</td>
</tr>
<tr>
<td>T20 Develop flood defense improvement plan</td>
<td>R20 Plan for flood defense improvement plan IM has been developed</td>
</tr>
<tr>
<td>T21 Approve flood defense improvement plan</td>
<td>R21 Plan for flood defense improvement plan IM has been approved</td>
</tr>
<tr>
<td>T22 Implement flood defense improvement</td>
<td>R22 Flood defense improvement IM has been implemented</td>
</tr>
<tr>
<td>T23 Inspect flood defense improvement implementation</td>
<td>R23 Inspection for flood defense improvement IM implementation has been done</td>
</tr>
</tbody>
</table>

Table 9: The TRT of the Flood Control Domain (Pro-action)

<table>
<thead>
<tr>
<th>TRANSACTION TYPE</th>
<th>RESULT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T24 Check flood response plan</td>
<td>R24 Checking of flood response plan for period P has been done</td>
</tr>
<tr>
<td>T25 Develop flood response plan</td>
<td>R25 Flood response plan FP has been developed</td>
</tr>
<tr>
<td>T26 Approve flood response plan</td>
<td>R26 Flood response plan FP has been approved</td>
</tr>
<tr>
<td>T27 Manage flood crisis training</td>
<td>R27 Flood crisis training for period P has been managed</td>
</tr>
</tbody>
</table>

Table 10: The TRT of the Flood Control Domain (Prevention)
T28 Plan flood crisis training  
T29 Implement flood crisis training  
T30 Evaluate flood crisis training

R28 Flood crisis training FT has been planned  
R29 Flood crisis training FT has been implemented  
R30 Flood crisis training FT has been evaluated

<table>
<thead>
<tr>
<th>TRANSACTION TYPE</th>
<th>RESULT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T31 Weather forecast check</td>
<td>R31 Weather forecast for period P has been checked</td>
</tr>
<tr>
<td>T32 Weather forecasting</td>
<td>R32 Weather forecasting WF has been done</td>
</tr>
<tr>
<td>T33 Flood forecast check</td>
<td>R33 Flood forecast for period P has been checked</td>
</tr>
<tr>
<td>T34 Flood forecasting</td>
<td>R34 Flood forecasting FF has been done</td>
</tr>
<tr>
<td>T35 High water control</td>
<td>R35 High water control for period P has been done</td>
</tr>
<tr>
<td>T36 Evaluate high water management measure</td>
<td>R36 High water management measure WMM has been evaluated</td>
</tr>
<tr>
<td>T37 Propose possible high water management measure</td>
<td>R37 High water management measure WMM has been proposed</td>
</tr>
<tr>
<td>T37 Select high water management measure</td>
<td>R38 High water management measure WMM has been selected</td>
</tr>
<tr>
<td>T39 Implement high water management measure</td>
<td>R39 High water management measure WMM has been implemented</td>
</tr>
<tr>
<td>T40 Manage flood defense operation</td>
<td>R40 Flood defense operation for period P has been managed</td>
</tr>
<tr>
<td>T41 Implement flood defense inspection</td>
<td>R41 Flood defense inspection I has been implemented</td>
</tr>
<tr>
<td>T42 Take flood defense temporary reinforcement measure</td>
<td>R42 Flood defense temporary reinforcement measure TRM has been taken</td>
</tr>
<tr>
<td>T43 Mobilize resource for temporary flood defense reinforcement measure</td>
<td>R43 Resource for temporary flood defense measure TRM has been mobilized</td>
</tr>
<tr>
<td>T44 Implement temporary flood defense reinforcement measure</td>
<td>R44 Temporary flood defense reinforcement measure TRM has been implemented</td>
</tr>
<tr>
<td>T45 Check operational resource</td>
<td>R45 Operational resource check for period P has been done</td>
</tr>
<tr>
<td>T46 Analyze operational resource</td>
<td>R46 Operational resource OR has been analyzed</td>
</tr>
<tr>
<td>T47 Draft operational resource bottleneck advise</td>
<td>R47 Advice for operational resource OR bottleneck has been drafted</td>
</tr>
<tr>
<td>T48 Take operational resource bottleneck measure</td>
<td>R48 Measure for operation resource OR bottleneck has been taken</td>
</tr>
<tr>
<td>T49 Inundation probability check</td>
<td>R49 Inundation probability check for period P has been done</td>
</tr>
<tr>
<td>T50 Perform inundation analysis</td>
<td>R50 Inundation analysis IA has been performed</td>
</tr>
<tr>
<td>T51 Provide expert advice</td>
<td>R51 Expert advice on inundation analysis IA has been provided</td>
</tr>
<tr>
<td>T52 Casualty evaluation</td>
<td>R52 Casualty flood damage evaluation for period P has been done</td>
</tr>
</tbody>
</table>

Table 11: The TRT of the Flood Control Domain (Preparation)
<table>
<thead>
<tr>
<th>TRANSACTION TYPE</th>
<th>RESULT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T53 Perform casualty analysis</td>
<td>R53 Casualty flood damage analysis CA has been performed</td>
</tr>
<tr>
<td>T54 Economic damage evaluation</td>
<td>R54 Economic flood damage evaluation for period P has been done</td>
</tr>
<tr>
<td>T55 Perform economic damage analysis</td>
<td>R55 Economic flood damage analysis EDA has been performed</td>
</tr>
<tr>
<td>T56 Prepare evacuation implementation</td>
<td>R56 Preparation for evacuation implementation for period P has been done</td>
</tr>
<tr>
<td>T57 Develop evacuation plan</td>
<td>R57 Plan for evacuation E has been developed</td>
</tr>
<tr>
<td>T58 Prepare evacuation resource</td>
<td>R58 Resource for evacuation E has been prepared</td>
</tr>
<tr>
<td>T59 Check evacuation</td>
<td>R59 Evacuation check for period P has been done</td>
</tr>
<tr>
<td>T60 Decide evacuation</td>
<td>R60 Evacuation E has been decided</td>
</tr>
<tr>
<td>T61 Complete evacuation</td>
<td>R61 Evacuation E has been completed</td>
</tr>
<tr>
<td>T62 Mobilize evacuation resource</td>
<td>R62 Resource for evacuation E has been mobilized</td>
</tr>
<tr>
<td>T63 Implement evacuation</td>
<td>R63 Evacuation E has been implemented</td>
</tr>
<tr>
<td>T64 Take shelter-care measure</td>
<td>R65 Shelter-care measure SC has been taken</td>
</tr>
<tr>
<td>T65 Shelter set up</td>
<td>R64 Shelter S has been set up</td>
</tr>
<tr>
<td>T66 Mobilize shelter-care resource</td>
<td>R66 Resource for shelter-care SC measure has been mobilized</td>
</tr>
<tr>
<td>T67 Implement shelter-care measure</td>
<td>R67 Shelter-care SC measure has been implemented</td>
</tr>
<tr>
<td>T68 Evacuation victim registration</td>
<td>R68 Evacuation victim registration ER has been done</td>
</tr>
<tr>
<td>T69 Cordon off evacuated area</td>
<td>R69 Cordon off CO evacuated area has been done</td>
</tr>
<tr>
<td>T70 Cordon off disaster arrangement</td>
<td>R70 Arrangement for cordon off CO has been made</td>
</tr>
<tr>
<td>T71 Mobilize cordon off resource</td>
<td>R71 Resource for cordon off CO has been mobilized</td>
</tr>
<tr>
<td>T72 Install cordon off equipment</td>
<td>R72 Installation of cordon off CO equipment has been done</td>
</tr>
<tr>
<td>T73 Monitor traffic</td>
<td>R73 Traffic monitoring for period P has been done</td>
</tr>
<tr>
<td>T74 Implement traffic control measure</td>
<td>R74 Traffic control measure TM has been implemented</td>
</tr>
<tr>
<td>T75 Recover failed flood defense operation</td>
<td>R75 Recovery of failed flood defense operation for period P has been done</td>
</tr>
<tr>
<td>T76 Develop flood defense repair plan</td>
<td>R76 Plan for flood defense repair RP has been developed</td>
</tr>
<tr>
<td>T77 Approve flood defense repair plan</td>
<td>R77 Plan for flood defense repair plan RP has been approved</td>
</tr>
<tr>
<td>T78 Implement flood defense repair</td>
<td>R78 Flood defense repair RP has been implemented</td>
</tr>
</tbody>
</table>

**Table 12: The TRT of the Flood Control Domain (Response)**
<table>
<thead>
<tr>
<th>Transaction</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T79 Damage claim organizing</td>
<td>R79 Damage claim DC has been organized</td>
</tr>
<tr>
<td>T80 Damage claim registration</td>
<td>R80 Registration for damage claim DC has been done</td>
</tr>
<tr>
<td>T81 Damage claim payment</td>
<td>R81 Payment for damage claim DC has been made</td>
</tr>
<tr>
<td>T82 Check return possibility</td>
<td>R82 Return possibility check for period P has been done</td>
</tr>
<tr>
<td>T83 Conduct return analysis</td>
<td>R83 Analysis for return R has been conducted</td>
</tr>
<tr>
<td>T84 Advise return</td>
<td>R84 Advise for return R has been provided</td>
</tr>
<tr>
<td>T85 Decide return</td>
<td>R85 Decision for return R has been made</td>
</tr>
<tr>
<td>T86 Complete return</td>
<td>R86 Return R has been completed</td>
</tr>
<tr>
<td>T87 Mobilize return resource</td>
<td>R87 Resource for return R has been mobilized</td>
</tr>
<tr>
<td>T88 Implement return</td>
<td>R88 Return R has been implemented</td>
</tr>
<tr>
<td>T89 Check flood crisis evaluation</td>
<td>R89 Flood crisis evaluation for period P has been checked</td>
</tr>
<tr>
<td>T90 Evaluate flood crisis</td>
<td>R90 Flood crisis evaluation EV has been undertaken</td>
</tr>
</tbody>
</table>

Table 13: The TRT of the Flood Control Domain (Recovery)

### 6.3 The Construction Model

After identifying the transactions in the Flood Control Domain, the next step is to show how the domain is constructed. The construction of the Flood Control Domain will be shown using the Construction Model. The Construction Model (CM) specifies transactions types and the associated actor roles, as well as information links between actor roles and information banks (a collective name for coordination banks and production banks). In short, the CM specifies the construction of the organization.

Two models make up the Construction model (CM): the Interaction model (IAM) and Interstriction Model (ISM). Instead of discussing the two models, this chapter will discuss only the Interstriction model (ISM) since it is an extension of the Interaction Model. The Interstriction model (ISM) will be expressed using the Organization Construction Diagram (OCD). In the Organization Construction Diagrams, one can visualize the initiator(s) and an executor for each of the identified transactions as well as the information links between the actor roles and the information banks.

Figure 16 presents the symbols that will be used in the Organization Construction Diagrams (OCDs) of the Flood Control Domain. The Construction Model for the Flood Control Domain will be developed using the five safety chain links: pro-action, prevention, preparation, response and recovery.
An explanation for the symbols above is provided below:

Actor roles are represented by a box. The actor roles are connected to the transaction symbol by means of a straight line. The producer/executor has, in addition, a small black box on the junction of this line and the box shape. All environmental components are colored gray and their codes start with a C for “composite.” For instance, in terms of actors, there can be an internal actor role named “elementary actor role” and an external actor role called “composite actor role.”

The transaction symbol is represented as a combination of production bank (the diamond) and the coordination bank (disk). A coordination bank contains all coordination facts created; they allow one to monitor the progress of all transaction instances. A production bank contains all created production facts. A dashed line is drawn between an actor role and an information bank to indicate that an actor role has access to the content of these information banks.

### 6.3.1 The ISM of the Flood Control Domain for the Pro-action Link

Based on the Performa Analysis regarding the pro-action link in Section 6.1.1 and the corresponding identified transactions presented in the Transaction Result Table 9, the Organization Construction Diagram (OCD) of the Flood Control Domain regarding the pro-action link is exhibited in Figure 17.
The following explanation applies to Figure 17. The names of actor roles are not a formal part of a Construction Model; however, using appropriate names may enhance readability of a diagram considerably. The readability is also enhanced by mentioning the transaction names next to the transaction symbols (Dietz 2006). An actor role A01 represents an authority whose role is to check the flood analysis conducted in a certain period of time. A01 therefore initiates and executes a transaction T01. A01 is a self-activating actor role. Self-activation means that operational cycle of the actor role is periodic, although the period does not to be fixed. According to the Explanatory Case, T01 has a fixed period: it is performed every six years. Every time a transaction T01 is initiated, transactions T02 and T03 have to be performed. That means transactions T01, T02 and T03 constitute a result structure, such that the result of a T01 is the end result, and the results of a T02 and a T03 are the components of this end result. Normally, the executor of a transaction type gets the same number of a transaction type. Therefore, the executor of T01 is an actor role A01, the executor of T02 is an actor role A02 and the executor of T03 is an actor role A03.

An information link from external production banks CPB01, CPB02 and CPB03 are drawn to an actor role A02. This means that actor role A02 needs that information. Similarly, an actor
role A03 needs land use data and spatial policy data, deduced from CPB04 and CPB05, respectively.

Next, I will explain the transactions T04 through T10. An actor role A04 that initiates and executes a transaction T04 is a self-activating actor role. However, there is no fixed period in which a transaction T04 is initiated. Every time a transaction T04 is initiated, transactions T05, T06, T09 and T10 have to be performed. That means for the completion of a transaction T04, transactions T05, T06, T09 and T10 have to be completed first. Similarly, in order to complete a transaction T06, transactions T07 and T08 have to be completed first. An actor role A05 needs to know about the flood analysis result, the produced spatial plan and the water assessment test (WAT) checklist, deduced from PB01, PB02 and CPB06, respectively. The water assessment test checklist is also needed by an actor role A07. Next, an actor role A09 needs to know about the land legislation (CPB07).

### 6.3.2 The ISM of the Flood Control Domain for the Prevention Link

The Organization Construction Diagram (OCD) of the Flood Control Domain regarding the prevention link is exhibited in Figure 18. This OCD is built from the Performa Analysis conducted in section 6.1.2 and the identified transactions presented in Transaction Result Table 10, both regarding the prevention link.
The above diagram will be examined here. Clearly, an actor role A11 that initiates and executes a transaction T11 is a self-activating actor role. A transaction T11 is initiated after every 5 years as mentioned in the Explanatory Case. Together, transactions T11, T12, T13 and T14 constitute a result structure. Every time a transaction T11 is initiated, transactions T12, T13 and T14 have to be performed. That means for the completion of a transaction T11, transactions T12, T13 and T14 have to be completed first. An actor role A13 needs that data that has been gathered during an assessment and safety assessment checklist, deduced from CPB08 and CPB09, respectively.

Next, I will explain the transactions T15 through T18. A self-activating actor role A15 initiates and executes a transaction T15. According to the Explanatory Case, the maintenance activity can be performed in a fixed period or in a variable period. Here, a variable maintenance is selected depending on the result of safety assessment (i.e. after T13). Every time a transaction T15 is initiated, transactions T16, T17 and T18 have to be performed. These transactions constitute a result structure, such that the result of a T15 is the end result, and the results of a T16, a T17 and a T18 are the components of this end result. The result of the safety assessment (PB13) can indicate whether the condition of a flood defense is threatening or not. Such information is needed by an actor role A15. An actor role A18 needs to know about the established flood defense standard (PB12).

Finally, the explanations for the transactions T19 through T23 are provided as follows. An actor role A19 that initiates and executes a transaction T19 is a self-activating actor role. That means a transaction T19 can be initiated periodically. The period in which a transaction T19 is initiated is not fixed. However, a T19 can be initiated after the national report about the safety assessment of flood defenses has been provided (i.e. after transactions T11 through T14 have complemented). And, every time a transaction T19 is initiated, transactions T20, T21, T22 and T23 have to be performed. That means for the completion of a transaction T19, transactions T20, T21, T22 and T23 have to be completed first. An actor role A19 needs to know about the results of PB11, which is the checking of the safety of the primary flood defenses. An actor role A22 needs to know about the established flood defense standard (PB12).

### 6.3.3 The ISM of the Flood Control Domain for the Preparation Link

The Organization Construction Diagram (OCD) of Flood Control Domain regarding the preparation link is shown in Figure 19. This OCD is constructed based on the Performa Analysis in Section 6.1.3 and the identified transactions presented in the Transaction Result Table 11, both regarding the preparation link.
Looking at the above diagram, it can be seen that an actor role A24 initiates and executes a transaction T24. A transaction T24 is initiated periodically. However, there is no fixed period in which a transaction T24 is initiated. An actor role A24 also initiates transactions T25 and T26. Transactions T24, T25 and T26 constitute a result structure, such that the result of a T24 is the end result and the results of a T25 and a T26 are the components of this end result. A flood scenario is needed by an actor role A25. An actor role A24 needs the evaluation report after each flood crisis training (PB30) and the evaluation report of a real flood crisis (PB90) after the occurrence of a flooding event.

Next, take a look at the transactions T27 through T30. A self-activating actor role A27 initiates and executes a transaction T27. A transaction T27 is executed periodically. The initiator of a transaction T27 is also the initiator of transactions T28, T29 and T30. That means transactions T27, T28, T29 and T30 constitute a result structure, and for the completion of a transaction T27, transactions T28, T29 and T30 have to be completed first.
The actor roles A27, A28, A29 and A30 need to know about the developed flood response plan.

6. 3. 4  The ISM of the Flood Control Domain for the Response Link

Different from other links, the response link is rather complex. In order to reduce this complexity, four Organization Construction Diagrams (OCDs) will be presented and discussed in this link. These Organization Construction Diagrams will cover the following areas:

1. Flood prediction and high-water management measures: operations focused on predicting a flood threat including weather forecasting and flood forecasting, as well as high-water management measures (e.g. pumping out water, flooding retention areas).

2. Flood defense management measures and operational resources preparations: operations focused on managing flood defenses through monitoring their execution, reinforcing or repairing (anticipated) weak spots in the water defenses, as well as managing and preparing operational resources to be used for flood fighting.

3. Flood inundation analysis and damage analysis: operations focus on analyzing of possible flooded areas, flood extent and flood time, and damage analysis in terms of casualties and economic damage.

4. Evacuation: operations focused on the preparations for and implementation of the removal of the inhabitants from the expected flood area, cordonning (securing) evacuated area and providing them with shelter and care in other areas.

The Perfoma Analysis conducted in section 6.1.4 regarding the response link and the Transaction Result Table 12 will be used in order to construct the Organization Construction Diagrams (OCDs) for the response link.

The first Organization Construction Diagram (OCD) of the Flood Control Domain regarding the response link is exhibited in Figure 20.
The explanations for the diagram above are provided as follows. A self-activating actor role A31 initiates a transaction T31. A31 represents an actor role responsible for monitoring the weather forecast to ensure that the weather data is collected and forecast is produced on time. A transaction T31 is initiated every hour, and a weather forecast can have a lead time of up to 10 days. An actor role A31 is also the initiator of a transaction T32. Together, T31 and T32 constitute a result structure. Therefore, for the completion of T31, a T32 has to be completed first. An actor role A32 needs weather data (CPB10).

Then, the transactions T33 and T34 can be explained as follows. An actor role A33 that initiates and executes a transaction T33 is a self-activating actor role. A31 represents an actor role responsible for monitoring the flood forecast to ensure that the water level data is collected and the forecast produced on time. A transaction T33 is initiated at least twice a day when a threat of flooding is foreseen. An actor role A33 is also the initiator of a transaction T34. Together, T33 and T34 constitute a result structure. Therefore, for the
completion of T33, a T34 has to be completed first. An actor role A34 needs both weather forecasting data (PB32) and water level measurements (CPB11).

Next, I will explain the transactions T35 through T39. At a certain time, an actor role A35 initiates and executes a transaction T35. Transactions T35, T36, T37, T38 and T39 constitute a result structure, such that the result of a T35 is the end result, and the results of a T36, T37, T38 and a T39 are the components of this end result. Flood forecast data and water level measurement data are needed by actor roles A35, A36, A37 and A38. An actor role A35 also needs river observation data.

The second Organization Construction Diagram of the Flood Control Domain regarding the response link is exhibited in Figure 21.
Figure 21 can be explained as follows. An actor role A40 initiates and executes a transaction T40. Transactions T40, T41 and T42 constitute a result structure. That means for the completion of a transaction T40, transactions T41 and T42 have to be completed first. Similarly, in order to complete a transaction T42, transactions T43 and T44 have to be completed first. An actor role A41 needs data about the type of damage that has occurred to a flood defense (CPB13), the location (CPB14) and the time (CPB15) that the damage has occurred. A resource list data (CPB16) is needed by an actor role A43.

Next, the explanations for the transactions T45 through T48 are provided as follows. A self-activating actor role A45 initiates and executes a transaction T45. A transaction T45 is initiated periodically. Transactions T45, T46, T47 and T48 constitute a result structure, such that the result of a T45 is the end result, and the results of a T46, T47 and a T48 are the components of this end result. A resource list data (CPB16) is needed by an actor role A46.

The third OCD of the Flood Control Domain regarding the response link is exhibited in Figure 22.
The following explanations hold for Figure 22. A self-activating actor role A49 initiates a transaction T49. A transaction T49 is performed periodically once a flood threat is predicted in order to determine which areas will be flooded and the time of flooding. Transactions T49, T50 and T51 constitute a result structure, such that the result of a T49 is the end result and the results of a T50 and a T51 are the components of this end result. Actor role A50 needs a combination of data which includes the weather forecasting data (PB32), flood forecasting data (PB34), flood defense inspection data (PB41), elevation data (CPB02) and the water level measurement data (CPB11).

Now, I will explain transactions T52 and T53. A self-activating actor role A52 initiates and executes a transaction T52. A T52 can be initiated early during an imminent flood and before an evacuation process has been performed in order to predict the consequence of flooding in terms of causalities. A T52 can also be initiated after an evacuation process has been conducted and even later after the actual flood has occurred in order to determine the real consequence of flooding in terms of causalities. An actor role A52, therefore, is also the initiator of a transaction T53. For a completion of a T52, a T53 has to be completed first. An actor role A53 needs to know about the population data (CPB17), the possible inundated area (PB50) and the data about the number of people that has been evacuated (PB68), if the evacuation occurs.

Next, the explanations for the transactions T54 and T55 are provided here. A self-activating actor role A54 initiates and executes a transaction T54. As for a transaction T52, a transaction T54 can be initiated early during an imminent flood in order to predict economic damage that will be caused by a flooding event. A T54 is also initiated after an actual flood has occurred in order to determine the economic damage caused by a flooding event. For the completion of a T54, a T55 has to be completed first. An actor role A55 needs to know about the possible inundation area (PB50) and the land use data (CPB04).

The fourth OCD of Flood Control Domain regarding the response link is exhibited in Figure 23.
Figure 23: OOD of the Flood Control Domain (Response-4)
Figure 23 can be explained as follows. At a certain time, an actor role A56 initiates a transaction T56. Transactions T56, T57 and T58 constitute a result structure. They are all initiated by an actor role A56. Therefore, for the completion of a transaction T56, transactions T57 and T58 are completed first. Actor role A56 needs to know about the forecasted water level deduced from PB34, the condition of flood defenses (PB41) and probability of flooding in an area (PB50). An actor role A57 needs to know about the developed flood disaster plan (PB25) which is used as a guideline in making a specific evacuation plan. In order to plan for an evacuation route and to determine the required evacuation time, an actor role A57 will also need to data about the road network (CPB18), the road capacity (CPB19) and the exit capacity (CPB20). An actor role A58 needs to know which resources can be allocated for evacuation purpose, deduced from CPB16.

Now, looking at the transactions T59 through T72, the following explanations are provided. At certain times, an actor role A59 initiates and executes a transaction T59. An actor role A59 also initiates transactions T60 and T61. Transactions T59, T60 and T61 constitute a result structure, such that for a transaction T59 to be completed, transactions T60 and a T61 have to be completed first. An actor role A61 is also an initiator of transactions T62, T63, T64, T68 and T69. Therefore, for the completion of a T61, transactions T62, T63, T64, T68 and T69 have to be completed first. Similarly, for the completion of a T64, transactions T65, T66 and T67 have to be completed first. The same thing holds for transactions T69 through T72. That is, for the completion of a T69, transactions T70, T71 and T72 have to be completed first. An actor role A60 needs to know about the available flood time (i.e. the time from the moment of the warning to the anticipated moment of flooding) deduced from PB50, the required time (i.e. the time required to evacuate all inhabitants from the disaster area) deduced from PB57 and advice from a flood expert (PB51). An actor role A62 needs to know about the resources that have been prepared for evacuation purposes (PB58) and data about the evacuation plan (PB57). Evacuation plan data (PB57) is also needed by an actor role A63. An actor role A65 needs to know about the location of shelter centers (CPB21), the size of the shelter centre (CPB22) and the available facilities in the shelter centers such as toilets (CPB23). An actor role A66 needs to know which resources are allocated for shelter-care measures, deduced from CPB16. The personal data (CPB24) are needed by actor role A68. An actor role A70 needs to know about the location of an area that need to be cordoned off (CPB25) and the resources that can be used for cordon off evacuated area (CPB16). The resource list for cordon-off activity (CPB16) is also needed by actor role A71.

Next, the explanations for the transactions T73 and T74 can be provided as follows. A self-activating actor role A73 initiates and executes a transaction T73. An actor role A73 also initiates a transaction T74. Therefore, for the completion of a transaction T73, a transaction T74 has to be completed first. The traffic data and data about the ongoing evacuation activity are needed by both actor roles A73 and A74.

6.3.5 The ISM of the Flood Control Domain for the Recovery Link

The Organization Construction Diagram (OCD) of the Flood Control Domain regarding the recovery link is exhibited in Figure 24. This Organization Construction Diagram (OCD) is built based on the Performa Analysis conducted in section 6.1.5 regarding the recovery link and the identified transactions presented in Transaction Result Table 13.
Figure 24: OCD of the Flood Control Domain (Response-4)
The explanations for Figure 24 are provided as follows. At a certain time, an actor role A75 initiates and executes a transaction T75. Transactions T75, T76, T77 and T78 constitute a result structure, such that the result of a T75 is the end result, and the results of a T76, a T77 and a T78 are the components of this end result. Actor role A75 needs to know about the failed flood defenses such as breached dikes, deduced from PB41.

Then, the transactions T79 through T81 can be explained as follows. A transaction T79 can be initiated when the evacuees are in shelter areas. While in shelter areas, the evacuees register for damage claims (T81), and their details are verified before the payment is done (T82). Therefore, transactions T79, T80 and T81 constitute a result structure, such for the result of a T79 is the end result, and the results of a T80 and a T81 are the components of this end result.

Next, I will provide the explanations for the transactions T82 through T88. At certain times, an actor role A83 initiates and executes a transaction T82. Transactions T82, T83, T84, T85 and T86 constitute a result structure, such that for a transaction T82 to be completed, transactions T83, T84, T85 and a T86 have to be completed first. Similarly, for the completion of a T86, transactions T87 and T88 have to be completed first. Actor role A82 needs data about flood forecasting (PB34), the condition of flood defenses (PB41) and weather forecasting (PB32) and survey data about the safety of an area to be returned to (CPB28). An actor role A87 needs data about the list of resources that can be used to return people from their evacuated areas.

Finally, I will explain the transactions T89 and T90. At certain times, an actor role A89 decides to initiate and execute a transaction T89. An actor role A89 also initiates a transaction T90, and for the transaction T89 to be completed, a transaction T90 has to be completed first. Data about situation reports (CPB29), which were exchanged among flood crisis organizations during the flood crisis, are needed by an actor role A90.
6.4 Practical Relevance of the Construction Model

After presenting the Construction Model of the Flood Control Domain, it’s time to assess the relevant application of such a model to an organization. Here are examples of useful applications of the Construction Model according to (Dietz 2006).

First, the Construction Model is a background for charting the existing information systems and other ICT applications in a domain. It can be used as the first step to study the overlap of these information systems, and finding the blank spots (activities that are apparently not supported by information systems). This may give rise to necessary studies of the current processes in more detail, using, in addition, the Process Model of the domain.

Second, the Construction Model shows the relationship between the (fulfiller of) an actor role and the needed information. There are two ways of realizing an information link. One is that the actor seeks for the information needed or by someone else (who has been appointed to do so). The ontological model suggests a preference for the first option. So, it is essentially the responsibility of the one who needs information to get it; he or she must become active. Fortunately, modern ICTs, in particular, the Internet, reinforce this point of view. By making access to information sources almost effortless, they facilitate the operating of information systems according to this insight. Therefore, the Construction Model can be used to show the information systems that the actors use to retrieve the information they need.

Third, the issue of data ownership is fully transparent by the Construction Model. Every fact is the result of a transaction; there are two actors involved, the initiator and the executor. One may choose either of them as the owner of the fact. The executor is the one who has brought about the fact, and, thus, the one who can be held responsible for having executed the truncation in a correct way. The initiator on the other hand has requested for the production of the fact, and thus, is the first candidate for legal owner of the fact, particularly if he or she has paid for it.

Fourth, the Construction Model shows the ontological units of competence, authorization and responsibility. This may offer fresh, new insight to human resource professionals, who have always struggled with finding the right chunks for the identification and classification of organizational functions. A comparison of the Construction Model with the current assignment of organizational functions to actor roles may provide the first ideas for improving it. This study may be pursued in more detail from the process model.
7. The Interrelationship between the essential operations

The previous chapter provided the overall picture about the essential operations performed by organizations within the Flood Control Domain. These essential operations were presented in form of transactions which were specified in the Transaction Result Tables (TRT) and visualized in the Organization Construction Diagrams (OCDs). In this chapter I will address how these transactions are interrelated hence providing an answer to the second research question: “How are the essential operations in the Flood Control Domain interrelated?”

Aiming to answer the question above, this chapter will discuss and present the Process Model of the Flood Control Domain. The Process Model for the domain will be developed using the five safety chain links: pro-action, prevention, preparation, response and recovery. After, discussing the Process Model, its practical relevancy and applicability to an organization will also be discussed.

7.1 The Process Model

According to the ontological aspect DEMO models presented as a triangle in Figure 11, the Process Model (PM) is put just below the Construction Model (CM) because it is the first level of detailing of the Construction Model, namely, detailing the identified transaction types. The Process Model contains for every transaction pattern in the CM, the specific transaction pattern of the transaction type. It also shows the logical sequence of steps for which a transaction is performed. The latter is also the main emphasis of this chapter. The Process Model (PM) of the Flood Control Domain will be constructed and expressed using a Process Structure Diagram (PSD). The Process Structure Diagram (PSD) can be regarded as a conceptual model for the business processes conducted within an organization or domain.

In the Process Structure Diagram (PSD), the transaction steps and the interrelationship between transaction types is shown using causal and conditional (waiting) links, symbolized in Figure 25. Because of the causal and conditional relations between transactions, the business process can be identified. The Process Structure Diagram also shows the actors who are responsible and authorized for each transaction. Moreover, the Process Structure Diagram shows the number of transactions that are initiated and indicated by k..n, where k stands for the minimum number and n for the maximum number. The default value is 1..1; this value is normally not indicated in the Process Structure Diagram.

Apart from the explanations provided in the paragraphs above, other symbols that will be used in the PSDs of the business processes of the Flood Control Domain are shown in Figure 25. It should also be remembered that the exhibited PSDs hereafter will only show the basic transaction pattern that is not concerned with all the disagreements between actor roles, for instance declining a certain request or rejecting a certain statement. Therefore the PSD will only show the five basic transaction steps: request, promise, execute, state and accept.
Figure 25: Legend of the Process Structure Diagram (Dietz 2006)

7.1.1 The PM of the Flood Control Domain for the Pro-action Link

The Process Model (PM) of Flood Control Domain regarding the pro-action link is derived from the Organization Construction Diagram (OCD) in Figure 17 and from additional information that is contained in the Explanatory Case. Two business processes are derived in this link. The first business process is expressed using the Process Structure Diagram (PSD) in Figure 26. Here transaction T01 can be referred to as the root of the business process 1 of the Flood Control Domain for the pro-action link.
As one can see in the above figure, the standard steps in a transaction are connected to each other by causal links. For example there is a casual link from T01/rq to T01/pm. There is also a causal link to every request step. The transaction T01 is initiated by means of self-activation. Therefore, in the outcome of dealing with the C-result T01/rq, an actor role A01 performs two actions. First, A01 performs a new request (T01/rq), with the requested occurrence time of the P-result that is 6 years from now, according to the Explanatory Case. Second, A01 performs the promise (T01/pm). Similarly, in the outcome of dealing with the C-result T01/pm, three actions are taken: T02/rq, T03/rq and T01/ex. However, there is a conditional link from T02/ac to T03/rq. The meaning for this conditional link is that, dealing with C-result T03/rq has to wait until the C-result T02/ac has been done. Likewise, the completion of a transaction T03 is a wait condition for the T01/ex step. So, the flood analysis review, that is conducted every 6 years, is said to be completed when the spatial plans for that period are received. The minimal and maximal cardinality of casual links is 1, unless otherwise specified. Lastly, the responsibility areas encompass all acts that the indicated actor role is allowed to perform.

The second business process in the pro-action link is expressed in Figure 27. T04 is referred to as the root of the business process 2 of the Flood Control Domain for the pro-action link. A transaction T04 is initiated internally, by means of self-activation. As the result of dealing with the agendum T04/pm, an actor role A04 performs five acts: T05/rq, T06/rq, T09/rq, T10/rq and T04/ex. The diagram shows several wait conditions. For example there is a wait condition for T04/ex, which is the creation of the C-result T10/ac. The minimal and maximal cardinality for most of the casual links is 1. An exception is the casual link from T06/pm to T08/rq. The interpretation of the range 0..1 is that, the initiating of transaction T08 within
T06 is optional. According to the Explanatory Case, T08 is performed if water management priorities (collect, store, and discharge) cannot be realized. The same optionality holds for the conditional link from T08/ac to T06/ex.

Figure 27: PSD of business process 2 of the Flood Control Domain for the pro-action link
7.1.2 The PM of the Flood Control Domain for the Prevention Link

The Process Model (PM) of Flood Control Domain regarding the prevention link is derived from the Organization Construction Diagram (OCD) in Figure 18 and from additional information that is contained in the Explanatory Case. Three business processes are derived in this link. They can be referred to as: business process 1, business process 2 and business process 3, of the Flood Control Domain regarding the prevention link.

The PSD of business process 1 of the Flood Control Domain for the prevention link is exhibited in Figure 28. It concerns the safety assessment of the primary flood defenses that is conducted every 5 years. It starts with an actor role A11 dealing with an agendum T11/rq. As the result of dealing with the C-result T11/rq, an actor role A11 performs two actions. First, A11 performs a new request (T11/rq), with the requested occurrence time of the P-result that is 5 years from now, according to the Explanation Case. Second, A01 performs the promise (T01/pm). Similarly, as the result of dealing with the agendum T11/pm, A11 performs four acts: T12/rq, T13/rq, T14/rq and T11/ex. There are several wait conditions. For instance there is a wait condition for T13/rq, which is the creation of the C-result T12/ac. Similarly, the transaction T14 will be performed, until T13 is successfully completed. Likewise performing T01/ex has to wait until T14 is successfully completed. The minimal and maximal cardinality of all the casual links in this business process is 1.
The PSD of business process 2 of the Flood Control Domain for the Prevention Phase is exhibited in Figure 29. It concerns the maintenance the flood defenses. A transaction T15 can be referred to as the root of this business process. It starts with an actor role A15 dealing with an agendum T15/rq. As the result of dealing with the C-result T15/rq, an actor role A15 performs two actions: the new request (T11/rq) and the promise (T11/pm). Similarly, as the result of dealing with the agendum T15/pm, A15 performs four acts: T16/rq, T17/rq, T18/rq and T15/ex. There are several wait conditions. For instance there is a wait condition for T17/rq, which is the creation of the C-result T16/ac. Similarly, the transaction T18 will be performed, until T17 is successfully completed. Likewise, there is a wait condition for T15/ex, which is the creation of T18/ac. Therefore, the maintenance control for a certain time period is considered to be completed when the maintenance activity is completed. The minimal and maximal cardinality of all the casual links in this business process is 1.
The PSD of business process 3 of the Flood Control Domain for the prevention link is exhibited in Figure 30. It regards to the improvement of the flood defenses. A transaction T19 can be referred to as the root of this business process. It starts with an actor role A19 dealing with an agendum T19/rq. As the result of dealing with the C-result T19/rq, an actor role A15 performs two actions: the new request (T19/rq) and the promise (T19/pm). Similarly, as the result of dealing with the agendum T19/pm, A19 performs five acts: T20/rq, T21/rq, T22/rq, T23/rq and T19/ex. Every transaction here has to wait for another transaction to complete. That is the completion of T20 is a wait condition for the step T21/rq, the completion of T21 is a wait condition for the T22/ac, the completion for the T22 is a wait condition for the T23/ac and the completion of T23 is a wait condition for the step T19/ex. The minimal and maximal cardinality of all the casual links in this business process is 1.
7. 1.3 The PM of the Flood Control Domain for the Preparation Link

The Process Model (PM) of Flood Control Domain regarding the preparation link is derived from the Organization Construction Diagram (OCD) in Figure 19 and from additional information that is contained in the Explanatory Case. Two business processes are derived in this link. They can be referred to as: business process 1 and business process 2 of the Flood Control Domain regarding the preparation link.
The PSD of business process 1 of the Flood Control Domain for the preparation link is exhibited in Figure 31. It concerns the checking of a flood response plan to ensure that it is up-to-date. It starts with an actor role A24 dealing with an agendum T24/rq. As the result of dealing with the C-result T24/rq, an actor role A24 performs two actions. First, A24 performs a new request (T24/rq), with the requested occurrence time of the P-result that is next period from now, according to the Explanatory Case there is no fixed period for this. Second, A01 performs the promise (T24/pm). Similarly, as the result of dealing with the agendum T24/pm, A11 performs three acts: T25/rq, T26/rq and T24/ex. However initiating transactions T25 and T26 within T24 is optional since once the flood response plan is checked, it may be decided that, there is no need to establish a new plan. And, in case a new flood response plan is developed, the plan has to be approved for usability. Therefore dealing with the C-result T26/rq has to wait until C-result T25/ac has been created, if there is a corresponding T25. Likewise, dealing with T24/ex has to wait until C-result T26/ac has been created, if there is a corresponding T26. So, the checking of the regional disaster plan for a certain period is considered to be completed as soon as the approval of the flood response plan is made.

Figure 31: PSD of business process 1 of the Flood Control Domain for the preparation link

The PSD of business process 2 of the Flood Control Domain for the preparation link is exhibited in Figure 32. It concerns the training of individuals and organizations within the Flood Control Domain. It starts with an actor role A27 dealing with an agendum T27/rq. As the result of dealing with the C-result T27/rq, an actor role A27 performs two actions. First, A27 performs a new request (T27/rq), with the requested occurrence time of the P-result
that is next period from now, according to the Explanatory Case such trainings are performed periodically. Second, A27 performs the promise (T27/pm). Similarly, as the result of dealing with the agendum T27/pm, A27 performs four acts: T28/rq, T29/rq, T30/rq and T27/ex. There are several wait conditions, this means that one transaction has to wait for the completion of another transaction. For instance, a wait condition from T28/ac to T29/rq means that a transaction T29 has to wait for the completion of a transaction T28. Likewise a transaction T30 has to wait for the completion of a transaction T29. And finally the completion of a transaction T27 has to wait for the completion of a transaction T30.

Figure 32: PSD of business process 2 of the Flood Control Domain for the preparation link
### 7.1.4 The PM of the Flood Control Domain for the Response Link

The Process Model (PM) of Flood Control Domain regarding the prevention link is derived from the Organization Construction Diagrams (OCDs) in Figure 20 through Figure 23 and from additional information that is contained in the Explanatory Case. More business processes are derived in this link as compared to other links. This can be explained by the existence of more Organization Construction Diagrams (OCDs) in the response link as shown in section 6.3.4. In total eleven business processes are derived in the response link. For easy understanding, Table 14 shows the relationship between these business processes and the Organization Construction Diagrams (OCDs) in section 6.3.4 from which they are derived from.

<table>
<thead>
<tr>
<th>Business process # and Figure #</th>
<th>Organization Construction Diagram (OCD) Figure # in section 6.3.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business process #</td>
<td>Figure #</td>
</tr>
<tr>
<td>1</td>
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</tr>
<tr>
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<td>10</td>
<td>42</td>
</tr>
<tr>
<td>11</td>
<td>43</td>
</tr>
</tbody>
</table>

**Table 14: Business processes and their derived OCDs**

The first PSD for the response link is provided in Figure 33. It concerns the weather forecasting which is done normally every hour. It starts with an actor role A31 dealing with an agendum T31/rq. As the result of dealing with the C-result T31/rq, an actor role A31 performs two actions. First, A31 performs a new request (T31/rq), with the requested occurrence time of the P-result that is an hour from now. Second, A31 performs the promise (T31/pm). And, as the result of dealing with the agendum T31/pm, A31 performs T32/rq and T31/ex. There is a wait condition for T31/ex, which is the creation of the C-result T31/ac. Therefore, the checking of the checking of weather forecast will be completed when the weather forecast is produced.
The second PSD for the response link is provided in Figure 34. It regards the flood forecasting which is done at least twice a day. It starts with an actor role A33 dealing with an agendum T33/rq. As the result of dealing with the C-result T33/rq, an actor role A33 performs two actions. First, A33 performs a new request (T33/rq), with the requested occurrence time of the P-result that may be 12 hours from now. Second, A33 performs the promise (T33/pm). In dealing with the agendum T33/pm, A33 performs T34/rq and T33/ex. There is a wait condition for T33/ex, which is the creation of the C-result T34/ac. So, the checking of the checking of flood forecast will be completed when the flood forecast is produced.
The third PSD for the response link is provided in Figure 35. It concerns with operational high water management (i.e. controlling high water). A transaction T35 can be referred to as the root of the business process 3. Every transaction here has to wait for another transaction to complete. That is the completion of T36 is a wait condition for the step T37/rq, the completion of T37 is a wait condition for the T38/rq, the completion of T38 is a wait condition for the T39/rq, and the completion of T39 is a wait condition for the T35/ex. Therefore, the control of a high water for a certain period of time is said to be completed when high water management measure has been implemented. The cardinality range of T36 is 0..n meaning that at most n transactions T36 are initiated. This number is equal to number of water management measures that will be evaluated. Consequently, there is a cardinality range of 0..k for transaction type T39, meaning that at most k transactions are initiated. This number is equal to the water management measures that will be implemented. The logical relationship between k and n is that, k≤n which means that the number of water management measures that will be evaluated less or equal to the number of water management measures that will be implemented.
The fourth PSD for the response link is provided in Figure 36. It concerns the managing and monitoring of flood defenses to ensure proper operation continuity disregarding the flood threat. A transaction T40 can be referred to as the root of the business process 4. T40 is done continuously. In dealing with T40/pm, A40 performs three acts: T41/rq, T42/rq and T40/ex. However, initiating transactions T42 within T40 is optional since there may not be a need to take temporary reinforcement measure, if the flood defense seems to be according to the required standard. The same optionality holds for the conditional link from T42/ac to
T40/ex. This link means, performing T40/ex has to wait until the C-result T42/ac has been created, if there is a corresponding T42. The same can be interpreted with other conditional links that occurs in this business process.

![Figure 36: PSD of business process 4 of the Flood Control Domain for the response link](image)

The fifth PSD for the response link is provided in Figure 37. It concerns the checking of operational resources (personnel and equipment) that are used for flood fighting activity. It starts with an actor role A45 dealing with an agendum T45/rq. As the result of dealing with the C-result T45/rq, an actor role A45 performs two actions. First, A45 performs a new request (T45/rq), with the requested occurrence time of the P-result that is next period from now; here the period is not specifically mentioned. Second, A45 performs the promise (T45/pm). As the result of dealing with the agendum T45/pm, A45 performs four acts: T46/rq, T47/rq, T48/rq and T45/ex. However, initiating transactions T47 and T48 within T45 is optional in a certain period when T45 is performed. For instance, transactions T47 and T48 may be initiated when the scale of flood crisis becomes bigger hence requiring more resources to fight for flooding. The same optionality holds for the conditional link from T47/ac to T48/rq and from T48/ac to T45/ex. The former link means, performing T48/rq has
to wait until the C-result T47/ac has been created, if there is a corresponding T47. The latter link means, performing T45/ex has to wait until the C-result T48/ac has been created, if there is a corresponding T48. So, we can say that the checking of operational resources at a particular is completed when operational resource bottleneck measure has been taken.

Figure 37: PSD of business process 5 of the Flood Control Domain for the response link

The sixth PSD for the response link is provided in Figure 38. It concerns the checking of possible flooded areas and possible flood break time. A transaction T49 can be referred to as the root of the business process 6. T49 is performed periodically. In dealing with T49/pm, A49 performs three acts: T50/rq, T51/rq and T49/ex. There is a wait condition from T50/ac to T51/rq. This means, dealing with the C-result T51/rq has to wait until the C-result T50/ac has
been created. Likewise, the transaction T49/ex will be performed, until T51 is successfully completed. So, the checking of inundation probability is considered to be completed when an expert advice has been provided.

Figure 38: PSD of business process 6 of the Flood Control Domain for the response link

The seventh PSD for the response link is provided in Figure 39. It concerns the casualty flood damage evaluation. It starts with an actor role A52 dealing with an agendum T52/rq. As the result of dealing with the C-result T52/rq, an actor role A52 performs two actions. First, A52 performs a new request (T52/rq), with the requested occurrence time of the P-result that is next period from now; here the period is not explicit mentioned. Second, A52 performs the promise (T52/pm). And, as the result of dealing with the agendum T52/pm, A52 performs two acts: T53/rq and T52/ex. There is a wait condition for T52/ex, which is the creation of the C-result T53/ac. So, the evaluation of casualty flood damage is considered to be completed as soon as the result of casualty analysis has been received.
The eighth PSD for the response link is provided in Figure 40. It concerns the economic flood damage evaluation. It starts with an actor role A54 dealing with an agendum T54/rq. As the result of dealing with the C-result T54/rq, an actor role A54 performs two actions. First, A54 performs a new request (T54/rq), with the requested occurrence time of the P-result that is next period from now; here the period is not explicit mentioned. Second, A54 performs the promise (T54/pm). As the result of dealing with the agendum T54/pm, A54 performs two acts: T55/rq and T54/ex. There is a wait condition for T54/ex, which is the creation of the C-result T55/ac. Therefore, the evaluation of economic flood damage is considered to be completed as soon as the result of damage analysis has been received.
The ninth PSD for the response link is provided in Figure 41. It regards the preparation for evacuation implementation. It starts with an actor role A56 initiating a transaction T56. This transaction is initiated when a potential flood is foreseen. An actor role A56 performs T56/pm as one of the result of dealing with agendum T56/rq. In dealing with the agendum T56/pm, A56 performs three acts: T57/rq, T58/rq and T56/ex. There is a conditional link from for T57/ac to T58/rq. This means, evacuation resources are prepared when an evacuation plan is completed. Likewise, performing T56/ex has to wait until T58 is successfully completed. Therefore, the preparation for evacuation implementation is considered to be completed when the evacuation resources have been prepared.

![Figure 41: PSD of business process 9 of the Flood Control Domain for the response link](image)

The tenth PSD for the response link is provided in Figure 42. It is the most complex business process as compared to other business processes. It regards the checking to whether an evacuation of the population in the potential flooded area is needed. At a certain time, when a flood risk is predicted, an actor role A59 may decide to initiate and execute a transaction T59. In dealing with the agendum T59/pm, A59 performs three acts: T60/rq, T61/rq and T59/ex. However, initiating transactions T60 and T61 within T59 is optional. According to the Explanatory Case, T60 will be performed depending on the way the available time (the time from the moment of the warning to the anticipated moment of flooding) and the required time (the time required to evacuate all inhabitants from the disaster area) are interrelated.
The same optionality holds from \( T60/ac \) to \( T61/rq \) and from \( T61/ac \) to \( T59/ex \). This means that dealing with \( T61/rq \) has to wait until the C-result \( T60/ac \), if there is a corresponding \( T60 \). Likewise, dealing with \( T59/ex \) has to wait until the C-result \( T61/ac \) has been created, if there is a corresponding \( T61 \). So, the checking to whether an evacuation should be performed is considered to be finished as soon as the evacuation process is completed. Moreover, as the result of dealing with the agendum \( T61/pm \), \( A61 \) performs six acts: \( T62/rq, T63/rq, T64/rq, T68/rq, T69/rq \) and \( T61/ex \). The transactions \( T63, T64, T68 \) and \( T69 \) are initiated in parallel to each other, by an actor role \( A61 \), and the completion of these transactions marks the completion of \( T61 \). This explains the reason for several waiting conditions to \( T59/ex \) such as: from \( T63/ac \) to \( T61/ex \), from \( T64/ac \) to \( T61/ex \), from \( T68/ac \) to \( T61/ex \) and from \( T69/ac \) to \( T61/ex \). A casual link from \( T61/pm \) to \( T68/rq \) means that in dealing with \( T61/pm \) a number of transactions \( T68 \) are initiated; as the cardinality range indicates minimally none and maximally unspecified (*) number. This number can be equal to the number of people evacuated from the disaster area.
Figure 42: PSD of business process 10 of the Flood Control Domain for the response link
The eleventh PSD for the response link is provided in Figure 43. It is referred to as the PSD of business process 11 of the Flood Control Domain for the Response Phase. It regards traffic monitoring during evacuation implementation. It is initiated internally, by means of self-activation, once an evacuation process is implemented, by actor role A73. As the result of dealing with the agendum T73/pm, A73 performs two acts: T73/rq and T74/ex. There is a wait condition for T73/ex, which is the creation of the C-result T74/ac. Therefore, traffic monitoring at certain period of time is considered to be completed when traffic control measure has been taken.

![Diagram of PSD for response link](image)

Figure 43: PSD of business process 11 of the Flood Control Domain for the response link

7. 1.5 The PM of the Flood Control Domain for the Recovery Link

The Process Model (PM) of Flood Control Domain regarding the response link is derived from the Organization Construction Diagram (OCD) in Figure 24 and from additional information that is contained in the Explanatory Case. Four business processes are derived in this link. They will be referred to as: business process 1, business process 2, business process 3 and business process 4 of the Flood Control Domain regarding the recovery link.

The first PSD in this link is exhibited in Figure 44. It is referred to as the PSD of business process 1 of the Flood Control Domain for the recovery link. It concerns the recovery operation of failed flood defenses. A transaction T75 is referred to as the root of the business process 1. T75 is initiated when the flood defense failures are detected (e.g. breaching, sliding). In dealing with T75/pm, A75 performs three acts: T76/rq, T77/rq, T78/rq and T75/ex. There are several wait conditions. For instance there is a wait condition for T77/rq, which is the creation of the C-result T76/ac. Similarly, the transaction T78 will be performed, until T77 is successfully completed. Likewise, there is a wait condition for T75/ex, which is the creation of T78/ac. Therefore, the recovery of failed flood defenses for a certain time period is considered to be completed when the repair activity is completed. The minimal and maximal cardinality of all the causal links in this business process is 1.
The second PSD is exhibited in Figure 45. It is referred to as the PSD of business process 2 of the Flood Control Domain for the recovery link. It concerns the organizing of damage claims. We start by considering a transaction T79 as the root of a business process. The initiator and executor of such a transaction is an actor role A79. In the outcome of dealing with the C-result T79/pm, three actions are taken: T80/rq, T81/rq and T79/ex. The cardinality range of T80 is 0..n meaning that at most n transactions T80 are initiated. This number is equal to the number of people who have registered for damage claim. Consequently, there is a cardinality range of 0..k for transaction type T81, meaning that at most k transactions are initiated. This number equals to the number of people who have received damage claim. The logical relationship between k and n is that, k≤n which means that the number of people who receive damage claim may be less or equal to the number of people who have registered for damage claims. This can happen when the data provided by the person who registered for damage claim cannot be verified and when there is lack of eligibility that that person has the right to receive the claim. Therefore, there is a wait condition for T81/rq, which is the creating of the C-result T80/ac. Similarly, there is a wait condition for T79/ex, which is the creating of the C-result T81/ac. So, the damage claim organizing is considered to be completed as soon as all payments have been made.
The third PSD is exhibited in Figure 46. It is referred to as the PSD of business process 3 of the Flood Control Domain for the recovery link. It regards to the checking of return of the evacuated population. It is initiated internally, by means of self-activation, by actor role A82. It is started once the evacuation process has been completed and finishes when the return of the evacuated population is completed. In dealing with T82/pm, A82 performs five acts: T83/rq, T84/rq, T85/rq, T86/rq and T82/ex. There are several wait conditions. For instance, there is a wait condition for T84/rq, which is the creation of the C-result T83/ac. Similarly, there is a wait condition for T85/rq, which is the creation the C-result T84/ac. This means, the decision to return the evacuated population waits until a return advice has been provided. Likewise, there is a wait condition for T86/rq, which is the creation the C-result T85/ac. This means, the return will be completed once a return decision has been made. There is also a wait condition for T82/ex, which is the creation of the C-result T86/ac. This means that, the checking of return of the evacuated population is considered to be completed once evacuees have returned to their pre-disaster residences or, if needed, to alternative locations.
The fourth PSD in this phase is exhibited in Figure 47. It is referred to as the PSD of business process 4 of the Flood Control Domain for the recovery link. It concerns the checking of flood crisis evaluation. It is initiated internally, by means of self-activation, by actor role A89. And, as the result of dealing with the agenda T89/pm, A89 performs two acts: T90/rq and T89/ex. There is a wait condition for T89/ex, which is the creation of the C-result T90/ac. So, the checking of flood crisis evaluation is considered to be completed as soon as the flood crisis has been evaluated.
7.2 Practical Relevance of the Process Model

The most distinguishable feature of the Process Model (PM) is undoubtedly that it shows the deep structure of the business processes in an enterprise, the independent of their implementation. This unique property of the process Model paves a way to a number of interesting applications (Dietz 2006).

First, the Process Model facilitates discussions about the redesign, as well as the re-engineering of business processes. This appears to be a tremendous advantage for discussing business process optimization.

Second, the Process Model facilitate the mapping of a process structure diagram (PSD) to business s process modeling techniques such as an event-driven process chains (EPC) or a Petri Net or any other “flat” technique. This makes the PM also ideal starting point for the purpose of programming a workflow management system.

Third, the PM shows that a component transaction can be optional or can be made optional. For example, a water management organization may set a rule once the inspection of a flood defense has been implemented and a damage or weak spot has been realized, the temporary reinforcement measures must be executed. The PM facilitates these decisions considerably because it clearly shows that these side paths are either full-fledged transactions (in which original facts are created) or not.

Fourth, the Process Model (PM) is very well suited to forward the discussion about the assignment of organization functions to actor roles within an organization with competence, authorization and responsibility, as mentioned in section 6.4.

Fourth, the Process Model (PM) is very useful as the starting point for the requirement engineering regarding supporting information systems. This is mainly because the Process Models contains all the information one needs to make a sensible discussion. The model leaves no room for unnecessary requirements, while at the same time it guarantees that nothing will be forgotten.
8. The Relevant Information Objects in the Flood Control Domain

The previous two chapters showed the essential operations performed in the Flood Control Domain and how these operations are interrelated with each other. In order to perform the identified essential operations, the organizations within the domain need certain information objects. These information objects are addressed in this chapter and hence the chapter aims to provide an answer to the third research question: “What information objects are relevant for the operation of the organizations in the Flood Control Domain?”

Aiming to answer the question above, this chapter will discuss and present the State Model of the Flood Control Domain. As it has been done for other DEMO aspect models, the State Model for the Flood Control Domain will also be discussed and presented following the five safety chain links: pro-action, prevention, preparation, response and recovery.

8.1 The State Model

According to the ontological aspect DEMO models presented as a triangle in Figure 11, the State Model (SM) is put just below the Construction Model (CM), and therefore the same level as the Process Model (PM), because it may also be viewed as the detailing part of the Construction Model (CM), namely, the contents of a transaction. The State Model practically aims to show the information items that are relevant for operations of an organization. In the State Model (SM), one can see the object classes, the fact types, and the result types, as well as the existential laws that hold. A State Model (SM) is expressed using an Object Fact Diagram (OFD) and an Object Property List (OPL).

The Object Fact Diagram (OFD) shows the object classes, the result types and the existential laws. The OFD is fully based on the language WOSL and its legend is presented in Figure 48. The Object Property List (OPL) specifies the fact types, that are proper (mathematical) functions, and of which the range is a set of values. These fact types in the Object Property List (OPL) are called properties (of object classes) and their range is normally an ordered set of values, called a scale. Five types of scales were distinguished and explained in section 5.2.2 and can be recapped here as follows:

- Categorial (C): a scale that measures data by name only. A categorial scale can sometimes be referred to as a nominal scale.
- Ordinal (O): a scale that measures data by rank order only.
- Interval (I): a scale that measures data using equal intervals with a 0 arbitrarily placed.
- Ratio (R): similar to an interval scale, with a 0 measurement that signifies the point at which the characteristic being measured vanishes.
- Absolute (A): fixed measurement scale

This chapter will present the relevant information objects in the Flood Control Domain and their properties using the Object Fact Diagram (OFD) and the Object Property List (OPL) respectively, following the five safety chain links.
8.1.1 The SM of the Flood Control Domain for the Pro-action Link

In this section I will develop the state model of the Flood Control Domain for the pro-action link. The state model will be presented using the Object Fact Diagram (OFD) as exhibited in Figure 49 and an Object Property List (OPL) as shown in Table 15. The fact types that are pure properties, i.e mathematical functions mapping from object class to a scale, are listed in the Object Property List in Table 15.

<table>
<thead>
<tr>
<th>Property type</th>
<th>Object Class</th>
<th>Range</th>
<th>Scale</th>
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</thead>
<tbody>
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<td>SQUARE METER</td>
<td>R</td>
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Table 15: OPL of the Flood Control Domain (Pro-action)

<table>
<thead>
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<th>Table 15: OPL of the Flood Control Domain (Pro-action)</th>
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</thead>
<tbody>
<tr>
<td><img src="#" alt="Table" /></td>
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</tbody>
</table>

Figure 49 shows three core categories, FLOOD ANALYSIS, SPATIAL PLAN and LAND USE PLAN, of which instances are created. There are two external objects (marked gray), AREA and PERIOD. The relationships between these objects are shown in figure 49 using the pertaining existential laws.
Flood analysis FA has been done

Flood control spatial plan SP has been developed

Advise for water management aspect regarding land use change plan LP has been provided

Water management related aspect regarding land use change plan LP has been assessed

Water management compensation mitigation measure regarding land use change plan LP has been proposed

Review for land use change plan LP has been done

Land use change plan LP for has been implemented

Land use change plan LP has been developed

Land use change for period P has been determined

Figure 49: The OFD of the Flood Control Domain for the pro-action link
8.1.2 The SM of the Flood Control Domain for the Prevention Link

The state model of the Flood Control Domain for the prevention link is developed in this section. Figure 50 shows the object types and fact types, and the pertaining existential laws. Here three core categories are shown, SAFETY ASSESSMENT, IMPROVEMENT and MAINTENANCE. The two external objects; FLOOD DEFENSE and PERIOD are considered as given. The fact types are listed in the Object Property List in Table 16.

<table>
<thead>
<tr>
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<th>Object Class</th>
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<th>Scale</th>
</tr>
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<tr>
<td>assessed_section</td>
<td>SAFETY ASSESSMENT</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>assessment_method</td>
<td>SAFETY ASSESSMENT</td>
<td>METHOD TYPE</td>
<td>C</td>
</tr>
<tr>
<td>assessment_result _category</td>
<td>SAFETY ASSESSMENT</td>
<td>(MEETS, NO JUDGEMENT, DOES NOT MEET)</td>
<td>O</td>
</tr>
<tr>
<td>maintenance_start_date</td>
<td>MAINTENANCE</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>maintenance_end_date</td>
<td>MAINTENANCE</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td># maintenance_days (*)</td>
<td>MAINTENANCE</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>maintenance_type</td>
<td>MAINTENANCE</td>
<td>(FIXED, VARIABLE)</td>
<td>C</td>
</tr>
<tr>
<td>maintenance_cost</td>
<td>MAINTENANCE</td>
<td>EURO</td>
<td>A</td>
</tr>
<tr>
<td>design_level</td>
<td>FLOOD DEFENSE</td>
<td>HEIGHT ABOVE SEA LEVEL</td>
<td>R</td>
</tr>
<tr>
<td>crest_level</td>
<td>FLOOD DEFENSE</td>
<td>HEIGHT ABOVE SEA LEVEL</td>
<td>R</td>
</tr>
<tr>
<td>soil_type</td>
<td>FLOOD DEFENSE</td>
<td>SOIL TYPE</td>
<td>C</td>
</tr>
<tr>
<td>flood_defense_category</td>
<td>FLOOD DEFENSE</td>
<td>(PRIMARY, SECONDARY)</td>
<td>C</td>
</tr>
<tr>
<td>flood_defense_ construction_year</td>
<td>FLOOD DEFENSE</td>
<td>YEAR</td>
<td>I</td>
</tr>
<tr>
<td>flood_defense_age (*)</td>
<td>FLOOD DEFENSE</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>improvement_start_date</td>
<td>IMPROVEMENT</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>improvement_end_date</td>
<td>IMPROVEMENT</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>improvement_period (*)</td>
<td>IMPROVEMENT</td>
<td>PERIOD</td>
<td>I</td>
</tr>
<tr>
<td>improvement_cost</td>
<td>IMPROVEMENT</td>
<td>EURO</td>
<td>A</td>
</tr>
</tbody>
</table>

Table 16: OPL of the Flood Control Domain (Prevention)

Derived properties are indicated by an asterisk between brackets. The derivation rules are as follows:
# assessments = < sum total assessments during safety assessment period>
# maintenance_days = < maintenance_end_date - maintenance_start_date>
flood_defense_age = <current_year - flood_defense_construction_year(FD)>
improvement_period = < improvement_end_date - improvement_start_date>
Flood defense safety assessment (SA) has been conducted.
Flood defense safety assessment (SA) has been evaluated.
Standard for flood defense safety assessment (SA) has been established.
Plan for flood defense maintenance (M) has been developed.
Plan for flood defense improvement (FDI) has been developed.
Plan for flood defense improvement (FDI) has been approved.
Flood defense improvement (FDI) has been implemented.
Inspection of flood defense improvement (FDI) implementation has been done.
Flood defense maintenance (M) has been executed.
Plan for flood defense maintenance (M) has been approved.
Flood defense assessment for period P has been checked.
Flood defense maintenance control for period P has been done.

Figure 50: The OFD of Flood Control Domain for the prevention link
8.1.3 The SM of the Flood Control Domain for the Preparation Link

The state model of the Flood Control Domain for the preparation link is developed in this section. Figure 51 shows the Object Fact Diagram (OFD) while Table 17 shows its corresponding Object Property List (OPL).

<table>
<thead>
<tr>
<th>Property type</th>
<th>Object Class</th>
<th>Range</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>plan_completed_date</td>
<td>FLOOD RESPONSE PLAN</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>approval_date</td>
<td>FLOOD RESPONSE PLAN</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>training_date</td>
<td>FLOOD CRISIS TRAINING</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>training_evaluation_date</td>
<td>FLOOD CRISIS TRAINING</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td># people_in_training</td>
<td>FLOOD CRISIS TRAINING</td>
<td>NUMBER</td>
<td>R</td>
</tr>
<tr>
<td>training_target_group</td>
<td>FLOOD CRISIS TRAINING</td>
<td>(Inter-organization, Intra-organization)</td>
<td>C</td>
</tr>
<tr>
<td># people_within_region</td>
<td>REGION</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>region_location_latitude</td>
<td>REGION</td>
<td>DEGREE</td>
<td>I</td>
</tr>
<tr>
<td>region_location_longitude</td>
<td>REGION</td>
<td>DEGREE</td>
<td>I</td>
</tr>
</tbody>
</table>

Table 17: OPL of the Flood Control Domain (Preparation)

Figure 51: The OFD of Flood Control Domain for the preparation link
Like its other ontological aspect models, the state model of the Flood Control Domain for the response link is rather complex. In order to simplify its presentation, two Object Fact Diagrams (OFDs) will be presented, one without the result types as shown in Figure 52 and the other with result types as shown figure 53. Its Object Property List (OPL) is presented in Table 18.

<table>
<thead>
<tr>
<th>Property type</th>
<th>Object Class</th>
<th>Range</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>weather_forecast_time</td>
<td>WEATHER FORECAST</td>
<td>TIME</td>
<td>I</td>
</tr>
<tr>
<td>forecasted_rainfall</td>
<td>WEATHER FORECAST</td>
<td>MILLIMETER</td>
<td>R</td>
</tr>
<tr>
<td>flood_forecast_time</td>
<td>FLOOD FORECAST</td>
<td>TIME</td>
<td>I</td>
</tr>
<tr>
<td>forecasted_water_level</td>
<td>FLOOD FORECAST</td>
<td>METER ABOVE SEA LEVEL</td>
<td>R</td>
</tr>
<tr>
<td>measured_water_level</td>
<td>FLOOD FORECAST</td>
<td>METER ABOVE SEA LEVEL</td>
<td>R</td>
</tr>
<tr>
<td>forecasted_discharge</td>
<td>FLOOD FORECAST</td>
<td>CUBIC METRE PER SECOND</td>
<td>R</td>
</tr>
<tr>
<td>inspection_time</td>
<td>INSPECTION</td>
<td>TIME</td>
<td>I</td>
</tr>
<tr>
<td>inspection_section</td>
<td>INSPECTION</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>inspection_method</td>
<td>INSPECTION</td>
<td>METHOD NAME</td>
<td>C</td>
</tr>
<tr>
<td>reinforcement_measure_type</td>
<td>TEMPORARY REINFORCEMENT MEASURE</td>
<td>(SANDBAG ,GEOTEXTILE , ...etc)</td>
<td>C</td>
</tr>
<tr>
<td># evacuation_required_hours</td>
<td>EVACUATION</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td># registered people(*)</td>
<td>EVACUATION</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>date_of_birth</td>
<td>PERSON</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>age(*)</td>
<td>PERSON</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>shelter_size</td>
<td>SHELTER</td>
<td>SQUARE METER</td>
<td>R</td>
</tr>
<tr>
<td>shelter_care_type_measure</td>
<td>SHELTER_CARE</td>
<td>(FOOD,SHELTER,MEDICAL,CARE...etc)</td>
<td>C</td>
</tr>
<tr>
<td>operation_resource_type</td>
<td>OPERATION RESOURCE</td>
<td>(PERSONNEL, EQUIPMENT)</td>
<td>C</td>
</tr>
<tr>
<td># operation_resource</td>
<td>OPERATION RESOURCE</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>economic_damage_amount</td>
<td>DAMAGE ANALYSIS</td>
<td>EURO</td>
<td>A</td>
</tr>
<tr>
<td># causalities</td>
<td>CASUALITY ANALYSIS</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>water_management_measure_type</td>
<td>WATER MANAGEMENT MEASURE</td>
<td>(PUMPING, RETENTION AREA...etc)</td>
<td>C</td>
</tr>
<tr>
<td>flood_defense_location_latitude</td>
<td>FLOOD DEFENSE</td>
<td>DEGREE</td>
<td>I</td>
</tr>
<tr>
<td>flood_defense_location_longitude</td>
<td>FLOOD DEFENSE</td>
<td>DEGREE</td>
<td>I</td>
</tr>
<tr>
<td>design_level</td>
<td>FLOOD DEFENSE</td>
<td>METER</td>
<td>R</td>
</tr>
<tr>
<td>crest_level</td>
<td>FLOOD DEFENSE</td>
<td>METER</td>
<td>R</td>
</tr>
<tr>
<td>flood_break_time</td>
<td>FLOOD</td>
<td>HOUR</td>
<td>I</td>
</tr>
<tr>
<td>flood_depth</td>
<td>FLOOD</td>
<td>METER</td>
<td>R</td>
</tr>
<tr>
<td>flood_velocity</td>
<td>FLOOD</td>
<td>METER PER SECOND</td>
<td>R</td>
</tr>
<tr>
<td>flood_discharge</td>
<td>FLOOD</td>
<td>CUBIC METER PER SECOND</td>
<td>R</td>
</tr>
</tbody>
</table>
The derivation rules for the derived properties are indicated as follows:

Age (P) = < current_date – date_of_birth (P)>

# registered people=< sum total of people in EV>
Figure 52: The OFD of Flood Control Domain for the response link (without result types)
8.1.5 The SM of the Flood Control Domain for the Recovery Link

As it has been done with other safety chain links, the state model of the Flood Control Domain for the Recovery Phase is developed in this section. Figure 54 shows the OFD while Table 19 shows its corresponding OPL.

<table>
<thead>
<tr>
<th>Property type</th>
<th>Object Class</th>
<th>Range</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td># people_registered (*)</td>
<td>DAMAGE CLAIM</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>total_claim_issued (*)</td>
<td>DAMAGE CLAIM</td>
<td>EURO</td>
<td>A</td>
</tr>
<tr>
<td>date_of_birth</td>
<td>PERSON</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>repair_start_date</td>
<td>REPAIR</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>repair_end_date</td>
<td>REPAIR</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td># repair_days(*)</td>
<td>REPAIR</td>
<td>NUMBER</td>
<td>A</td>
</tr>
<tr>
<td>repair_cost</td>
<td>REPAIR</td>
<td>EURO</td>
<td>A</td>
</tr>
<tr>
<td>return_date</td>
<td>RETURN</td>
<td>DATE</td>
<td>I</td>
</tr>
<tr>
<td>area_location_latitude</td>
<td>AREA</td>
<td>DEGREE</td>
<td>I</td>
</tr>
<tr>
<td>area_location_longitude</td>
<td>AREA</td>
<td>DEGREE</td>
<td>I</td>
</tr>
<tr>
<td>area_size</td>
<td>AREA</td>
<td>SQUARE KILOMETER</td>
<td>R</td>
</tr>
</tbody>
</table>

Table 19: OPL of the Flood Control Domain (Recovery)

The derivation rules for the derived properties are indicated as follows:

- \# people_registered (P)= \(<\text{ sum total number of people in DC}>\)
- total_claim_issued = \(<\text{ sum total number of people times amount paid}>\)
- \# repair_days = \(<\text{ repair_end_date - repair_start_date}>\)
Plan for flood defense repair RP has been developed
Flood defense repair RP has been implemented
Damage claim DC has been organized
Registration for damage claim DC has been done
Payment for damage claim DC has been made
Return possibility check for period P has been done
Flood crisis evaluation for period P has been checked
Decision for return R has been made
Resource for return R has been mobilized
Return R has been completed
Analysis for return R has been conducted
Advice for return R has been provided
Return R to A
Evaluation EV evaluates measures taken during F
Flood F occurs in A
Person P lives in A
Flood defense FD mitigates F effects
Recovery of failed flood defense operation for period P has been done
Recovery of failed flood defense operation for period P has been done

Figure 54: The OFD of Flood Control Domain for the recovery link
8.2 The Practical Relevance of the State Model

The State Model (SM) is the source of ontological knowledge about the production world. This makes it very suitable, in practice, for several major applications.

First, it is the ideal starting point for developing and maintaining the data dictionary of an enterprise. It delivers the stable core of such a dictionary. Not only does it provide the concepts that are essential for the enterprise, but also helps in conceiving the best concepts. We have seen examples of this in Section 8.1 whereby concepts such as safety assessment, flood response plan, flood forecasting, damage claim, were identified.

Second, the state model is structured in chunks around the main object types, which are mostly categories. These object types are the variables in the result types, which are mostly categories. These object types are the variables in the result types of the distinct transaction types. This property facilitates the business component-based design of databases, the business components being the distinct result types. Every business component manages a single business abstraction. Therefore, identifying distinct business components can assist in application or information systems development projects within an organization.

The connections of the result types with the transaction types in which they are created provide the basis for a sensible discussion of the issue of data ownership. This issue which talks of who is really the data owner between the initiator of a transaction or the executor of a transaction is elaborated in Section 6.4.
9. The use of the enterprise ontology for the Flood Control Domain in the Netherlands and USA

In the previous chapters, you saw how the ontological aspect models of the Flood Control Domain were developed using DEMO methodology. The presented ontological models of the Flood Control Domain are fully abstracted from the implementation, as according to the description of enterprise ontology in Section 4.2. They do not contain organizational names or functions (e.g. the water boards or Rijkswaterstaat) or references to individuals (e.g. Mayor or Minister). The aim of this chapter is to go beyond the limits of DEMO methodology and show the organizations responsible for performing the identified essential operations of the Flood Control Domain. The chapter also aims to go beyond the Netherlands, the country in which the research was conducted, by also exploring the existing organizations in the United States responsible for performing identifiably essential operations in the Flood Control Domain. Therefore, this chapter aims to provide an answer to the fourth research question: “Which organizations are involved in performing the essential operations of the Flood Control Domain in the Netherlands and the United States?

In order to answer the question above, I will re-draw the Organizations Construction Diagrams (OCDs) constructed in Section 6.3, now with existing organizations both in the Netherlands and the United States, instead of the abstract actor roles.

Below is a list of abbreviations for the names of organizations that may be seen in the coming paragraphs.

**Netherlands Organizations**
- VenW: Ministry of Transport, Public Works and Water Management
- BZK: Ministry of the Interior and Kingdom Relations
- RWS: Rijkswaterstaat
- RIZA: The Institute for Inland Water Management and Waste Water Treatment
- DID: Data-ICT-Service
- KNMI: The Dutch weather Institute
- LCO: National Flood Threat Coordinating Commission
- LOCC: National Operational Coordination Centre
- NCC: National Coordination Centre
- DCC: Departmental Coordination Centre
- ROT: Regional Operation Team
- CRAS: Central Damage Registration and Reporting Point
- CRIB: Central Registration and Information Bureau
- NRK: The Netherlands Red Cross

**USA Organizations**
- NWS: National Weather Service
- NOAA: National Oceanic and Atmospheric Administration
- USGS: U.S. Geological Survey
- USACE: U.S. Army Corps of Engineers
- FEMA: Federal Emergency Management Agency
- DOT: Department of Transport
- DHS: Department of Homeland Security
- ARC: America Red Cross
9.1. Pro-action

This section describes the existing organizations responsible for performing the essential flood control operations in pro-action links both in the Netherlands and the United States. These organizations are shown after redrawing an OCD presented in Figure 17 in section 6.3.1. This new OCD with existing organizations in the Netherlands and the United States is presented in Figure 55.

Explanations for Figure 55 can be provided as follows.

The Netherlands:
The water boards are mapped to the actor roles A01, A02 and A03 due to their roles in flood risk analysis and spatial plans for flood risk areas. The current spatial plans emphasized in the Netherlands are the “Room for river policy” and reserving of special areas that can be flooded during flooding or high-water situations.

Figure 55 shows a mapping of the actor roles A04, A05 and A10 to the three governmental levels: local government, regional government and national government. The reason for the mapping above is because all three governmental agencies have authority on land use decisions and can be referred to as the land use authority (Voogd 2006). Therefore, a land use decision can be initiated by the local government, regional government or national government (Voogd 2006). On the other hand, according to (Voogd 2006), an actor role A09 who is responsible for reviewing land-use decisions can be mapped to the provincial or national government. For example, the provincial authority reviews land-use decisions taken by municipal authorities.

According to (Voogd 2006), the actor roles A06, A07 and A08 can be played by the water authority which can either be the water board, ground water authority or national Rijkswaterstaat.

The United States
The Actor roles A01, A02 and A03 are mapped to FEMA due to its role in the National Flood Insurance Program and flood hazard mapping. FEMA manages the National Flood Insurance Program (NFIP). In support of the NFIP, FEMA has undertaken a massive effort of flood hazard identification and mapping to produce Flood Hazard Boundary Maps (FHBMs), Flood Insurance Rate Maps (FIRMs), and Flood Boundary and Floodway Maps (FBFMs). Several areas of flood hazards are commonly identified on these maps. One of these areas is the Special Flood Hazard Area (SFHA), which is defined as an area of land that would be inundated by a flood having a one percent chance of occurring in any given year (also referred to as the base or 100-year flood). Flood insurance is required for insurable structures within the SFHA (Scawthorn June 1999).

Actor roles A04, A05 and A10 are mapped to the local governments because of their responsibility in land use and zoning decisions that direct floodplain and coastal development. However, numerous federal and state flood policies and programs influence local and individual decision-making (Cody and Carter June 2008).

So far, I haven’t found a specific reference which describes the mapping of actor roles A06, A07 and A08 any organization in the United States.
Figure 55: OCD of the Flood Control Domain with existing organizations (Pro-action)
9.2. Prevention

The existing organizations in the Netherlands and the United States responsible for performing the essential operations in the Flood Control Domain regarding the prevention are shown in this section. These organizations are shown in Figure 56 as the result of re-drawing an OCD presented in Figure 18 in section 6.3.2.

Explanations for the figure 56 can be provided as follows.

The Netherlands

The figure above shows a mapping of actor roles A13, A15, A16, A17, A18 and A22 to both the water boards and Rijkswaterstaat. The reason for these mappings is mainly because both the water boards and Rijkswaterstaat are responsible for the management, maintenance and operations of flood defenses within their boundaries. The water boards managing 90% of the primary flood defense and all the secondary flood defenses, and Rijkswaterstaat managing 10% of the primary flood defenses (Bake and Wolters; Rijkswaterstaat 2006). Both the water boards and Rijkswaterstaat are responsible for conducting the safety assessment of the primary flood defenses. The standards for the safety assessment are made by the Directorate General Water. The safety assessments are evaluated by the Transport and Water Management Inspectorate at the national level. After the evaluation, the Transport and Water Management Inspectorate submits the national report of the assessment to the Minister of Transport, Public Works and Water Management (VenW). Based on the summary of the report, the Minister of VenW informs the parliament about the state of all of the primary flood defenses in the country and draws up a program of improvement, known as the Flood Protection Program, based on the results (Inspectorate September 2006). The improvement of flood defense is carried out by the responsible organization; either the water board or Rijkswaterstaat.

The United States

The safety assessment of flood defenses in the Netherlands can be related to the levee inspection in the United States. Before the inspection program started, the US Army Corps of Engineers (USACE) conducted a survey of federal program levee systems and developed a national database (also called levee inventory), to capture information about each levee, including the location and last recorded inspection rating. The survey which was completed in July 2006 included three types of levees:

- **Federally Constructed, Locally Maintained and Operated Levees**: Levees built by the Corps and turned over to a local sponsor such as a levee district to operate and maintain.
- **Federally Constructed, Federally Maintained and Operated Levees**: Levees built by the Corps and maintained by the Corps of Engineers. These projects are typically built to provide protection from flooding due to high lake levels and are funded and operated by the Corps of Engineers Operation and Maintenance program.
- **Locally built and maintained**: these are levees which were built by private individuals or local community but maintained locally and meet the specified USACE standards.

Both local sponsors and the USACE are required to conduct regular inspections to ensure that levees are properly maintained (GAO December 2005; Cody and Carter June 2008). The levee districts conduct levee inspection every quarter of the year. The USACE makes annual inspections of each levee unit and reviews plans submitted by the levee districts for work on or adjacent to the levees. The USACE inspections concentrate on the problems reported by
the levee district during the levee district quarterly inspections (Ardoin July 2007). These are the reasons for the mapping of actor roles A13, A15, A16 A17 and A18 to both the local sponsors and the USACE.

I haven’t found a specific reference which describes the mapping of actor roles A19 to A23 to either the local sponsors or the USACE.
Figure 56: OCD of the Flood Control Domain with existing organizations (Prevention)
9.3. Preparation

The organizations responsible for performing the essential operations in the preparation link in the Netherlands and United States are described here. These organizations are shown in Figure 57 as the result of re-drawing an OCD presented in Figure 19 in section 6.3.3.

Figure 57: OCD of the Flood Control Domain with existing organizations (Preparation)
Figure 57 can be explained as follows.

The Netherlands:
The actor roles A24, A25 and A26 are mapped to the local government, regional government and Ministry of the Interior and Kingdom Relations at the national government because of the following reasons. According to the Disaster Act, the local governments are also required to have contingency plans that address each hazard in their areas (e.g. flooding, and explosions). Such plans also exist at the regional level. An example of a region with a flood disaster plan is the region of Nijmegen as described in an Explanatory Case in Appendix C and the Performa Analysis in section 5.3.3. At the national level, the National High Water and Flooding Emergency Response Plan was developed for a high-water (impending) disaster which could strike multiple regions simultaneously and where preparations at local or regional levels would be insufficient. The management of the National Emergency Response Plan is in the hands of the Crisis Control department of the Ministry of the Interior and Kingdom Relations (BZK January 2007).

Once the flood response plan has been approved, it is necessary to test the plans. The testing of the plans aims to check whether the plans works well and can be used during a real flooding emergency, to improve the plan and to enable the flood responders to know what steps are to be taken when a particular scenario occur. The testing of the plan is done by conducting training, a drill or an exercise. Normally, the initiator of the flood response plan also is responsible to check whether the plan works well and to improve the plan. This explains the reason for the mapping of actor roles A27, A28 and A29 to the local government, regional government and at the Ministry of the Interior and Kingdom Relations at the national level. Actor role A30 is mapped to the training participants which normally include the government authorities (local, provinces and national) and functional organizations (the water boards, Ministry of Transport, Public Works and Water management and its divisions). Other training participants may include police, fire, army, volunteers and the Red Cross.

The United States
As for the Netherlands, the governments at all levels (local, state and federal) in the United States are required to develop detailed, robust, all-hazards response plans (DHS January 2008). This explains the mapping of actor roles A24, A25 and A26 to all governmental levels. The response plans include both hazard-specific as well as comprehensive all-hazards plans that are tailored to each respective jurisdiction. Among the many contingencies that response plans must address is the planning for evacuations. An example of such plans includes the National Response Plan (NRP), administered by the DHS which sets forth the roles and responsibilities of federal and certain non-federal entities after catastrophes overwhelm state or local governments (Bea September 2005).

In addition to developing flood response plan, the local, tribal, state, and federal jurisdictions should exercise their own response capabilities and evaluate their abilities to perform expected responsibilities and tasks. Flood response trainings or exercise are normally organized at local, state or at national levels. This explains the mapping of actor roles A27, A28 and A29 to the local government, state government and the Department of Homeland Security (DHS) at national level. For instance, the Department of Homeland Security (DHS) established and coordinates the National Exercise Program (NEP). NEP is scheduled every five years and includes exercises across federal agencies, state and local level (DHS February 2007; Petersen, Kapp et al. November 2008). An actor role A30 is mapped to the individuals involved in the trainings participants which might involve local,
tribal, state, and federal jurisdictions. In order to support the evaluation activity, a web-based system called the Homeland Security Exercise and Evaluation Program (HSEEP) Toolkit was developed by the DHS (DHS February 2007).

9.4. Response

This section describes the existing organizations in the Netherlands and the United States responsible for performing the essential operations in the Flood Control Domain regarding the response link. Due to the complexity of the operations in the response link, four Organizations Construction Diagrams (OCDs) were presented in section 6.3.4. As already mentioned, these OCDs covered the following areas:

1. Flood prediction and high-water management measures: operations focused on predicting a flood threat including weather forecasting and flood forecasting, as well as high-water management measures (e.g. pumping out water, flooding retention areas).

2. Flood defense management measures and operational resources preparations: operations focused on managing flood defenses through monitoring their execution, reinforcing or repairing (anticipated) weak spots in the water defenses, as well as managing and preparing operational resources to be used for flood fighting.

3. Flood inundation analysis and damage analysis: operations focus on analyzing of possible flooded areas, flood extent and flood time, and damage analysis in terms of casualties and economic damage.

4. Evacuation: operations focused on the preparations for and implementation of the removal of the inhabitants from the expected flood area, cordonning (securing) evacuated area and providing evacuees with shelter and care in other areas

Initially, Figure 58 presents the organizations in the Netherlands and the United States which act as initiators and executors of the identified transactions as shown in Figure 20 in section 6.3.4.
Figure 58: OCD of the Flood Control Domain with existing organizations (Response -1)
Explanations for Figure 58 can be provided as follows.

**The Netherlands**
The actor roles A31 and A32 are mapped to the Dutch weather Institute (KNMI) due to its role in weather forecasting. The weather forecast data from KNMI and the water level measurements data collected by Data-ICT-Service (DID), a division of Rijkswaterstaat, are used for flood forecasting. At the national level, the Inland Water Information Centre, which is part of the Institute for Inland Water Management and Waste Water Treatment (RIZA), is responsible for flood forecasting along the main rivers (i.e. Rhine and Maas). RIZA is a division of Rijkswaterstaat. This explains the reason for mapping actor roles A33 and A34 to RIZA. However, at regional and local levels, the actor roles A33 and A34 can be mapped to Rijkswaterstaat regional departments and the water boards, respectively.

The actor roles A35, A36, A37, A38 and A39 are mapped to both the water boards and Rijkswaterstaat because of their role in high-water management operations.

**The United States**
The National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration, is widely known as the Federal agency in charge of weather forecasting and warning for the nation. The NWS also is charged by law with the responsibility for issuing river forecasts and flood warnings (USGS June 1995). This explains the mapping of the actor roles A31, A32, A33 and A34 to the National Weather. To clarify, for flood forecasting from the main rivers, the National Weather Service (NWS) depends on the U.S. Geological Survey (USGS) for the data about the river depth and flow (USGS).

The actor roles A35, A36, A37, A38 and A39 are mapped to the US Army Corps of Engineers (USACE) due to its role in high-water management operations.

Next, Figure 59 presents the existing organizations in the Netherlands and the United States which act as initiators and executors of the identified transactions as shown in Figure 21 in section 6.3.4.
Figure 59: OCD of the Flood Control Domain with existing organizations (Response -2)
Explanations for Figure 59 can be provided as follows.

**The Netherlands**
The actor roles A40, A41 and A42 are mapped to the water board with an assumption that the flood defense structure is managed by the water boards. As already mentioned, when temporary reinforcement measure (e.g. sandbagging) is necessary, the water board depends on assistance from other organizations such as the army and local community. Depending on the crisis coordination level, temporary reinforcement measure can be mobilized at the local, regional or national level by either the water board, the Regional Operation Team (ROT) or the National Operational Coordination Centre (LOCC), respectively. LOCC, for instance, can request the Minister of Defense for the army’s assistance. The water boards can call for trained volunteers within the local community. This explains the mapping of actor role A43 to the water board, ROT and LOCC. On the other hand, an actor role A44 is mapped to the water board plus the assistance it gets from the army and/or the local community in implementing the flood defense reinforcement measure.

Since a flood crisis in the Netherlands is commonly coordinated at regional level, the actor roles A45, A46, A47 and A48 are mapped to the Regional Operational Team (ROT). However, in case a national coordination is needed, these actor roles are mapped to the National Operational Coordination Centre (LOCC). Both ROT and LOCC are responsible to ensure that there are enough resources to fight the effects of a flood. These resources can be used for activities such as temporary reinforcement measures, evacuation, shelter and care, traffic monitoring, clearing up a flooded area and ensuring road accessibility (BZK January 2007).

**The United States**
The actor roles A40, A41, A42, A43 and A44 are mapped to the local sponsor such as a levee district for the levees that are operated and maintained by a local sponsor. The levee districts are generally the first entities responsible for monitoring levee conditions and for emergency responses when a flood threatens the levees that are within their domains. However, if a flood or other emergency exhausts the levee district’s flood-fighting resources, the district typically contacts the state. The state will contribute its flood-fighting resources to the local effort; as the state’s resources are exhausted, it typically will contact the US Army Corps of Engineers (USACE) at the federal level for assistance. The USACE is authorized to take immediate advanced measures to protect life and property, such as constructing temporary flow restriction structures (such as sandbagging) and removing log debris blockages (Stockton April 2008). Therefore, apart from the local sponsor, an actor role A43 can also be mapped to the state government and the USACE. The state assistance, which may include resources like the National Guard, and USACE, can also be mapped to an actor role A44.

At the early stage of a crisis or a disaster, actor roles are A45, A46, A47 and A48 are mapped to the local government. However, the local government can seek additional resource assistance from the state or even the federal government if an incident is beyond the local government’s capabilities. This federal assistance is normally coordinated by FEMA. Therefore, a mapping of an actor role A48 to the state government and FEMA is also provided.
Next, Figure 60 presents the existing organizations in the Netherlands and the United States which act as initiators and executors of the identified transactions as shown in Figure 22 in section 6.3.4.

**Figure 60: OCD of the Flood Control Domain with existing organizations (Response -3)**
Explanations for the Figure 60 can be provided as follows.

**The Netherlands**

The actor roles A49, A50 and A51 are mapped to the water boards and the National Flood Threat Coordinating Commission (LCO) at local and national levels, respectively. LCO is a virtual team of flood experts that is activated by the Departmental Coordination Centre (DCC) within the Ministry of Transport, Public Works and Water Management. LCO combines the factual information with other information (such as weather forecasts, anticipated water levels and the condition of the threatened water defenses) and advises the decision-makers within the general administrative and water sector of the chances that the threatened area will actually be flooded, the size of the (potential) flood area and the time left before the flood breaks (BZK January 2007).

Damage evaluation in the form of economic and human casualties is performed at the local level, hence a mapping of actor roles A52, A53, A54 and A55 to the local government.

**The United States**

The actor roles A49, A50 and A51 are mapped to the US Army Corps of Engineers (USACE) due to their knowledge of the strength of the flood control structures such as levees. The Corps of Engineers can predict if the levees are going to hold or not during flooding situation and inform the emergency responders at the local government, state government and FEMA.

Actor roles A52, A53, A54 and A55 are mapped to the local government, state government and FEMA due to the following reasons. Under the Stafford Act, a governor may request that the President declare an emergency or a major disaster. A governor's request is based on "a finding that the disaster is of such severity and magnitude that effective response is beyond the capabilities of the state and the affected local governments and that Federal assistance is necessary. Normally, prior to the submission of the governor’s request, the state and local officials together with FEMA conduct a joint preliminary damage assessment (PDA) to estimate the extent of the disaster and its impact on individuals and public facilities. The PDA includes the estimated economic damage, the estimated number of people displaced, and the threat to health and safety caused by the crisis event. This information is included in the governor’s request. However, when an obviously severe or catastrophic event occurs, the governor’s request may be submitted prior to the PDA (FEMA).

Next, Figure 61 presents the existing organizations in the Netherlands and the United States which act as initiators and executors of the identified transactions as shown in Figure 23 in section 6.3.4.
Figure 61: OCD of the Flood Control Domain with existing organizations (Response-4)
Explanations for the Figure 61 can be provided as follows.

**The Netherlands**

The evacuation preparations can be initiated due to the possibility of flooding. These preparations are done at the regional or provincial government with a threat of flooding. Therefore, this is the reason for mapping the actor roles A56, A57, A58, and A59 to the threatened regional or provincial government.

When enough information has been gathered about the possibility of flooding, the extent of flooding, the time of flooding and the evacuation’s required time, the Minister of the Interior and Kingdom Relations (BZK) at the national level may order an evacuation. This explains the mapping of actor role A60 to the Minister of the Interior and Kingdom Relations. However, actor role A60 can also be mapped to the Queen’s Commissioner, the head of the province or to the coordinating mayor within a region, when flooding crisis is coordinated at province level and regional level, respectively.

Based on the decision of the Minister of the Interior and Kingdom Relations (BZK), the threatened Regional Operation Team (ROT) will complete the evacuation process. In that case, the ROT in the threatened area will mobilize evacuation resources such as personnel. This explains the mapping of actor roles A61 and A62 to the ROT in the threatened regions. However, in case of insufficient resources, the ROT can ask for the additional resources from the National Operational Coordination Centre (LOCC), hence a mapping of A62 to the LOCC. The police are among the emergency responders who implement the evacuation of the population from the disaster area under the coordination of the ROT. This explains the mapping of the actor role A63 to the police.

On the other hand, when the evacuation has to be implemented, the ROT in the threatened regions informs the ROT in the unthreatened regions for shelter-care implementation measures. At the national level, the coordination of shelter-care measure is done by the LOCC. This explains the mapping of actor role A64 to the ROT in the unthreatened region and the LOCC. The actor role A65 is mapped to the local government due to its role in setting up of shelter centers. The actor roles A66 and A67 are mapped to the ROT in the unthreatened region where shelter-care measures have to be taken by the Dutch Red Cross (NRK) and the LOCC because of their roles in mobilizing and implementing shelter-care measures as well as providing basic needs to disaster victims. An actor role A68 is mapped to the Dutch Red Cross (NRK) and CRAS Team due to their role in registering the disaster victims. The CRAS Team is initiated by the local government.

Once the evacuation has been done, the evacuated area needs to be cordoned off to prevent a people from returning to their homes and for the security of the evacuated properties. The cordoning off of evacuated areas, cordoning arrangements (i.e. determining which areas are to be cordoned off) and mobilizing cordon-off resources to the evacuated areas are presided over by the police. This explains the mapping of the actor roles A69, A70 and A71 to the police. The installment of cordoning materials is performed by local government individuals; hence a map to actor role A72.

Last, but not least, is the traffic monitoring and traffic control measures. Traffic monitoring is crucial during the evacuation process, and the ability to remove traffic barriers can assist in on-time implementation of the evacuation activity. These roles which are executed by the actor roles A73 and A74 can be mapped to the traffic control centers at the Ministry of Transport, Public Works and Water Management and the police.
The United States
The local government and the state government also have a lot of responsibility in the whole evacuation process. According to (Arkansas 2008), the local governments have primary responsibility and have authority for evacuation planning and for the transportation, sheltering, public safety and security of persons within their jurisdictions. The state departments, agencies, or divisions are also responsible for developing evacuation plans for state facilities, including correctional facilities, hospitals, universities, offices and office buildings, and other state-owned or leased facilities. However, state agencies are required to coordinate with local authorities to ensure synchronization between state actions and local emergency evacuation plans and requirements (Arkansas 2008). This explains the reason for the mapping of actor roles A56, A57, A58, A59, A61, and A62 to both the local government and state government.

An actor role A57 responsible for evacuation planning can also be mapped to the Department of Transport (DOT). DOT provides technical assistance to federal, state, local, and tribal governmental entities in evacuation or movement restriction planning, and in determining the most viable transportation networks to, from, and within the incident area, as well as alternative means to move people and goods within the area affected by the incident.

An actor role A60 is mapped to the governor of the state. However, the emergency response command structure also differs in every state. By law, governors in most states had the ultimate authority to order evacuations. However, some governors delegated this authority to local-level officials, such as a mayor, city council, county sheriff, county judge, or county president (Urbina, Wolshon et al. 2001). This is primarily because local level managers have a better knowledge of local characteristics and are better informed on current local conditions. Table 20 shows the evacuation ordering authority in the surveyed states. Governors maintain their authority in fourteen of sixteen responding states.

<table>
<thead>
<tr>
<th>STATE</th>
<th>STATE AGENCIES</th>
<th>LOCAL AGENCIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Governor</td>
<td>Mayor</td>
</tr>
<tr>
<td>NEW HAMPSHIRE</td>
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<tr>
<td>MASSACHUSETTS</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>RHODE ISLAND</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>CONNECTICUT</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>NEW YORK</td>
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<td></td>
</tr>
<tr>
<td>NEW JERSEY</td>
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<td>x</td>
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<tr>
<td>DELAWARE</td>
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<td>MARYLAND</td>
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<tr>
<td>VIRGINIA</td>
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<tr>
<td>TEXAS</td>
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<td>x</td>
</tr>
</tbody>
</table>

Table 20: Authority to Order Hurricane Evacuations (Urbina, Wolshon et al. 2001)
An actor role A63 which implements the evacuation can first be mapped to the first responders including the police, fire, rescue, emergency medical and evacuation operations team (EOT). Apart from evacuation implementation, the first responders, especially the police, are responsible for providing security for homes/businesses once evacuees leave. This explains the mapping of actor roles A69, A70, A71 and A72 to the first responders.

The police as the first responder and the Department of Transport (DOT) are mapped to the actor roles A73 and A74 due to the following reasons. The police is responsible for performing activities such as expediting the flow of traffic out of the coastal areas during an evacuation, controlling access to evacuation routes during the evacuation, maintaining order and security on designated evacuation routes, monitoring the flow of traffic during the evacuation and keeping the Emergency Operation Centers informed of the status (COVEOP June 2009). On the other hand, the Department of Transport (DOT) is responsible for providing updated information on road conditions, load-bearing capacities and usability to support evacuation or rerouting of traffic, equipment and manpower to maintain or repair roads and bridges to a usable condition in support of an evacuation. DOT personnel may assist in traffic control by erecting barricades, warning lights and signs, or providing manpower (Dunlop September 2003).

Finally, the actor roles A64, A65, A66 and A67 are mapped to the local government, the American Red Cross and the Federal Emergency Management Agency (FEMA) because of the following reasons. The local governments, supported by private relief agencies, provide an initial response to mass care requirements of emergency/disaster victims. State and federal agencies, when requested and authorized, support the activities of local government in providing mass care. This assistance can be provided by the American Red Cross (ARC) and the FEMA as described in the Emergency Support Function-6 (ESF#6) in the National Response Plan. The Emergency Support Functions (ESFs) are the primary means through which the federal government provides assistance to state, local, and tribal governments or to federal departments and agencies conducting missions of primary federal responsibility. While the ESFs are shown in Table 21, below is the description of issues discussed in the ESF#6:

- **Mass Care**: Includes sheltering, feeding operations, emergency first aid, bulk distribution of emergency items, and collecting and providing information on victims to family members.
- **Emergency Assistance**: Assistance required by individuals, families, and their communities to ensure that immediate needs beyond the scope of traditional mass care services at the local level are addressed. These services include support of evacuations (including registration and tracking of evacuees), reunification of families, pet evacuation and sheltering, support of specialized shelters, support of medical shelters, nonconventional shelter management, coordination of donated goods and services, and coordination of voluntary agency assistance.
- **Housing**: Includes the housing components of the Stafford Act, such as rental assistance, repair, replacement, manufactured housing, semi-permanent and permanent construction, and access to other sources of housing assistance.
- **Human Services**: Includes the implementation of programs to help disaster victims recover their non-housing losses, including programs to replace destroyed personal property, and help obtain disaster loans, food stamps, crisis counseling, disaster unemployment, case management, and other state and Federal benefits.
The FEMA is the coordinator of ESF#6 and is the primary agency responsible for housing and human services. The American Red Cross is the agency primarily responsible for mass care (e.g. care for people in shelters).

<table>
<thead>
<tr>
<th>ESF</th>
<th>Primary Department or Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESF #1 Transportation</td>
<td>DOT</td>
</tr>
<tr>
<td>ESF #2 Communication</td>
<td>DHS (NCS)</td>
</tr>
<tr>
<td>ESF #3 Public Works and Engineering</td>
<td>DOD (USACE) and DHS (FEMA)</td>
</tr>
<tr>
<td>ESF #4 Firefighting</td>
<td>USDA (Forest Service)</td>
</tr>
<tr>
<td>ESF #5 Emergency Management</td>
<td>DHS (FEMA)</td>
</tr>
<tr>
<td>ESF #6 Mass Care, Housing, and Human Services</td>
<td>DHS (FEMA) and ARC</td>
</tr>
<tr>
<td>ESF #7 Resource Support</td>
<td>GSA</td>
</tr>
<tr>
<td>ESF #8 Public Health and Medical Services</td>
<td>HHS</td>
</tr>
<tr>
<td>ESF #9 Urban Search and Rescue</td>
<td>DHS (FEMA)</td>
</tr>
<tr>
<td>ESF #10 Oil and Hazardous Materials Response</td>
<td>(EPA) and DHS (U.S. Coast Guard)</td>
</tr>
<tr>
<td>ESF #11 Agriculture and Natural Resources</td>
<td>USDA</td>
</tr>
<tr>
<td>ESF #12 Energy</td>
<td>DOE</td>
</tr>
<tr>
<td>ESF #13 Public Safety and Security</td>
<td>DHS and DOJ</td>
</tr>
<tr>
<td>ESF #14 Long-Term Community Recovery and Mitigation</td>
<td>DHS (FEMA), USDA, DOC, HUD, USBA</td>
</tr>
<tr>
<td>ESF #15 External Affairs</td>
<td>DHS (FEMA)</td>
</tr>
</tbody>
</table>

Table 21: Emergency Support Functions

9.5. Recovery

This section describes the organizations in the Netherlands and the United States responsible for performing the essential operations in the recovery link. In order to show these organizations, an OCD presented in Figure 24 in section 6.5 will be re-drawn. Figure 62 presents the re-drawn OCD with the existing organizations in the Netherlands and the United States responsible for performing the identified essential operations (i.e. the transactions).
Recover failed flood defense operation

Develop flood defense repair plan

Approve flood defense repair plan

Implement flood defense repair

Damage claim registration

Damage claim payment

Damage claim organizing

Figure 62: OCD of the Flood Control Domain with existing organizations (Recovery)
Explanations for Figure 62 are provided as follows.

**The Netherlands**
Among the main issues that need to be taken into account immediately after a flood is the repair of failed flood defense structures such as breached levees. The water boards are mapped to the actor roles A75, A76, A77 and A78 with an assumption that the flood control structure is within their jurisdiction.

At this stage, an agreement may be made on the compensation of the flood victims or evacuees. The organization of the claim is done by the Central Damage Registration and Reporting Team (CRAS). The CRAS Team is responsible for damage registration and processing. This explains the mapping of actor roles A79 and A80 to the CRAS Team. The national government is responsible for the damage claim payment, hence being mapped to actor role A81.

Another concern at this stage is the return of the evacuees to their original areas. Once people are evacuated, the LCO and the water boards research if and when inhabitants can return depending on the flood risk. Although the evacuation might have occurred, the flood may not actually occur depending on the ability of the flood control structures to withhold the high-water situation without being breached or overtopped. The return of inhabitants may occur when the National Flood Threat Coordinating Commission (LCO) and water boards do not expect a flood to happen within the foreseeable future, when acute phases of the high water crisis are over and a stable situation gradually resumes. Based on their analysis, the LCO and the water boards can advise the decision-makers at the ministerial level to scale down crisis coordination and hence the return of the people. Moreover, the return of the inhabitants is also influenced by the safety of the disaster area. Due to its responsibility in ensuring the safety of the people at the local level, the local government is required to check the safety of the disaster area and provide advice to decision-makers on whether a return to the disaster area is possible or not. Therefore, due to these responsibilities, the actor roles A82, A83 and A84 are mapped to the water boards, the National Flood Threat Coordinating Commission (LCO) and the local government.

An actor role A85 is mapped to the Minister of the Interior and Kingdom Relations (BZK) with an assumption that the flooding crisis is coordinated nationally. However, this actor role can also be mapped to the Queen’s Commissioner, the head of the province or to the coordinating mayor within a region when a flooding crisis is coordinated at province level and regional level, respectively.

The Regional Operation Team (ROT) completes the return of the evacuees. In order to do so, ROT mobilizes the resource needed for the return. The ROT can request additional resources from the National Operational Coordination Centre (LOCC) when necessary. This explains the mapping of the ROT to actor role A86 and the mapping of actor role A87 to both the ROT and LOCC. The actor role A88 responsible for implementing the return of the people is mapped to the police. This is due to the police’s role in ensuring safety and security of the public.

Finally, an evaluation of the crisis has to be undertaken. Evaluation process can be initiated in the response link when flood crisis measures are taken. However, after the flood event, a final evaluation is made. At the national level, the evaluation process is initiated by the Inter-ministerial policy team (IBT), formed by various representatives from other ministries and chaired by the Minister of the Interior and Kingdom Relations (BZK). The Ministerial
Policy Team (MBT) is composed of several ministries and chaired by the Minister of BZK. The MBT team deliberate and decides on the evaluation of flood situations regarding measures taken. The evaluation of flood situations is crucial for reflection and for (possibly) rendering narrative accounts to States General (BZK January 2007). This explains the mapping of actor role A89 to the Inter-ministerial policy team and actor role A90 to the Ministerial Policy Team.

The United States
The actor roles A75, A76, A77 and A78 are mapped to the US Army Corps of Engineers (USACE) with an assumption that the flood control work is active in the Corps’ Rehabilitation Inspection Program (RIP). According to (USACE September 2008), the flood control works under RIP include the following:

- **Non-Federally Constructed Flood Control Works:** — An Initial Eligibility Inspection (IEI) must be requested by the project sponsor and conducted by Corps of Engineers personnel. The project sponsor is usually a government entity with authority to levy assessments for project maintenance, which has constructed and assumed maintenance responsibility for the project. Corps of Engineers technical staff experienced in flood control project design, construction, maintenance, and damage investigations will perform this inspection. The IEI determines the general functional and structural integrity of the project, and thus the project's ability to provide reliable protection against floods. If the project meets the Corps' condition standards, with the public sponsor assuming maintenance, the project may be included in the RIP.

- **Federally Constructed / Locally Maintained Flood Control Works:** — Flood Control Projects built by the Corps of Engineers with a public sponsor responsible for maintenance do not require an initial eligibility inspection as they have been built to established Federal standards and are eligible for rehabilitation assistance, assuming proper sponsor maintenance. These projects are periodically inspected to assure proper maintenance and continued eligibility for Federal rehabilitation assistance. Failure by the project sponsor to correct deficient maintenance may result in removal of the project from the Inspection of Complete Works program and from eligibility for emergency rehabilitation.

On the other hand, the Federal Emergency Management Agency (FEMA) is mapped to actor roles A79, A80 and A81 with an assumption that a president has declared that a major disaster or emergency exists after being requested by the governor. A Presidential major disaster declaration triggers long-term Federal recovery programs, some of which are matched by state programs, and designed to help disaster victims, businesses, and public entities. Funds to support long-term federal recovery programs comes from the President’s Disaster Relief Fund, which is managed by FEMA, and the disaster aid programs of other participating Federal departments and agencies. In order to get assistance, the disaster victim must register for assistance and establish eligibility. FEMA (or the providing agency) will verify eligibility and need before assistance is offered. FEMA disaster assistance falls into three general categories:

- **Individual Assistance** — aid to individuals, families and business owners;
- **Public Assistance** — aid to public (and certain private non-profit) entities for certain emergency services and the repair or replacement of disaster damaged public facilities;
- Hazard Mitigation Assistance — funding for measures designed to reduce future losses to public and private property

The participants of the National Flood Insurance Program (NFIP), administered by FEMA, can also claim for the damage to the buildings and contents caused by floods.

The next concern is the return of the evacuees to their pre-disaster residences or, if needed, to alternative locations. Each local government is responsible for conducting its own immediate needs assessment to determine return possibilities. This assessment will determine if the locality is safe to permit re-entry of residents, property/business owners. However, state and federal assistance may also be available to assist or to conduct such an assessment. An amendment to the Emergency Management Reform Act of 2006, which was made after Hurricane Katrina, expands the role of the Federal government beyond merely assisting states and localities in evacuations by authorizing the Federal government to return evacuees to their pre-disaster residence (Lindsay November 2008). This Federal assistance is coordinated and managed by FEMA (Charleston January 2008; Lindsay November 2008). FEMA, in conjunction with state, tribal, and local governments, coordinates the transportation of evacuees back to the affected area, and provides vehicles, including accessible vehicles. Therefore, due to its primary role in checking and conducting return analysis, the local government is mapped to the actor roles A82, A83 and A84. Together, the local government, the federal government represented by FEMA and the state government are mapped to the actor role A86 and A87.

The mayor of the city can authorize the return to the evacuated areas, hence that role being mapped to an actor role A85.

The implementation of the return includes operational agencies such as the police which needs to ensure order and security during the return of the people. Moreover, the transportation sector managed by the Department of Transport (DOT) plays a role in supporting the return of evacuees. It can contribute to making the roadways safe for return travel by aiding in damage assessments of the roads, clearing debris, and reestablishing services (Houston December 2006). Consequently, the police and the DOT can be mapped to actor role A88.

So far, I haven’t found a specific reference which describes the mapping of actor roles A89 to A90 to any organization in the United States.
9.6. Analysis of enterprise ontology use in the Netherlands and the United States

This section aims to provide an analysis of the results provided in the previous chapter. In general, the developed enterprise ontology for the Flood Control Domain seems to be generic since most of the actor roles who acted as initiators and executors of certain transactions could be mapped to the existing organizations in the Netherlands and the United States. However, there are some differences in the implementation of flood control operations in the Netherlands and the United States. Some of the observed differences are listed below:

- **Flood defense management**

  In United States, both the US Army Corps of Engineers and the local sponsor (e.g., a levee district) are responsible for the management of flood defenses. The relationship between these two organizations is more hierarchical. This can be seen for instance with the inspection of flood defenses which is carried out by both the local sponsors (e.g., the levee district) and the US Army Corps of Engineers (USACE). However, the inspections of the local sponsors are reviewed by the USACE. The USACE inspections concentrate on the problems reported by the levee district during the levee district. Due to this relationship, the USACE has more power over the flood defenses compared to the local sponsors.

  In the Netherlands, on the other hand, both the water boards and Rijkswaterstaat are responsible for the management of flood defenses. The water boards manage 90% of primary flood defenses and all the secondary flood defenses, while Rijkswaterstaat manages 10% of the primary flood defenses. The relationship between the water boards and Rijkswaterstaat is more horizontal. The water boards and Rijkswaterstaat carry out their work independent from each other and they both report to the province. This can be seen by explanations about the safety assessment of flood defenses in the Netherlands which is the responsibility of both the water boards and Rijkswaterstaat. The water boards and Rijkswaterstaat report to the provinces. The provincial assessments are submitted to the Minister of Transport, Public Works and Water Management. At the ministerial level, the Inspectorate assesses nationwide. Eventually, the Minister of Transport, Public Works and Water Management reports the national overview to the parliament.

- **Role and responsibilities of local governments**

  The local governments have more roles and responsibilities in the United States as compared to the Netherlands. For instance, the local government in the United States is responsible for the land use decisions and regulations; however, the laws made by the state and federal governments can influence the local government’s land use decisions. In the Netherlands, land use decisions are the shared responsibility of all governments: national, regional and local. The local governments in the United States also take a lot of responsibilities in responding to a flood crisis. In the Netherlands, a flood is rarely coordinated at local level; hence, this role is commonly taken at the regional, provincial and even national level. This can be explained by the size difference, the population and government types between the two countries as shown in Table 22. For instance, the local governments in the United States include the counties and the municipalities. There are many more counties and municipalities in the United States as compared to the number of municipalities in the Netherlands. The number of people in one local government, for instance in New York City, is more than half of the whole population of the Netherlands.
Therefore, while the flood coordination in New York can be coordinated at a local level, a national coordination would be needed in the Netherlands. All of these examples explain the reason for more responsibilities held by the local governments in the United States compared to the Netherlands.

<table>
<thead>
<tr>
<th>The Netherlands</th>
<th>The USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land total area: 33,883 km square</td>
<td>Land total area: 9.83 million km square</td>
</tr>
<tr>
<td><strong>Government Types:</strong></td>
<td><strong>Government Types:</strong></td>
</tr>
<tr>
<td>- National government: 1</td>
<td>- Federal government: 1</td>
</tr>
<tr>
<td>- Provinces: 12</td>
<td>- States: 50</td>
</tr>
<tr>
<td>- Municipalities: 441</td>
<td>- Local government include:</td>
</tr>
<tr>
<td></td>
<td>- Counties: 3024</td>
</tr>
<tr>
<td></td>
<td>- Municipalities: 3022</td>
</tr>
<tr>
<td>An average population of a municipality: 20,000-50,000 people</td>
<td>An average population of a county: 100,000 people</td>
</tr>
<tr>
<td>The most populated municipality: Amsterdam located in the province of Holland, with a population of 1.36 million, on January 2008.</td>
<td>The most populated city: New York located at the state of New York, with a population of 8,363,710 people.</td>
</tr>
</tbody>
</table>

Table 22: Some facts about the Netherlands and the USA

Another example can be seen by the size of the city of New Orleans which was, according to the U.S. Census Bureau in July 2005, 453,726. This population of New Orleans exceeds the population of the provinces of Zeeland or of Flevoland, ranked at 2004 (See Table 23). Such a flooding in the Netherlands could have been higher than the highest Coordinated Regional Incident-Management Procedure (GRIP) level, GRIP 4, and coordinated at the national level by the Minister of Interior and Kingdom Relations which assumes the coordinating role if more than one province is affected (Wikipedia).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Province</th>
<th>Population</th>
<th>%</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>Netherlands</td>
<td>16,254,800</td>
<td>100.0%</td>
<td>391.4</td>
</tr>
<tr>
<td>1</td>
<td>South Holland</td>
<td>3,453,000</td>
<td>21.2%</td>
<td>1,207.3</td>
</tr>
<tr>
<td>2</td>
<td>North Holland</td>
<td>2,583,900</td>
<td>15.9%</td>
<td>971.4</td>
</tr>
<tr>
<td>3</td>
<td>North Brabant</td>
<td>2,406,900</td>
<td>14.8%</td>
<td>487.4</td>
</tr>
<tr>
<td>4</td>
<td>Gelderland</td>
<td>1,967,600</td>
<td>12.1%</td>
<td>393.9</td>
</tr>
<tr>
<td>5</td>
<td>Utrecht</td>
<td>1,159,200</td>
<td>7.1%</td>
<td>854.9</td>
</tr>
<tr>
<td>6</td>
<td>Limburg</td>
<td>1,143,000</td>
<td>7.0%</td>
<td>527.5</td>
</tr>
<tr>
<td>7</td>
<td>Overijssel</td>
<td>1,105,800</td>
<td>6.8%</td>
<td>331.4</td>
</tr>
<tr>
<td>8</td>
<td>Friesland</td>
<td>642,500</td>
<td>4.0%</td>
<td>191.2</td>
</tr>
<tr>
<td>9</td>
<td>Groningen</td>
<td>575,900</td>
<td>3.5%</td>
<td>245.7</td>
</tr>
<tr>
<td>10</td>
<td>Drenthe</td>
<td>482,300</td>
<td>3.0%</td>
<td>181.9</td>
</tr>
<tr>
<td>11</td>
<td>Zeeland</td>
<td>378,300</td>
<td>2.3%</td>
<td>211.1</td>
</tr>
<tr>
<td>12</td>
<td>Flevoland</td>
<td>356,400</td>
<td>2.2%</td>
<td>249.9</td>
</tr>
</tbody>
</table>

Table 23: Ranked population figures of the provinces in the Netherlands (Wikipedia)
Role of insurance in the USA

The United States is among the countries that impose insurance policies to properties in flood-prone areas. The insurability of properties in flood-prone areas is linked directly to the probability of flooding. The insurance policy is commonly used to direct spatial developments, hence regarded to follow in the pro-action link. The insurance policy in the United States, commonly known as the National Flood Insurance Program (NFIP) can be described as follows:

The National Flood Insurance Program (NFIP)

Spurred by the increasing level of flood damages throughout the nation and the significant percentage of the costs of those damages that fell to taxpayers as well as a push from those favoring non-structural approaches to flood damage reduction, in 1969 the US Congress created the National Flood Insurance Program (NFIP). The Federal Emergency Management Agency’s Flood Insurance and Mitigation Administration (formerly the Flood Insurance Administration) manages the NFIP and oversees its operations. The insurance is actually sold and administered by private insurance companies or through independent brokers.

Any resident – homeowner or business person - of a community participating in the NFIP may purchase flood insurance. Under the NFIP, in order for a community to join the program, it must agree to establish and enforce floodplain management ordinances designed to limit development in the floodway and at elevations below the 1 percent flood level (the 100-year flood). In 2002, nearly 20,000 communities were participating in the NFIP with over 4 million policies in effect. Those buying homes in a NFIP community and who require loans from a federally regulated or federally insured lender are required to purchase flood insurance if they live in a designated flood risk zone (the 1 percent flood zone). Those who do not live in NFIP communities are not eligible for participation in the federal program. The rates for flood insurance for structures built after the community joined the NFIP and after a flood map was developed for the community are actuarial. Rates for those whose homes were already built are slightly subsidized by the federal government. In both cases, the costs of NFIP administration are borne by the federal government. If, in the course of periodic program evaluations, FEMA determines that the community’s program is especially effective; it will reduce the insurance rates for those in the community. More than 70 percent of homes in the NFIP are insured at the actuarial rates and the percentage grows each year as older homes leave the program.

In support of the NFIP, FEMA has undertaken a massive effort of flood hazard identification and mapping to produce Flood Hazard Boundary Maps (FHBMs), Flood Insurance Rate Maps (FIRMs), and Flood Boundary and Floodway Maps (FBFMs). Several areas of flood hazards are commonly identified on these maps. One of these areas is the Special Flood Hazard Area (SFHA), which is defined as an area of land that would be inundated by a flood having a 1-percent chance of occurring in any given year (also referred to as the base or 100-year flood). The 1-percent annual chance standard was chosen after considering various alternatives.

FEMA has modernized its Flood Insurance Rate Maps (FIRMs) to include the information about the safety provided by the levee systems. Some levee systems are shown on effective FIRMs as providing protection from the 1 percent-annual-chance flood event (sometimes called the base, or 100-year, flood). To determine whether the levee systems
shown on FIRMs still provide that level of protection, the levee system must be certified. FEMA requires levee owners to obtain and submit certain data and documentation to show that the levee systems continue to provide 1-percent-annual-chance flood protection. Once FEMA has received and reviewed the required levee data and documentation, FEMA will "accredit" the levee system and will revise the affected FIRM to show the area behind the levee system as having a moderate flood risk. FEMA will label the levee-impacted area as Zone X (shaded).

If a levee system cannot be certified as providing protection from the 1-percent-annual-chance flood, FEMA will not accredit the levee system or will de-accredit a levee system that had previously been shown as providing a 1-percent-annual-chance level of flood protection on an NFIP map. Because FEMA will not accredit the de-certified of uncertified levee systems, these systems will not be depicted on FIRMs as providing a 1-percent – annual-chance level of protection. FEMA will remap the levee-impacted areas landward of these levee systems as high-risk areas, called Special Flood Hazard Areas (SFHAs). Flood insurance is required in SFHAs for any property that is federal backed, regulated or insured.

To assist community officials and levee owners with the compilation and submittal of the required levee data and documentation, FEMA developed a "how-to" checklist for floodplain managers and engineers titled Meeting the Criteria for Accrediting Levees on NFIP Flood Maps: How-To Guide for Floodplain Managers and Engineers. The certification finding must be accomplished by either a registered professional engineer or a Federal agency with levee design and construction qualifications such as USA Army Corps of Engineers.

While insurance policy works well in the United States, such a policy is considered as unrealistic in the Netherlands since the large part of the country is a flood risk. While seven percent of the total land area of the United States of America is subject to flooding (Arnold 1982), one third (1/3) of the Netherlands is estimated to be below sea level and is hence flood-prone (Demmers and Dircke January 2006). Almost eight million people, which is more than half of the population in the Netherlands, live in flood-prone areas. Having a large part of the country below sea level is also the reason for the strong flood protection systems in the Netherlands whose standards vary from 1/10000 to 1/1250 per year (Pilarczyk).

- **Operations in the Recovery link**

As compared to the Netherlands, the United States has put much emphasis on operations on the recovery link. The United States Federal government also plays an active role in the recovery link as it provides assistance to the disaster victims through FEMA; it is responsible for the repair of the flood defenses through the US Army Corps of Engineers; and it takes a major role to assist the return of people to their homes. For the Netherlands, there are limited documentations on the implementation of the recovery operations. Therefore, this can be a learning point for the Netherlands from the United States.
10. Conclusions and Recommendations

10.1 Conclusions

Based on the research objective, in the following sections I will present the conclusions specifically for each research question.

10.1.1 Essential operations of the Flood Control Domain

“What are the essential operations performed by organizations in the Flood Control Domain?” This was the main question I investigated in Chapter 6. Investigating this question seemed necessary, as it provides basis information about the activities performed in the domain. I investigated this question by conducting an analysis of the Flood Control Domain. During the analysis, I gathered several documentations and one case study which describe the domain in the Netherlands. Based on the gathered knowledge of the domain, I made an Explanatory Case of the Flood Control Domain which can be seen in Appendix C. This Explanatory Case was analyzed using the Performa Analysis, which is described as the first procedure in developing an ontological model of an organization. Based on the Performa Analysis, the transactions in the Flood Control Domain were identified and specified in the Transaction Result Table. These transactions, which present the essential operations of the Flood Control Domain, together with the actor roles (initiators and executors) and the information links between the actor roles and the information banks, were presented using the Construction Model. This model was expressed using the Organization Construction Diagram (s) following the five safety chain links.

10.1.2 The interrelationship between the essential operations

“How are the essential operations in the Flood Control Domain interrelated?” The second research question was investigated in Chapter 7. In order to answer this question, a Process Model (PM) for the Flood Control Domain was developed using the Process Structure Diagram (PSD). The Process Model for the Flood Control Domain was developed based on the information provided in the Explanatory Case and detailed the Construction Model made in Chapter 6, namely, detailing the identified transaction types. In the Process Model, the specific transaction pattern for every identified transaction type was shown. The interrelationship between transactions was shown in the form of conditional and causal links. The Process Model also showed the cardinality range of each transaction type hence expressed transactions that were performed as mandatory, optional and when many transaction types of similar kind had to be performed. The Process Model was also developed following the safety chain links.
10.1.3 The Relevant Information Objects in the Flood Control Domain

“What information objects are relevant to the operation of the organizations in the Flood Control Domain?” This was the third research question and was investigated in Chapter 8. In order to provide an answer to this question, the State Model (SM) for the Flood Control Domain was developed using the Object Fact Diagram (OFD) and the Object Property List (OPL). The Object Fact Diagram (OFD) specified the object classes, the result types and the existential rules. The relationship between the identified object classes was also shown in the Object Fact Diagram (OFD). The Object Property List (OPL) specified the fact types, also seen as the properties (of object classes), the range and the scale for each identified property. Each property was categorized according to the five scale types: categorical, ordinal, interval, ratio and absolute.

10.1.4 The use of the enterprise ontology in the Netherlands and USA

“Which organizations are involved in performing the essential operations of the Flood Control Domain in the Netherlands and the United States? This was the third research question and was investigated in Chapter 9. In order to provide an answer for this question, the Organizations Construction Diagrams (OCDs) in Section 6.3, which expresses the Construction Model of the Flood Control Domain, were re-drawn. The new Organizations Construction Diagrams (OCDs) showed the existing organizations both in the Netherlands and the United States, instead of the abstract actor roles presented before. With few exceptions, most of the actor roles could be replaced with the existing organizations in the Netherlands and the USA. This shows that the developed enterprise ontology for the Flood Control Domain is relative generic and can be used to show the organizations in different countries that perform almost similar operations like the Dutch organizations.
10.2 Recommendations for future work

There are many possibilities to extend this work. First, because the Construction Model, the Process Model and the State Model of the Flood Control Domain are already developed, a mapping of the applications or information systems to the identified transactions business processes and information objects can be made. Through the mapping, an application landscape is created and can be compared between the Netherlands and the United States. The application landscape will also assist to study the overlap of these applications or information systems, and finding the blank spots (activities that are apparently not supported by information systems). It may be the case that the blank spots found in the Netherlands are different from the blank spots found in the United States. Therefore, the organizations in the two countries can learn from each other and fill the blank spots in applications or information systems.

Mapping the transactions to applications to transactions for was one of the interests of this project at the beginning. But due to time limitation this was recommended to be a future work. However, some analysis of the applications in the Netherlands was already done. This analysis is shown in Appendix E. Therefore the information in Appendix E can be used as a starting point for the mapping of the applications or information systems to the identified transactions business processes and information objects.

Second, the Construction Model of the Flood Control Domain presented in Section 6.3 provides a detailed overview of how the domain is constructed and operated. During the last few weeks of my thesis project, I have learned that such a model could have also been built in a high-level view which could easily be presented to various individuals. Therefore, developing a high-level Construction Model of the Flood Control Domain could be a starting point for future work.

Third, the enterprise ontology of the Flood Control Domain was developed using the Construction Model, the Process Model and the State Model. Besides these models, DEMO still has the Action Model. The Action Model is very important for any organization as it shows the action rules which serves as guidelines for an actor. Through the Action Model, one can understand why a certain actor acts in a certain way and can be also used to modify and improve the action rules within an organization. Thus, building the Action Model could be an extension for this work.

Fourth, due to time limitation, the developed enterprise ontology for the Flood Control Domain was shared with some individuals and a group of people within the domain. With these individuals and a group of people, possible useful applications, recommendations for future work and feedback about the developed enterprise ontology were discussed. It could be even more interesting if the developed enterprise ontology could be shared with a large group of individuals from different organizations.

Fifth, at the moment, there is no ideal enterprise ontology for the Flood Control Domain that countries can compare themselves. Such a comparison is useful for countries to evaluate their performance as compared to the ideal situation. This thesis work can be used as a starting point for developing ideal enterprise ontology for the Flood Control Domain that can be used internationally. Thus, developing ideal enterprise ontology for the Flood Control Domain could be an extension of this work.
11. Project General Reflections

In the following sections I present some general reflection on my research, my research approach, the project objectives and the results.

11.1. The research

In the first quarter of my first year of my master’s studies, I was briefly introduced to the concept of enterprise ontology. Developing an ontology of an enterprise seems to be very beneficial to organizations today. Enterprise ontology assists in coping with the current and future problems related to an organization by making the operations and business processes of an organization transparency. Without such a transparency, managing an organization and implementing changes can be very difficult. For practical experience, several assignments on how to develop enterprise ontology were provided in the class. At the time the assignments were small, aimed for small companies or departments such as the pizzeria, the library, the student administration desk in a university. Since I never had an experience in developing an enterprise ontology for a domain, this thesis project was quite a challenge for me.

The first challenge in my project was to understand the Flood Control Domain. Although several literatures were reviewed, it was difficult to understand the domain due the involvement of multiple organizations which perform several operations. During the literature research, I also found many documents describing the activities in the domain using a safety chain concept. Since the concept is common and well adopted in many countries, I decided to use it to generalize and simplify an understanding about the Flood Control Domain. Several issues about the domain could be discussed using the safety chain concept. In fact all the research four questions were answered using the safety chain concept.

The next challenge during the research was to get an understanding about ontology and enterprise ontology as well as the methodology for developing enterprise ontology. This understanding was important since the main objective of this project was to develop an enterprise ontology for the Flood Control Domain. Although various definitions of ontology exist, the chosen definition of ontology is: a formal, specification of shared conceptualization. This definition entails what one has to expect from ontology of any kind, here in particular of an enterprise. This definition says ontology has to be described in a formal way. For this purpose, DEMO methodology was used to develop an enterprise ontology of the Flood Control Domain. The definition also says that ontology is a conceptualization that needs to be shared. For this purpose it was necessary to plan for the meetings with experts to share the results of the project and to get feedback. Hence the chosen ontology was used as a guideline and a reminder on what has to be done when developing the enterprise ontology for the Flood Control Domain.

As already mention, although I had knowledge on developing enterprise ontology, my knowledge was limited to a small organization with a clear boundary. Therefore, it took me quite a while to find out the possible way to model the Flood Control Domain. However, through several discussions with my main supervisors Prof.Jan Dietz, the founder of DEMO methodology and Bram Havers from IBM, I was able to find a way to complete this project.
11.2. The research process

In order to reach the research objective, I adapted the research approach suggested by (Hevner and Ram March 2004). I found this approach more suitable for the stated purpose than other approaches. The main reason for this preference was that Hevner’s approach suggests a focus on literature (illuminating the state of the art). The approach also provides guidelines that were used, although not all, to conduct this research. Several authors suggested different research methods depending on the type of question asked. The reasons to conduct a case study as a research method are well described by (Benbasat, Goldstein et al. September 1987). Due to these reasons, a case study method was used to complement to interviews and literature review in order to get an understanding the Flood Control Domain.

The chosen research approach was only used as a guideline on how to go through the research. For this purpose I can say that the approach was useful. However, the whole research did not go as smoothly as it was expected. The research objective was changed from developing enterprise architecture for the Flood Control Domain to developing enterprise ontology for the Flood Control Domain for the feasibility of the project. Apart from changing the objective, the research questions were also changed several times. As the experts in the domain were the external organizations, I conducted several dozen interviews with external experts in the domain in order to get a more understanding about the domain.

During the research itself, one notices a balance of focus, both on analysis of the domain and developing the enterprise ontology for the domain. I have spent a major part of my time in reviewing literatures in order to understanding the Flood Control Domain as I have spent in developing an enterprise ontology for the domain. However, more research is needed especially in understanding the operations performed by various flood control organizations. As one can see in Chapter 9 when the use of enterprise ontology was analyzing in the Netherlands and the United States, several times a transaction was executed by more than one organization. Instead of mapping more than one organization in a transaction, only one organization with a primary role could be mapped. But understanding who has the primary or secondary role needs further discussions with the specific organizations.

11.3. The project objectives and results

As point of departure, the main problem for research was formulated as following problem: “It is difficult to compare the construction and operation of the Flood Control Domain in different countries, for instance, in terms of the organizations involved, the essential operations performed, the interrelationship between the operations and the information objects that are relevant for an organization”.

Accordingly, the main objective of this research was to: “develop an enterprise ontology that will show how the Flood Control Domain is constructed and operated by identifying the essential operations performed in the domain, highlighting the interrelationships between these operations and information objects that are relevant for the operations in the domain, and illustrating its use in the Netherlands and the United States”.

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Considering the main results of this investigation, I claim that the main objective for this research is achieved. This thesis contains an extensive description of the enterprise ontology of the Flood Control Domain. The developed enterprise ontology of the Flood Control Domain provides insight on the essential operations performed in the domain (sub objective B), and the interrelationships between the identified essential operation in the domain (sub objective C). Moreover, the enterprise ontology of the Flood Control Domain shows the relevant information objects that are relevant for the organizations in the domain (sub objective D). The use of the enterprise ontology in the Netherlands and the United States was also shown (sub objective A).

Are all my objectives achieved? I would say yes, with each objective described extensively. However, I can’t say the developed enterprise ontology for the Flood Control Domain is completed. Since such a project has never been done it is difficult to compare the results. The experts that were presented with the results of the project were quite impressed with the results and realized there is a need to have a conceptual model that could provide an understanding of such a complex domain. Although most of the experts had no knowledge of DEMO before it wasn’t very hard to discuss with them the results due to the abstraction of the methodology. Many comments were given during the discussions that were recommended as possibilities to extend this work.
Appendix

A Interviews

This section provides a brief description about the flood control organizations in the Netherlands that were interviewed. In choosing which organizations we wanted to interview we first looked at organizations that are in the water sector and crisis management sector. Looking at these two sectors, we made a list of organizations that we wanted to interview. Based on the list we used IBM advanced water management team and clients’ representatives to get contacts with some individuals within the organizations that we wanted to interview. Even though questions for the interviews were sent earlier in advanced in order to structure the interviews, sometimes a free flow of conversation was preferred for the purpose of getting a general understanding of the domain from the real experts. Table 6 in Section 3.5 provides the list of individuals from six organizations that we interviewed including:

- Rijkswaterstaat Data-ICT-Dienst
- Rijkswaterstaat Water-Dienst
- Departmental Coordination Centre-VenW
- Water board De Dommel
- Water Net
- TNO-ICT

Almost all the interviews were focused on the prepared questions with an exception of the interview with individuals from TNO-ICT. The interview with individuals from TNO-ICT mainly aimed at sharing the thesis subject and get comments on how to approach the project. Among the questions that were asked during these interviews are summarized in Table 24:

<table>
<thead>
<tr>
<th>Element</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>What type of data is needed in the domain?</td>
</tr>
<tr>
<td></td>
<td>• Water level data</td>
</tr>
<tr>
<td></td>
<td>• Waves data</td>
</tr>
<tr>
<td></td>
<td>• Rain data, also from the German and Switzerland</td>
</tr>
<tr>
<td></td>
<td>• Snow melting data</td>
</tr>
<tr>
<td></td>
<td>• Historical data</td>
</tr>
<tr>
<td></td>
<td>• Elevation or Land height data</td>
</tr>
<tr>
<td></td>
<td>• Land use data</td>
</tr>
<tr>
<td></td>
<td>• Wind (speed, shear), tides, and astronomical tides</td>
</tr>
<tr>
<td></td>
<td>• Satellite data + combined with in-situ data -location data.</td>
</tr>
<tr>
<td></td>
<td>• The topography of the river</td>
</tr>
<tr>
<td></td>
<td>• Flood vulnerability data including: number of people, the economic value and/or ecological values</td>
</tr>
<tr>
<td></td>
<td>• Infrastructure</td>
</tr>
<tr>
<td>Data sources</td>
<td>• KNMI - meteo data</td>
</tr>
<tr>
<td></td>
<td>• Rijkswaterstaat - waves and water level data, elevation data</td>
</tr>
<tr>
<td></td>
<td>• Municipality - the local land use data</td>
</tr>
<tr>
<td></td>
<td>• The water boards - water level data, discharge of river and</td>
</tr>
<tr>
<td>Organization/Department roles &amp; responsibilities</td>
<td>What are the main tasks of your organization?</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
</tbody>
</table>
| Rijkswaterstaat                               | • Water level forecasting and warning - mainly done by the water dienst and the regional offices  
• Storm forecasting - mainly done by the Storm Warning Service (SVSD)  
• Flood Protection |
| The Departmental Coordination Centre within the Ministry of Transport, Public Works and Water Management | • Tasks fall under the safety chain links: pro-action, prevention, preparation, response and recovery or post event.  
  - Main tasks: preparation and response for a disaster  
• Crisis management including:  
  - Consistent crisis management  
  - Coordination the crisis process  
  - First contact for crisis and major incidents within the Ministry  
  - Information Coordination  
  - Interdepartmental coordination with other ministries  
• Conduct trainings and exercises |
| The Dommel water board                        | • Involved in the 4 safety chain links: pro-action, prevention, preparation, response.  
• Spatial planning role: as any other water board, the Dommel is responsible to deliver information every 6 years for which areas will be flooded now and in the future  
During flooding  
• Implementing good water management such as pumping out additional water  
• Delivering flooding information about which areas will be flooded and when will they flood |
| Water Net                                     | • Responsible for the whole water chain which involves: Drinking water, waste water and water from canal.  
• It is involved in the whole water system which involves: water quality and water quantity.  
• Manage the polders |
| Collaboration with other parties              | The Departmental Coordination Centre within the Ministry of Transport, Public Works and Water Management  
Collaboration with other centers within the Ministry of Transport, Public Works and Water Management such as:  
• The Departmental Coordination Centre  
• The Shipping Center  
• The Traffic Center  
• Rijkswaterstaat Regional Departments  
Collaboration with other organizations such as:  
• The municipalities  
• The safety Regions  
• The water boards |
### Applications

<table>
<thead>
<tr>
<th>What applications or information systems exist in the domain?</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Databases for: meteo information from the Netherlands, but also rain from German and Belgium, Hydro information, Wind information e.g. wind speed, wind shear is important for predictions along lake IJsselmeer and north sea</td>
</tr>
<tr>
<td>- Flood early warning system (FEWS) is used by Deltares to collect information and prepare the forecast models.</td>
</tr>
<tr>
<td>- Fair way Information System (FIS) is going to replace BC2000 which was used for communication during high water. FIS is an EU directive standard.</td>
</tr>
<tr>
<td>- FLIWAS (Flood Information and Warning System) – provides water level information (monitored measurements and forecasted), Incident and evacuation plans, Flood forecasting, Risk maps, 2D flooding models, Evaluation.</td>
</tr>
<tr>
<td>- Infraweb</td>
</tr>
</tbody>
</table>

Table 24: Summary from the interviews
B Scaling up diagram for river flooding

Organisational (and administrative) scaling up bestuurlijke (operatieve)

- RWS RDs/water board councils: Normal control
- Organisational (and administrative) scaling up bestuurlijke (operatieve)
- Water sector (operational): National contact and water board councils: Normal control
- General sector: (administrative) • Director safety region • Queen's Commissioners • Ministry
- Pre-warning in connection with preparations for evacuation
  • RWS: DZK
  • RWS: DCC
  • Director Safety regions
  • Queen's Commissioners
  • Ministry
- Pre-warning at water level: Alarm at water level
- Determined action

Informative scaling up

- RWS RDs/water board councils: Preparation crisis organization
- Water sector (Administrative): Director Board of DOCC & NOCC
- General sector: (administrative) • Director safety region • Queen's Commissioners • Ministry
- Pre-warning in connection with preparations for evacuation
  • RWS: DZK
  • RWS: DCC
  • Director Safety regions
  • Queen's Commissioners
  • Ministry
- Pre-warning at water level: Alarm at water level
- Determined action

Figure 63
C An Explanatory Case

Pro-action

According to the interview conducted with the Dommel Water board, the water boards are required every 6 years to provide a report of the possible future flooded areas and about their spatial plans. In order to provide such a report, they perform flood analysis. The result of flood analysis is a report, which can aid in the formation of a map, showing the possibility of flooding in certain areas, for instance in the coming 100 years. Among the data that the water boards need to perform flood analysis include the following: the average rainfall data obtained from the Royal Dutch Meteo Institute (KNMI), elevation data which obtained from Rijkswaterstaat and the internal data that comes from the water boards themselves such as different flooding scenarios.

Based on flood analysis, the Water boards develop spatial plans. Spatial plans are one of the measures that can be taken to reduce the risk of flooding and protect water resources. Spatial measures address land use, and exclude the construction of built-up areas in sensitive locations and changes in land use so that the area can also be used as an artificial water basin, etc., when necessary. For making spatial plans, the water boards also gets inputs from the European Commission located in Brussels and from the Ministry on the policy issues that should be taken into account.

The water boards send their reports to the municipalities and the provinces. These authorities use the water board’s reports to make land use plans. Land use authorities: the municipalities, the provinces or the national government can initiate land-use change, for example, the development of urban areas, infrastructures, or natural environments. In order to implement land use change, the initiator has to develop a land use plan. Among the things needed to assess a land-use plan is the Water Assessment Test (WAT). The WAT is a general framework for assessing land-use proposals. The WAT framework consists of a checklist and a clarification of the roles of the actors involved. The framework includes all relevant water management aspects (flood protection, water quality and depletion). A WAT has three types of actors: the initiator, the advisor and the reviewer (Voogd 2006).

The initiator is the land-use authority that wishes to implement a land-use change, for example, the development of urban areas, infrastructures, or natural environments. This can be a local, regional or national authority. As already mentioned, this can be the municipality, the province or the national government. However, the initiator can also be a private organization. In such cases, the responsible public authority (municipal, provincial or national) performs the WAT.

The advisor is the water authority with jurisdiction: the water board, groundwater authority or national Rijkswaterstaat. The water authority assists the land use authority in conducting the water assessment test. If water management priorities (collect, store, and discharge) cannot be realized, explanations must be provided and compensatory measures taken. The water authority proposes mitigation and compensation measures that can be taken. The water authority then advises the land use authority on how the water management aspects can be incorporated. However, it is the responsibility of the land use authority to decide whether to incorporate the proposed mitigation and compensation measures.

The land use decision then has to be reviewed according to urban and regional planning legislation. For example, the provincial authority reviews land-use decisions taken by municipal authorities. Finally, the land use authority can implement the land use plan.
Prevention

Without flood defenses such as dikes and dunes, more than half of the Netherlands would be regularly inundated. So, the extensive system of flood defenses is essential to the safety and habitability of the country and an absolute precondition for healthy economic development.

There are two main categories of flood defenses in the country: primary and secondary flood defenses. All flood defenses structures along the major rivers of the Netherlands and the area around Lake IJsselmeer (including Lake Markermeer) and the delta are part of the primary flood defense system. The total length of these primary flood defenses is over 4,000 km, consisting of dikes, dams and dunes; they include over 800 structures such as pumping stations, navigation locks and quay walls. These defenses are managed 90% by the water boards and 10% by Rijkswaterstaat (Bake and Wolters).

All other flood defense structures are generally identified as regional or secondary flood defense structures (Rijkswaterstaat 2006). There are 14 000 km of secondary flood defense structures, including regional river dikes (for the smaller rivers), storage basin dikes, dikes/flood defense structures used to separate areas with different functions (compartment dikes), polder dikes and dikes/flood defense structures dividing differences in ordnance datum, all of which are managed by the Water boards (Rijkswaterstaat 2006).

These flood defenses have been constructed according to specific standards. For instance, the safety standard for the primary flood defenses ranges between 1/250 per year (upriver) and 1/10,000 (coast) per year (Rijkswaterstaat 2006). This safety standard is defined as the probability of exceedence of the hydraulic conditions.

In order to achieve the same level of protection against flooding, the flood defenses need to be maintained in the future. The Water Embankment Act requires the water boards and Rijkswaterstaat to report on the safety assessment of primary flood defense every 5 years. The safety standard that includes guidelines (VTV) and hydraulic boundary conditions (HR) for safety assessment is established by the Directorate General Water within the Ministry of Transport, Public Works and Water Management. The water boards and Rijkswaterstaat conduct the safety assessment. During the assessment, they check whether the strength of the flood defenses meets the statutory safety standards(Bake and Wolters). The assessment of a flood defense can lead to three categories: the flood defense “meets” the standard, the flood defense “does not meet” the standard, or because of insufficient information “no judgment” can be made.

The water boards and Rijkswaterstaat send their assessment reports to the provincial authorities that make an assessment, which is then attached to the reports and submitted to the Minister of Transport, Public Works and Water Management. Based on its independent position, the Transport and Water Management Inspectorate evaluates whether the assessment or management has been conducted in accordance with the regulations (this is known as official judgment). The results are summarized to create a national picture and analysis is provided together with its findings and conclusions. The Transport and Water Management Inspectorate submits this report to the Minister of Transport, Public Works and Water Management. Based on the summary, the minister informs Parliament about the state of all the primary flood defenses in the country and draws up a program of improvement, known as the Flood Protection Programme, based on the results.(Inspectorate September 2006).
During the safety assessment period, preventive maintenance can be performed when the condition of flood defense seems to be threatening. Such maintenance can be called “variable maintenance,” as it is performed after the safety assessment when the condition of flood defense is identified to be threatening. However, there might be a fixed maintenance, performed in particular time interval to ensure good condition of flood defenses. For the maintenance to be implemented, a maintenance plan has to be developed. Such a plan includes things like an area that will be maintained, the equipment that will be used, personnel, maintenance period and maintenance cost. The maintenance plan needs to be approved before the maintenance is implemented.

As already mentioned, an improvement program is drawn based on the safety assessment results. In order to conduct an improvement program, an improvement plan has to be established. This plan can be established by the flood defense manager, the water board or Rijkswaterstaat. The improvement plan contains the necessary project provisions as well as mitigating and compensating measures for damage done. Moreover, the plan clarifies which measures will be taken to promote the values of landscape, nature, and cultural heritage, the so-called LNC-values (Olsthoorn and Tol February 2001). The established plan has to be approved by the province involved (Olsthoorn and Tol February 2001) before the improvement is implemented. The flood defense improvement implementation has to be inspected to check whether the improvement is done according to the established and approved plan. The flood defense inspection role is the responsibility of the Transport and Water Management Inspectorate

Preparation

Flooding in the Netherlands is fortunately rather uncommon. This means that the practical knowledge of how to deal with threats of extreme floods and actual flooding is limited. To raise preparedness among all parties involved in flood response and recovery, flood disaster plans or high-water plans are prepared. In addition to the flood disaster plans, training is organized within individual groups with a role in the decision-making chain to practice skills related to their individual task.

The government authorities (i.e. municipality, region and province) are responsible for the preparation and updating of flood disaster plan or high-water plan. Such plans need to be checked periodically for reviews.

A good example of a region in the Netherlands with such a plan is the region of Nijmegen (Bezuyen, MPA et al. Winter 1998). Because of the possibility of floods and the threat of a dike breach, a disaster plan was developed for the region of Nijmegen in the early 1980s. After the flood of 1993 from the river Meuse and the fact that there appeared to be real threat of weakening and breaching of the dikes along the river Waal, the board of mayors from the region decided to update the plan. At the end of 1994, this model was accepted and sent to other regions in the province. Although the other regions had not formally accepted this plan before the 1995 flood occurred, most of the regions could use it as a guideline for their response to the flood. Among the issues dealt in this plan include the following: inundation scenarios, evacuation planning for persons, evacuation planning for animals, communication plan and information for the population. Because the region was well-prepared, it was possible to evacuate about 60,000 people in the region of Nijmegen. The successful evacuation of Nijmegen gave confidence to the other regions that an evacuation of a large number of people was possible.

Apart from the regional flood disaster plans, the National High Water and Flooding Emergency Response Plan has been developed recently (BZK January 2007). Such a plan was
deemed to be necessary in the event of high water. The (impending) disaster will strike multiple regions simultaneously, and regions that are not hit will also be involved in coming to the aid of the affected regions and in the care of people evacuated from the regions. Here, the preparations confined to municipal or regional level are insufficient.

As already mentioned, training is also used to raise preparedness among parties involved in flood response and recovery. By implementing multidisciplinary training courses and large-scale exercises, the government is ensuring that relief workers can acquire the right kind of knowledge and skills for potential disasters, so that when needed, they can carry out their tasks efficiently and effectively. Training is also used to test the established flood disaster plans or the high-water plan. Tests will always be needed to establish whether the established plans work, which is why exercises are the final step in effective preparations.

For example, in November 2008, large-scale training was conducted in the Netherlands that involved many stakeholders in the water domain and safety domain. The Flooding Taskforce Management (TMO) was in charge of organizing the large-scale flooding exercise in November 2008. Large-scale training sessions are infrequently conducted, as compared to small-scale training sessions. Due to the importance of training for disasters in the Netherlands, several training institutions recently combined forces and founded a consortium to provide training courses to anyone involved in disaster control or crisis management. This consortium includes Bestuursacademie Nederland (BAN), Crisis Onderzoek Team (COT) of the University of Leiden, Nederlands Bureau Brandweerexamens (NBBe), Nederlands Instituut voor Brandweer en Rampenbestrijding (Nibra), Politie Instituut Openbare orde en Veiligheid (PIOV), and Stichting Opleiding en Scholing Ambulance Hulpverlening (SOSA) (Interior Affairs).

After the training has been conducted, an evaluation regarding measures and the whole flooding process has to be performed. The evaluation is important since during training or a real flood crisis, a new scenario may unfold that was not in the flood disaster plan. As a result, it may take a long time to figure out who could resolve issues presented during such a scenario and how those issues could be resolved. If necessary, and when it is foreseen that such a scenario can happen again in the future, the manager of the flood disaster plan may decide to update the existing flood disaster plan to include the new scenario.

Response

The response phase deals with operations that are directed at managing, containing and combating the consequences of an imminent flood (also referred to as high water) even before the actual flood has occurred. High water occurs when the water rises above a specific pre-defined level; the water defenses have not yet been breached. Although in this situation the disaster has not (yet) taken place, it is considered a crisis situation and large-scale action is taken: full crisis control measures are mobilized (pre-crisis response). This situation thus differs from that of many other types of emergencies (post-crisis response). High water can, but not necessarily, be followed by flooding. In this phase, we will consider actions that are taken not only during the actual flood, but also during an imminent flood.

Therefore, we can say that the response phase starts when a flooding event is predicted through flood forecasting activity. The Inland Information Centre within RIZA, Rijkswaterstaat Regional Departments and the water boards are responsible for daily water level measurement and water level forecasting at the national, regional and local levels, respectively. Under normal conditions, water level forecasting is done every morning, mainly for the benefit of navigation. In times of flood, forecasts are made at least twice a day, again
for navigation but also for river management authorities, crisis organizations and population (Sprokkereef 2001).

Among the data needed for flood forecasting is the data about water level measurements and weather forecasts. The water level measurements are collected every 10 minutes by the Geo-Information Department. The Royal Netherlands Meteorological Institute (KNMI) provides weather forecasts on an hourly basis to government agencies, commercial weather bureaus, broadcasters and media (SGI).

Flood forecasting organizations mentioned above use a high-water scaling up procedure as a guideline to initiate crisis actions. This procedure shows what actions can be taken when a certain water level is reached and/or expected to increase. A scaling diagram with regard to river flooding is provided, and the flooding scenario is provided in appendix B.

After a flooding event is predicted, the forecasting authorities warn water management authorities and/or crisis organizations according to the high-water scaling level. Operational high-water management is among the activities that are initiated early when a flooding event is predicted. The water boards and Rijkswaterstaat are responsible for the operational high-water management. They can propose several operational high-water management measures such as pumping out of water, deciding to flood a certain retention area, etc. The effects of the proposed measures are analyzed in advance before they are selected as the right measures that will be implemented.

Another activity that is also initiated during the early stages of a flooding event is the periodic monitoring or inspection of flood defense such as dikes. The information about the condition of dikes is important for initiating actions like evacuation. It is the role of the water boards to provide the information about the condition of the dykes to other crisis organizations. To do that, the dyke guards are called to inspect the conditions of the dykes. Based on the inspection, or because of known condition of the dyke, the water boards can initiate temporary dyke reinforcement measures such as sandbagging. Because a lot of manpower is needed to perform sandbagging activity, the water boards request additional help from the local people and the army.

During a flood crisis, operational effort needs to be coordinated. At the national level, LOCC is responsible the efficient, coordination of manpower, resources and expertise (the fire service, police, emergency medical aid (offered by the GHOR) and Ministry of Defense) if there is a threat or acute serious crises. Regionally, the coordination of operation efforts is the responsibility of the Regional Operation Team (ROT). Therefore, in case a flood crisis is coordinated nationally, it is the responsibility of LOCC to ensure the availability of operational resources. To achieve that purpose, LOCC periodically analyzes operational resources by checking what resources are available, where these resources are and how many resources are needed. In case of insufficient operational resources, LOCC drafts an advice report requesting additional resources. The decision for additional resources is taken at the Inter Ministerial Policy team meeting (BZK January 2007).

Once a flooding is predicted, people need to know about the possible flooded areas and the time of the flooding. This information is provided locally by the water boards. At the national level, the National Flood Threat Coordinating Commission (LCO) becomes responsible. LCO is activated and managed by the Departmental Coordination Centre within the Ministry of Transport, Public Works and Water Management. The water boards and LCO perform an analysis for the possible flooding areas and flood break time. In order to perform the
analysis, a combination of information is required including the water level measurements, weather forecast, flood forecast and the condition of the threatened water defenses. Based on their analysis, the LCO advises the Inter Ministerial Policy Team and the Ministerial Policy Team of the chance that the threatened area will actually be flooded, the size of the (potential) flood area and the time left before the flood breaks (BZK January 2007).

In addition to the prediction of possible flooded areas and flooding time, the effects of flooding in terms of casualties and economic damage in the predicted areas need to be analyzed in advance. This information is important to initiate actions that aim to reduce flooding effects such as evacuation. The municipalities perform both the causality analysis and economic damage analysis.

Due to the possibility of flooding, evacuation preparations are initiated. On one hand, some authorities are responsible for the preparations of evacuation implementation. In doing so, they develop an evacuation plan and prepare resources needed for the evacuation purpose. Among the things included in the evacuation plan are the required evacuation time, the exit points and evacuation routes that people can take to evacuate from the flooded area. An evacuation plan and evacuation process discussed here is a general one. However, specific evacuation plans must be integrated together. For instance, these plans may be specific for population in a threatened area without a need of assistance, the population in a threatened area with the need of assistance (e.g. the nursing homes, the patients in hospitals), prisoners and animals.

On the other hand, some authorities are responsible for checking whether an evacuation has to be done. In doing so, an evacuation decision-making process is initiated. At the national level, if a disaster affects more than one province or country, the Minister of Interior Affairs decides on evacuation. If a disaster affects a single province, the Queen’s Commissioner can decide to evacuate the population. Regionally, if flooding affects more than one municipality, the appointed coordinating Mayor within a region can decide on evacuation. Locally, when a single municipality is affected, moreover, and this is very rare for a flooding disaster type in the Netherlands, the Mayor of the municipality could decide on the evacuation.

Let’s consider a flooding crisis coordinated at the national level. Therefore, the evacuation decision is made by the Ministry of Interior Affairs. He does this after consulting with the regional authorities and Queen’s Commissioners and discussing the decision in the Ministerial Policy Team meeting. Among important information needed for evacuation decision making is the available time (i.e. the time from the moment of the warning to the anticipated moment of flooding) and the required time (i.e. the time required to evacuate all inhabitants from the disaster area). Depending on the way in which these timeframes interrelate, the Minister of Interior Affair will decide whether or not to evacuate wholly or partially on the ground of the Population Evacuation Act (BZK January 2007).

Once an evacuation has been decided, some relief activities will focus on implementing the evacuation, some relief activities will focus on measures to manage or cordon off the area (prevent further disaster after the flood), while other relief activities in the non-threatened regions/provinces will focus on setting up shelters, implementing shelter care measures and registering evacuated victims. LOCC coordinates all these activities. In doing so, LOCC mobilizes the necessary operational resources required for carrying out these activities.
Moreover, traffic control measures need to be implemented in case a large-scale evacuation is implemented. Without implementing traffic control measures, it may be impossible to evacuate a large population within a certain time limit.

Recovery

As already mentioned, the recovery activities ensure that the affected population can return to its normal routines. Recovery operations should commence as early as possible during flood response operations. Therefore, it is important to note that the links in the safety chain approach are not sequential. They can be regarded as aspects of management, not phases.

While in evacuated shelters, people register for damage settlement and the damage claims are organized. This registration is done by the Central Damage Registration and Reporting Point (CRAS) team. The state government is responsible for the claim payments (BZK January 2007).

Another concern during this period is the restoration of flood defenses to normal operations. In doing so, the repair of failed flood defenses is initiated. Each repair has to be planned. Among the things that are included in the repair plan are resources that will be used and the cost of repair. The developed repair plan has to be approved before the repair work is implemented.

Moreover, other authorities research when people can return. The water board councils and LCO perform the return analysis. Based on their analysis, LCO provides advice to the Ministerial Policy, which then decides on scaling down crisis activities in consultation with the highest administrative parties. Based on the LCO’s advice, the Ministry of Interior Affairs can decide whether to return evacuated victims to their original homes; LOCC coordinates the return. In doing so, LOCC mobilizes operational resources needed for implementing the return activity.

Finally, the whole flood crisis has to be evaluated, regarding measures taken. An evaluation document will provide an insight and can be used to provide lessons to all the organizations that were involved during the crisis. Such lessons can be used to update existing flood scenarios as well as the flood disaster plan or high-water plan.
D Thesis Result Discussions & Feedback

During this research, I have investigated what Enterprise Ontology for the Flood Control Domain entails, of which essential operations it consists, the interrelationship between the essential operations, the information objects required for the operations of flood control organizations and how the enterprise ontology is used in the Netherlands and in the USA. I started this research because the Advanced Water Management Team was curious about the Flood Control Domain and wanted to get an understanding of the domain in terms of operations performed in the domain not only in the Netherlands but also in the USA. The team was also interested in applications used in the domain both in the Netherlands and the USA, but due to time limitation this was agreed not to be the scope of this project. However, a little analysis about the applications used in the Flood Control Domain for the Netherlands was done and can be seen in Appendix E. Accordingly, the main objective of this thesis project was “Develop an enterprise ontology for the Flood Control Domain and illustrate its use in the Netherlands and the USA.”

In order to reach the objective, three research methods were used: literature reviews, interviews and a case study. The interviews were conducted with the experts in the Flood Control Domain in the Netherlands. Through these interviews, I was able to gather a lot of information that helped me to model the Flood Control Domain. These interviews also aimed to familiarize the interviewees about my thesis project and to request from them future participation in this project in case any question arose during the project and for me to share and discuss my thesis results at the end of the project. The thesis results were presented to the experts in the Flood Control Domain in the last month of this project.

On 4th August 2009, I had an opportunity to present my thesis results to Drs. Ben Knikman, a senior advisor and a specialist in Enterprise Architecture at Rijkswaterstaat Data-ICT-Dienst, Delft. Then, on 11th August 2009, I had an opportunity to present my thesis results at Rijkswaterstaat, Lelystad to approximately fifteen people from different Rijkswaterstaat departments. This meeting was organized by Teunis, Boris from Rijkswaterstaat Water Dienst, Lelystad. The next presentation is scheduled for the IBM Advanced Water Management Team on 25th August 2009.

Some of the issues discussed with flood control experts and the feedback on the thesis results are discussed below.

The main aim for presenting the thesis project to the experts in the domain was to be able to share the thesis results and get feedback about the thesis work from them. Among the issues discussed in these meetings is the possible use of the developed enterprise ontology. The following usability was discussed:

- The developed enterprise ontology can be used to provide a shared understanding of the Flood Control Domain. The experts haven’t seen such a conceptual picture of the Flood Control Domain before. However, many experts have a conceptual picture of the domain in their minds; but not shared.
- The developed enterprise ontology can be used to identify applications to execute identified transactions. With the knowledge of applications used both in the Netherlands and the USA, an application gap can be discovered and hence learn from each other on how to improve.
• The developed enterprise ontology can be used as a starting point to develop ideal enterprise ontology for the Flood Control Domain which different countries can use for comparison and hence improve their flood management activities.

• The developed enterprise ontology models can be used to support the ongoing development projects within Rijkswaterstaat as the model can help the developers to concentrate on certain specific areas or processes. In these developments, transactions could be mapped to the functionalities needed by an application.

• The developed enterprise ontology models can be used to support decision making in time of crisis for instance in the ongoing development of Flood Control Room.

• The developed enterprise ontology models can be used to optimize data use and re-use data.

Apart from the discussion about the possible use of the developed enterprise ontology for the Flood Control Domain, the participants were interested with the Action model since this model could describe the rules by which and reasons for which a certain organization to act. Moreover, the participants were interested with the implementation details of the developed enterprise ontology. Their interests were expressed with the following questions:

• How can you compare the performance of the two countries (i.e. the Netherlands and the USA)?
• How efficient is the Netherlands with enterprise ontology implementation?
• How are the failures of communication lines addressed in the developed enterprise ontology?
• What is the next step of this thesis project?

In addition, the discussions conducted with flood control experts provided several points of improvements for the developed enterprise ontology for the Flood Control Domain. Through this discussion, the participants commented on the following issues that the models need to specify in details including

• Evacuation of animals, sick people and prisoners

• The collaboration between countries in response to flooding.

Now, for instance several European countries can assist each other when a flood occurs. For instance, there is cooperation between the Netherlands, Poland, Germany, Estonia and the United Kingdom. The organizations in the partnering countries are expecting to participate in an exercise called Floodex which is planned to be conducted in September 2009 in order to test coordination of international civil protection (http://www.floodex.eu/subjects/floodex). The National Operations Centre has been assigned by the Netherlands Ministry of the Interior and Kingdom Relations to coordinate the EU Floodex 2009 exercise.

• The additional data needed by specific actors
<table>
<thead>
<tr>
<th>Actor role in Construction Model</th>
<th>Data needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Monitor (A74)</td>
<td>• Evacuation plan</td>
</tr>
<tr>
<td></td>
<td>• Shelter location</td>
</tr>
<tr>
<td></td>
<td>• Flooded roads</td>
</tr>
<tr>
<td>Return Analyst (A83)</td>
<td>• Damage assessment of evacuated area</td>
</tr>
<tr>
<td>Flood Forecaster (A34)</td>
<td>For floods from the sea:</td>
</tr>
<tr>
<td></td>
<td>• Wind direction</td>
</tr>
<tr>
<td></td>
<td>• Astronomical tide</td>
</tr>
</tbody>
</table>

The developed conceptual models for the Flood Control Domain were improved based on the feedback obtained from the flood control experts.

In general, the flood control experts to whom I presented the enterprise ontology for the Flood Control Domain were impressed with the results, felt the developed enterprise ontology to be rather complete and were interested to see what the next steps are.
Applications used in the Flood Control Domain in the Netherlands

1. Flood Early Warning System (FEWS)

Background
After the floods of 1993 and 1995 in the Rhine basin, the ICPR Action Plan on Flood Defense (ICPR, 1998) was drawn up, after which the environmental affairs ministers of the Rhine riparian states agreed on several measures on the subject of improvement of flood forecasting and warning systems in the Rhine basin. One of the targets of this action plan is the extension of the forecasting period for reliable flood forecasts in the entire Rhine basin. For the Dutch gauging station Lobith on the German-Dutch border the forecasting period should be extended from two days to three days in the year 2000 and to four days in the year 2005.

Water level forecasts for Lobith are made by the Institute for Inland Water Management and Waste Water Treatment (RIZA). Under normal conditions this is done every morning, mainly for the benefit of navigation. In times of flood, forecasts are made at least twice a day, again for navigation but also for river management authorities, crises centers and population. Flood forecasts are made when the water level at Lobith is above 14.00 m +NAP and expected to rise above 15.00 m +NAP (the mean level at Lobith is approximately 10.00 m +NAP).

Until 1999 water level forecasts for Lobith were made with a simple statistical model based on multiple linear regression technique. The model uses present and antecedent water levels of the Rhine and its main tributaries, observed and forecasted precipitation for the German part of the Rhine basin. In most cases the forecasts for the first two days were within the desired accuracies. The three and four-day forecast however were not suitable for publication.

To achieve the goal of the Action Plan for the year 2000 a new forecasting system called FloRIJN was developed in the period between 1995 and 1998. This system consist of a combination of a hydrodynamic model of 250 km of the German Rhine from Andernach to Lobith, two rainfall-runoff models for the tributaries Sieg and Lippe and a sub model, computing lateral exchange between river and groundwater. The FloRIJN system proved to be capable of producing a reliable three-day forecast during some minor floods at the end of the last century.

To meet the requirements for the year 2005, further efforts are needed. In order to meet the requirement for the year 2005 which means producing reliable 4 days forecast, the Flood Early Warning System (FEWS Rhine) was developed in the period 2000 – 2001 with financial support of the EC within the framework of the Interreg program IRMA-SPONGE.

Development of FEWS
The development of Flood Early Warning Systems (FEWS) is an essential element in regional and national flood alert strategies within the Rhine basin. Within the IRMA-SPONGE framework RIZA, FOWG, WL|Delft Hydraulics and SMHI developed two FEWS prototype systems, one for the Rhine basin upstream of Basel (CH) and one for the Lobith gauging station. The aim of the last one is to provide flood forecasts at the Lobith gauging station for four days in advance.

The key elements of a forecasting system operating in a real time environment are:
- Real time data acquisition for observed meteorological and hydrological conditions;
- Hydrologic and hydraulic models for simulation;
- Forecast of meteorological conditions;
- Updating and data assimilation.

Figure 64: illustrates the procedures that are necessary to provide end-users with a flood warning.

FEWS-RHINE provides information on the current state of the water system within the Rhine basin, as well on the precipitation, snow line, and temperature. It forecasts the discharge and water levels at specified locations up to four days. To explore the uncertainties it also allows the user to explore the effects on the water levels and discharges of uncertain rainfall and temperature forecasts.

**FEWS Components**

FEWS-RHINE is build from a series of integrated components, which all provide a specific service. This is illustrated in figure 65.
FEWS components can be briefly described as:

1. **FEWS Database and Database module**
   The core modules of the FEWS are the “FEWS Database” and “Database module”. These modules are responsible for the integration of all sorts of data, e.g. time series data, spatial grid data or model schematizations, and control the data flows within the FEWS. The “Database Module” has an interface through which all other modules communicate with the “FEWS Database”.

2. **Import module**
   The “Import module” reads the on-line available meteorological and hydrological data from external databases. It can handle time series - e.g. from hydrological gauging station data - as well as grid data e.g. weather forecast data provided by meteorological services. Hourly data for temperature, precipitation, water levels and discharges are stored for further use in the FEWS-RHINE database.

3. **Validation Services**
   Imported data should be carefully validated before proceeding with forecasting. The generally large amount of data that is usually imported requires that validation is done at least partly automatically by the system, only warning the user when pre-set criteria are not met. Standard imported data is checked for missing values, outliers and unlikely gradients in time. The user receives a message when such suspect data series are imported. The stations whose data contain such suspicious values get an icon in front of their station name in the location list in the main window. These icons also appear on the map.

   The system automatically completes series with missing values by either interpolation in time or in space.
4. **Interpolation Services**

The Interpolation module generates new data by means of serial or spatial interpolation. It is applied for filling in of missing data in measured on-line data as well as to derive spatially distributed data on meteorological variables like precipitation and temperature based on point information. Within the FEWS-RHINE only spatial interpolation is used.

The spatial interpolation procedures allow for filling in of missing data and provide variable values at locations for which no measurements are available. The basis for the spatial interpolation calculations is an irregular grid with so-called “interpolation points”. For each of these points the latitude, longitude and altitude are known relative to an ordnance datum such as mean sea level. The Interpolation module offers procedures to interpolate to this irregular interpolation grid from for example meteorological monitoring station data or grids of meteorological forecasts.

5. **Graphic Services**

After import all data to carry out a forecast are validated and ready for use. The user may wish to view the imported data and eventually to edit these data. All data can be viewed while only the imported measured data can be edited. To view and edit point time series data the user should first choose the variable and station.

6. **Linking of Hydraulic and Hydrological models**

Hydrodynamic models are usually calibrated and run using discharge data of tributaries. Thus, the most basic approach of combining them with precipitation-runoff modeling is to simulate discharge of the gauging stations used within the hydrodynamic models by means of precipitation-runoff modeling. This approach is followed for the gauging stations that are used as point inflow to the hydrodynamic Sobek model.

To link the HBV models to the FEWS shells are built around the cores of the hydrological HBV and hydraulic Sobek models. These shells are referred to as wrappers. Wrappers are included in FEWS-RHINE to allow later for integration of other models when necessary.

The primary task of the wrappers is to arrange the communication between the models and the other components of the FEWS. A wrapper transfers data from the FEWS database to the model file format, maintains the files required for running the models (initial conditions, lateral flows, etc.), starts the model, and eventually transfers of results from the model file format to the FEWS database.

![Figure 66: Model wrapper tasks](image-url)
The wrappers are generally, model dependent because each model system has its own input and output file formats. However, once a wrapper is developed for a specified modeling system, it can be applied for all models developed with this modeling system.

7. **Report Services**

The “Report module” generates output from the FEWS. It provides standard output formats that are used by RIZA and FOWG.

**Dissemination of forecasts**

In case of a flood on the River Rhine, information bulletins containing water level forecasts are disseminated by RIZA at least twice a day. The users of this information are the Crisis Centers on national, provincial and regional levels, the press and the public.

For dissemination of this information use is made of telephone, telegrams, telefax and the Monitoring System Water Levels (MSW), a computer program that allows authorized users to consult a central database for hydrological data. For the population, forecasts and flood warnings are published on the internet (http://hwg.waterland.net/hoogwater1/) and on teletext.

The exceedence of the water level of the Rhine at Lobith of 16.50 m +NAP is considered as an emergency situation. The protection of the population has the highest priority and the government, at different levels, puts Coordinating Crises Centers into operation and prepares decisions regarding immediate support actions or evacuations.

2. **The High Water Information System (HIS)**

HIS was initiated after the floods of 1993 and 1995. HIS is developed by the Road and Hydraulic Engineering Division (DWW) division of Rijkswaterstaat (part of the Dutch Ministry of Transport, Public Works and Water management). The Provinces and Water boards are responsible for providing the HIS with data from their own regions and also for the implementation of the system. The first version of the HIS was completed in 2001. Target group of HIS is the Dutch national government, provinces and Water boards.

**Objectives of the HIS**

The High-water Information System (HIS) is designed to provide the information needed to support the combating of disasters in a user-friendly way. HIS objectives are:

- Improved information supply during high-water situations (unambiguous and reliable)
- Insight into the seriousness of a high-water situation (threatened flood defences)
- Insight into the possible consequences of a flood
- Supportive instrument for decision makers / flood managers
- Support the flood preparation phase (development evacuation plans)

**Application of the HIS**

The HIS can be used in various phases of the chain of safety:
• Spatial Planning & Prevention phase
The policy component of the HIS can be used during the pro-action (spatial planning) and prevention phase. Calculations with the modules have been made for different studies concerning possible retention areas, flood risks (Flood risk and safety in the Netherlands: FLORIS), for the political safety discussions and for spatial planning in general. The provinces and water boards involved mainly carry out the necessary calculations.

• Preparation phase
HIS can also be used during preparation phase, where contingency plans are made in order to reduce possible damage in case of floods. Contingency plans can be based on scenarios calculated with the policy preparation part. In the preparation phase the HIS can also be used for training and the HIS project will participate in large scale calamity trainings, organized with other projects.

• Response
In the emergency response phase the operational part of HIS provides the needed information for provinces, water boards and national government, in particular. During this phase, the HIS combines the information concerning flood levels and predictions with the conditions of the flood defenses and informs about the currently threatened areas. This information is supplied to the bodies responsible for public order and safety. The latter consist of the National Coordination Centre, Departmental Coordination Centre, Provincial Coordination Centers, Regional Coordination Centers, the municipalities and operational services.

Components of HIS

The HIS consists of two components: Operational component and Policy component (See Figure 67).

<table>
<thead>
<tr>
<th>Policy Component</th>
<th>Operational Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood module</td>
<td>Monitoring module</td>
</tr>
<tr>
<td>Simulates the effect of breach of dikes</td>
<td>Indicates the risk of breaching of dikes</td>
</tr>
<tr>
<td>Damage and Casualty module</td>
<td>Log book</td>
</tr>
<tr>
<td>Calculates the possible consequences of breaching dikes</td>
<td>Records Observations and Reports</td>
</tr>
<tr>
<td>Evacuation module</td>
<td></td>
</tr>
<tr>
<td>Gives information for evacuation plans</td>
<td></td>
</tr>
</tbody>
</table>

Figure 67: Components of HIS
1. **THE OPERATIONAL COMPONENT**

*Monitoring module*

The monitoring module provides a detailed map of measured and predicted water levels. The module can compare the water levels with the height of the flood defenses. Flood defenses that the water threatens to overflow are shown on the map in red. This gives an indication of the flood danger. For a reliable indication the input data must be very up-to-date so therefore the HIS is linked directly to the observation networks and the high-water reporting system. Example of the monitoring module is shown in Figure 68: the dike sections threatened by a measured or predicted water level are shown in red.

![Figure 68: An example of monitoring module](image)

*Logbook module*

The logbook module provides an unambiguous and simple means by which the users can access and record the reports that reach the HIS via the coordination centre during periods with high water levels. This information may include observations of flooding, seepage in the flood defense, or relevant shipping reports and it can be used to assess the danger of flooding.

![Figure 69: An example of a logbook module](image)
THE POLICY COMPONENT

Flood module

The flood module shows what happens when the dike is breached at a specific place: how quickly the polder is filled by water, what place the water reaches first and how deep the water will eventually be. The user enters the position where the breach in the dike occurs and the water level of the river, sea or lake. With the flood module it is possible to estimate what measures will be most effective in limiting the consequences of the breach. Figure 70 shows an example of how inundation occurs after a dyke breach as shown in the Flood Module.

Depth of flood in meters:

- > 4
- 3 - 4
- 2 - 3
- 1.5 - 2
- 1 - 1.5
- 0.75 - 1
- 0.5 - 0.75
- 0.25 - 0.5
- 0 - 0.25

Figure 70: Flood Module
**Damage and casualty module**

The Damage and Casualty Module calculates the consequences of a possible breach in a dike. The user enters the characteristics of the flood, such as the depth of the water and the flow velocity. These can be the results of the Flood Module. Based on the characteristics of the flood, the Damage and Casualty Module calculates the number of casualties and the economic damage (see Figure 73). With the Damage and Casualty Module it is possible to determine how, by taking measures, one can limit the consequences. It has recently become possible to enter the effect of preventive evacuation (result of the evacuation calculator) into the Damage and Casualty module. In this way it is possible to obtain a more accurate prediction of the number of casualties.

![Image of Damage and Casualty Module](image)

**Figure 71:** Example of a calculation with the Damage and Casualty module: the distribution and the extent of the damage and the number of casualties for the scenario entered (in this case the results that are shown in the example of the flood module).

**Evacuation module**

This module has been built to estimate evacuation possibilities, thereby improving the calculation of casualties in the damage- and casualty module. The input consists of the road network in the area, the capacity of the roads and the capacity of the exits. On the basis of this information, the module calculates how much time is needed for the evacuation of all residents, which routes are available and how many people can make use of these.
2. PoldEvac

About PoldEvac

PoldEvac is an IRMA (Interreg Rhine -Meuse Activities) project concerning a decision support system for the evacuation of people and cattle and the possible environmental damage from flooded polders. The project was initiated by the regional Fire brigade of Nijmegen and encloses the Maas & Waal and Ooy-polders in the Netherlands and Germany.

PoldEvac is an acronym for the geo-Spatial Decision Support System (geo-SDSS), for evacuation of inhabitants and cattle out of a flooding polder. PoldEvac system and applications mainly aim to meet demands of decision makers on when and where to evacuate in case of a high flood risk within their jurisdiction(s). PoldEvac addressed not only flooding and evacuation as disaster management issues, but also modules concerning land use planning, object-related storage of hazardous chemicals, simulation of emissions and explosions, standard fire fighting required information and cadastre connected geographically large-scale data handling.

Objectives of PoldEvac

- Knowledge concerning (geo-spatial) information demanded for decision making under (inundation) risk circumstances.
- Insight in the time-tempo flood process in case of a dike breach and a consequent polder inundation. This insight is relevant for all distinguished flood films that is inundation scenarios along the Rhine, Waal and Maas rivers.
- Overview of the consequences of each of the polder inundation scenarios worked out.
- Information regarding land use planning and regulations.
- Awareness of risks by dangerous, hazardous substances present in the (possible flooding) polder areas for environmental and operational disaster reduction workers.

Components of PoldEvac

PoldEvac integrative approach embraced several modules:

1. Extensive large and small geographical scale geo-spatial mapping and data handling
2. Flood modeling and, where and when, ‘time-tempo’ flood films.
3. Traffic and transport network data handling, in combination with an operational dynamic traffic load and accident registration opportunity, save navigation and warn routing.
4. Evacuation module for large scale and pro-active as well as operational traffic calculations
5. Hazardous, chemical substances data handler and (emission/explosion) simulator in combination with related object information.
6. Fire fighting module inclusively information regarding special objects, sirenes, extinguish water resources and hydrant locations, sewerage network and discharge opportunities, and an option for a direct incident locator connected to the control-switch room of the regional fire brigade/safety organization.
7. Land use plan module.
Inundation (Flood Modeling)
The module concerns inundation risk analysis contains a series of time-tempo inundation simulations based upon DelftFLS produced and applied by WL | Delft Hydraulics together with the Bundesanstalt für Gewässerkunde and the Province of Gelderland.

DelftFLS is capable of computing dynamic flow, including transitions from sub-critical to super-critical flow and from super-critical to sub-critical flow as well as the flooding of initial dry land.”

Land use planning
The land use planning and spatial regulations module has more or less an initial status. It is a preparation, which is relevant in connection with the Dutch and German national political view expressed in the words “Space for the river”.

The module includes digital data regarding the so-called detailed land use plans, planning measurement tools such as distance measurement, circle representations, etc., and design tools to be seen as an optional issue.
**Effect analysis**

The effects of inundation are calculated in the PoldEvac system using different flooding scenarios. 68 inundation scenarios have been placed in a library of flood films. With the aid of this library a most fitting film can be chosen in case of a possible dike breach at a certain location.

Effects studied are various, amongst others including units hit by the flood as follows:

- Hectares of land
- Road segments
- Inhabitants
- Cattle
- Buildings and properties
- Monuments
- Special buildings (e.g., museums, archives)
- Dangerous, hazardous substances.

Using effect analysis, PoldEvac shows, according to time-tempo, flood consequences. That is, during the flooding process calculations are executed to ascertain numbers of units, areas, lengths, etc. Beyond effect analysis calculations, detailed object related data is directly retrievable.

**Road network**

The road network module embraces both data handling and analysis. The data handling concerns all road segment and road junction connected data relevant for evacuation and general support to disaster management. Also road profile data have been included.

The analysis included concerns in particular shortest and moreover for fire and disaster fighters safe path ascertainments and the computation of optimal routes for warning purposes.

Moreover, in the case of calamities caused by dangerous substances, that is emission and/or explosion may occur which have geo-spatial effects. Major emission/explosion features are displayed as area extensions that are called damage templates standardized in relation to parameter settings such as volume, density, boiling temperature, reaction characteristics, etc.

**Evacuation**

The integrative part of the PoldEvac concept puts special emphasis upon evacuation. The evacuation module therefore includes the following:

- Shortest time/distance (road network related) areas calculated out of the available exit location of the polder evacuation area.
- Evacuation road network with connected exit locations.
- Municipal or time block area assignments to the evacuation network specified.
- Evacuation movement processes on the evacuation road network in direct connection with time-tempo inundation scenarios or flood films.
- Relation between flooding and evacuation based upon a dry-feet leave approach.
- Capacity oriented approach for the evacuation process over the evacuation road network.
- Traffic flow monitor for the handling of (temporary) traffic barriers caused by e.g., accidents and the ascertainment of a consequent re-evacuation flow pattern.

Figure 73 shows the tracking scheme for the geo-spatial information and decision support system.
Development of PoldEvac to AQUAMARS to VIKING

In 2000, within the framework of preparations for the Interreg III C program, both the Nijmegen Regional Fire Brigade and Compuplan Institute elaborated the PoldEvac concept and prepared a new proposal. This has been submitted as IDMS (Integrated Disaster Management System) to a committee for Interreg preparations (WGBP-2000), in 2003 further elaborated and finally baptized as AQUAMARS (April 2004).

For this water management, evacuation and disaster mitigation and prevention system, development and application were foreseen for the various flood risk relevant regions along Waal, Maas and Ijssel in the provinces Gelderland and Overijssel in the Netherlands and in the Kreis-regions Kleve and Wesel, at the right and left hand sides of the Rhine in Germany.

As objectives have been indicated:
- Development of an instrument useful for disaster management and (after) care, proactive, preventive and preparative, operational and strategic, as well as the collection of all for that purpose required data, detailed, in the whole cross-bordering Dutch and German regions,
- Continuation and further elaboration of and knowledge enhancement through the PoldEvac project particularly with regard to inundation and other environmental disasters, as well as with regard to evacuation and connected decision and policy making.

Development and application of a geo-spatial decision support system for integrative flood disaster management, AQUAMARS, “Water Management Evacuation Disaster System”, concerns therefore the development and application of geo-spatial integrated disaster management and decision support system, in which the emphasis is laid upon: (high) water, flood scenarios and Evacuation.

The system focuses upon high water risks along the mentioned rivers in particular. Moreover it focuses upon risks induced by hazardous chemical substances transported over these rivers or being stored in the living and working areas adjacent to these rivers. The provincial Risk/Safety maps are incorporated in the AQUAMARS system, preferably dynamically updated, instead of the currently more or less fixed (and pitifully incomplete) internet provisions. The foreseen system approach embraces emphatically integration of (geo-spatial) disaster risk estimation, evacuation and (after) care provision, combined with decision support in concern with land use planning, design and regulation, as well as environmental enforcement. It implied simultaneously a shift of digital land use planning into IMRO (Information model for Spatial Planning) coding. AQUAMARS was also a cross-bordering project, and from the beginning of its composition highly supported through the involved German partners.

Due to various external circumstances, the Province of Gelderland decided to upscale the approach, taking the lead coordination, included the three provincial Regional Fire Brigades, re-baptized the Compuplan (IDMS/ AQUAMARS) document into “Verbetering Informatievoorziening in Nordrhein-Westfalen en Gelderland” (VIKING) and limited to small-scaled mapping and the presentation of flood scenarios (time-tempo flood films) only. The evacuation part has been transferred to another Interreg activity, called FLIWAS, and limited to a so-called general traffic-transportation origin-destination modeling, based upon small
scale transportation network using zones or settlements as departure origins. The relationship between PoldEvac, AQUAMARS, VIKING and FLIWAS is shown in Figure 74.

Figure 74: PoldEvac evolving

3. Geautomatiseerd Draaiboek Hoogwater/Automated Flood Contingency Plan (GDH)

Background of GDH
The water boards in the Netherlands are responsible for the performance of flood defense works. They use contingency plans to handle the complex situation during flood threat situations. Depending on the expected water level, responsibilities change and actions have to be taken. Recent flood threat situations both in 1992 and 1995 have caused awareness that the human factor constitutes an important risk. As a result, the Water Boards initiated the development of an automated tool for information management during flood threat situations: GDH (Geautomatiseerd Draaiboek Hoogwater/Automated Flood Contingency Plan.

Automation of information management can cause a significant reduction of risk: by using computers for what they are good at (storing information, handling predefined procedures), humans can focus on what they are better at: dealing with unexpected developments and making decisions based on incomparable criteria.

The result is GDH: a generic tool that any flood risk management organization can use to automate its own contingency plan and that serves as an information management tool during floods. Main features:

- Presentation of all relevant information in a consistent form;
- Warnings to the flood manager if required actions are not taken in time;
- Automatic communication by fax, text or e-mail;
- Automatic logging of all actions (both by system and operator), enabling full post event evaluation;
- Basic ingredients of situation reports.
General Use of the GDH
GDH works with a flexible system of password protected user rights, to be attributed by a system manager. All functionalities can be activated through menus. Two modes of GDH exits:

1. Off-line mode
2. On-line mode

GDH has distinct functionalities for off-line and on-line use. The off-line mode is normally only used outside the flood season, for updating and maintaining the automated contingency plan. At the start of the flood season, the system is switched to the on-line mode, fixing the automated contingency plan at the same time.

1. Off-Line Mode

The off-line mode offers all required functionalities for creating and maintaining the automated contingency plan. The initial translation of the contingency plan into GDH is a major task (see Implementation experiences), but after that the maintenance of GDH is comparable to the yearly maintenance that is carried out on the contingency plan itself. It is customary that the water boards check and update their contingency plans each summer season, and that the updated version is formally approved by the water board’s management team before the next flood season. For GDH, similar procedures can be followed.

2. On-Line Mode

The on-line mode is used for the actual operational flood management. Upon starting and logging in, the user enters the default main screen, which shows current water level data and warnings. Through the menu, the user can get several views of contingency plan data, highlighting the current situation. For example, the top half of Figure 76 shows the stage trigger values of one dike section and the current water level of the two relevant gauges. The current stage is highlighted. The same information can be presented graphically as well, as shown in the bottom half of Figure 76.
Water level data from both national and local gauges are constantly and automatically entered (they can also be entered manually). As soon as a water level measurement exceeds one or more of the predefined threshold levels, GDH generates the “stage change advice pop-up”. GDH doesn’t automatically scale up or down to the next stage; it is always the responsibility of the flood manager to make that decision.

A decision by the flood manager to change the stage means that all actions that are linked to the new stage become active. GDH presents a list of all these actions, with filters that the user can choose. The list of actions shows all relevant data, including the actual status of each action, which can be updated automatically or by the flood manager. This action window is one of the most important monitoring tools in GDH. Actions will be triggered by GDH using
text, e-mail or fax, if this is predefined. Other actions still have to be started by the flood manager himself if response is delayed beyond a predefined limit, GDH will generate warnings (“watch dog functionality”), and if there is still no reaction, a second person can be warned.

Apart from these core functionalities, GDH contains a number of features that can further improve operational flood management:

- The user can find out what actions are required if a certain water level is reached.
- During flood threat situations, there are always unpredictable incidents (such as a ship crashing into a lock door), requiring un-predefined actions; GDH can be used for the management and monitoring of these unexpected incidents as well. In such a situation, the incident can be defined, actions can be selected and linked to functionaries, and from that moment GDH treats these actions similarly to the predefined actions.
- GDH produces the basic ingredients of a situation report; the user can export these ingredients to include them in his own standard format.
- GDH provides GIS visualization of the emergency situation, providing a clear insight into the current stages and the location of gauges, dike sections, structures and incident sites. An example is presented in figure below.

![Figure 77: Example of GIS visualization, on-line mode](image)

### 4. Infra-web

**About Infra-web**

Infra-web is a web-based application that supports the communication between organizations on national level. Infra-web is developed within the Ministry of Transport, Public Works and Water Management and its primary task is to support the registration, communication and dispatching of incidents.
Infra-web is used by staff who delivers information about an incident or crisis, staff in traffic centers, experts who advice the crisis managers. It is used both in the Netherlands and Germany.

The following can be said about Infra-web:
- Computer program on Internet
- GIS system
- Registration of incidents, standard forms
- Management reports
- Alert and communication system for incidents
- Various connected databases
- Storage of incidents in data base
- Logbook

**History of Infra-web**
- Operational in 1994 name = Aquabel
- GIS module in 1997
- Start web version, **Aquaweb 1999**
- Introduction of other users 2002 (road, air)
- New name = **Infra-web**
- New name = Infra-web
- 1 January 2004 operational in the Netherlands

**How Infra-web works**
Infra-web thinks in terms of processes. The usage process is every time the same, it does not matter what type of incident accrue. The usage of Infra-web can be seen in Figure 78.

The common way of using the system offers a good experience to the users of the system as it can be in all the situations no matter how small an incident is. Several forms exist in the Infra-web database that can be used for a specific type of incident. Therefore for, every type of incident has its own (shared) forms in the data base. These forms detail the incident scene, the informer and some other general information. Based on this input information, the accident is classified and the emergency services (and other authorities) are contacted accordingly.
Figure 79 shows a user interface of Infra-web.

![Infra-web interface](image)

**Figure 79: Infra-web interface**

5. **Flood Information and Warning Systems (FLIWAS)**

**About FLIWAS**

In the Interreg IIIb funded project NOAH project partners from the Netherlands, Germany and Ireland joined forces to improve information transfer during high water events along rivers. Main objectives of the project are development and implementation of an automated high water information system called *Flood Information and Warning System (FLIWAS)* and involving the general public in high.

FLIWAS is a new, advanced information system for flood time management. The objective of FLIWAS is optimal flood preparation. The system provides, to the parties concerned, access to current and relevant information in the event of a flood (threat). FLIWAS is intended for the water column as well as the public order and safety (POS) column.

The development of FLIWAS started in autumn 2005. According to the actual planning, the building of FLIWAS had to be completed by autumn 2007.
FLIWAS functionalities
Some of the functionalities of FLIWAS are:

1. **Monitoring**
   The functionality aims at monitoring the high water situation on the river using available measurement information and forecasts. This information will be used to initialize actions to protect areas against flooding.

2. **High water protection (for structures and embankments)**
   The functionality aims at setting up scenarios and action plans for structures and embankments to protect areas and cities against flooding. It also aims at initializing and monitoring measures, predictions and actions based on warning stages and direct communication to all involved staff.

3. **2D flood modeling**
   The functionality aims at supporting real time calculation of flood scenarios in endangered areas. In NOAH a prototype area along the upper Rhine River will be modeled. As a result, flood maps and scenarios of the upper Rhine River between Iffezheim and Mannheim will become available. The experience gained during the building of this real time-model can be used in other regions.

4. **Evacuation**
   The functionality aims at designing of evacuation plans in advance and assisting during the execution during calamity situations, using results of the 2D-flooding model, data of geographic maps, population distribution and infrastructure. A decision about evacuation has to be taken after signals from the High Water Protection-model.

5. **Evaluation**
   Use FLIWAS for evacuation of a high water period using logged data to improve calamity and evacuation plans and train users.

Some general features of the system are its ability to communicate automatically with key staff, its workflow function to control execution of actions and its logging module.

**Development of FLIWAS**
The concept of FLIWAS is developed in close co-operation with end users. Starting point was the knowledge of and experience with local prototypes in Germany ‘Hochwasserinformationssystem zur Gefahrenabwehr’ (HzG) and ‘Hochwasser-Informations und Schutz-System’ (HOWISS) and the Netherlands ‘Geautomatiseerd Draaiboek Hoogwater’ (GDH). During its development, workshop sessions were conducted were users from the project regions were invited to submit their wishes and demands. This resulted in the overall functional design for FLIWAS.

FLIWAS builds upon existing measurement and flood prediction systems, geo-info, alert plans, flood risk maps and calamity scenarios. All relevant information of these building blocks will be bundled and made available through an internet-oriented Geographic Information System (GIS) based application. This will be structured in such a way that decision makers, water management and calamity professionals as well as private companies and the public will receive all relevant information, optimized for their needs, accessible at their level.
The modular design of the information system enables organizations to install only the needed functionality. After an intensive coordination effort with other ongoing projects, NOAH was able to incorporate other initiatives as well, such as the Dutch High Water Information System (HIS), which is being developed by Rijkswaterstaat/DWW. Close cooperation with the program VIKING (Province of Gelderland and Nord-Rhein Westphalia) ensures that the communication to the calamity management organizations (police, fire-brigades) is optimized.

Figure 80 shows several applications have been integrated in FLIWAS’s modules.

**Use of FLIWAS**

FLIWAS is a generic system. The input to FLIWAS customizes the system to the organization that uses it. FLIWAS enables organizations to implement their own calamity plans and basic data on one hand and to structure the information and initiate actions during events on the other hand.

FLIWAS will be used to define calamity and evacuation plans, resources and geographical data, to test plans and to evaluate previous events. The appointed users will define high water stages or threshold limits, determine actions needed for those stages and link actions with responsible persons and necessary auxiliaries by a duty roster. The way actions are initiated and communicated (e.g. by phone, fax, e-mail or SMS) is also determined.

During the high water season or during a high water event the system is in an operational mode. Information such as telemetry data, water level forecasts or rainfall predictions are used to determine the phase in which a monitored object is, related to threshold values set by the administrator of the system. If a threshold is exceeded, the system will inform the user and suggest going to the next stage. If the user decides to accept, the system will initialize actions predefined for this stage. The system will then monitor progress and log the actions on completion.
Each user has restricted rights and will have access to the functionality and information that is relevant to him/her. As the system allows data import during high water events, it will always display the latest status of the situation on the ground. Ad hoc actions may be imported too. For decision makers this kind of reliable information is very important; it helps them to decide on the actual safety situation.

FLIWAS runs on one or more web servers. On client PCs, PDAs and palmtops FLIWAS is accessed through a graphical user interface, using a web browser. For the communication between web server and clients the Internet or an intranet is used. If this infrastructure is not available because of the calamity situation, FLIWAS can still be operational. To enable stand-alone operation the data (geo-data, calamity plans and evacuation scenarios and operational data) can be mirrored to a local system. If communication fails, FLIWAS can still be used on the local system. As soon as the network becomes available again the data of the local system and the web server are synchronized and the

6. **BC2000**

**About BC2000**

BC2000 is an automated, administrative information system used by the Inland Water Information Centre within RIZA for reporting water information. This information includes daily water information along the main rivers, ice coverage, water quality, water temperature, flood coverage along main rivers. Daily water information along main rivers is important for shipping activities; however such information is also used to initiate flood forecasting activities and if necessary to warn the emergency services as well as the public during high water situation.

**Modules of BC2000**

BC2000 is modular and consists of the following main modules:

1. **Nautical reporting**
   The nautical reporting module collects and publishes the (predicted) water, drainage, bridge heights, regimes weirs, navigation messages (restrictions, etc.) and the ice situation on the fairways. This reporting is essential to the safety of water transport management.

2. **Environmental coverage**
   The environmental reporting module collects and calculates the duration and concentration of discharged pollutants in surface water of the Rhine and Meuse. It also includes the construction of a water map for the National Coordination water (LCW) to the task.

3. **Security Alerts**
   The security alert module provides predictions about the water levels and discharges during flood in Lobith (Rhine) and Borgharen (Meuse). It also includes the prediction of wave impact against the dikes of the IJsselmeer and Markermeer area for monitoring the dam during an expected storm. During a flood or storm, the concerned authorities and managers, through the BC2000 system, are warned. The information is also used to initiate actions when water shortage is foreseen.
4. **Models and interfaces to external systems**

For gathering data, processing data and distributing information to the external systems, BC2000 is connected to those external systems through interfaces as listed Table 25.

<table>
<thead>
<tr>
<th>Interface Input</th>
<th>Interface Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring System Water Heights (MSW) / Multi Functional Presentation System (MFPs)</td>
<td>Internet (Internet Information Site of the Inland Waters)</td>
</tr>
<tr>
<td>KNMI (Royal Netherlands Meteorological Institute)</td>
<td>Notice to Skip Press (NTS) standard</td>
</tr>
<tr>
<td>FLORiver calculation flood forecasting (Flood forecast Meuse)</td>
<td>Teletext editor (ASTED)</td>
</tr>
<tr>
<td>RHINE BRANCHES MODEL (SOBEK calculation for the downstream area of the Dutch Rhine / IJssel)</td>
<td>BICS (Inland shipping information and communication system)</td>
</tr>
<tr>
<td>WDIJM calculation (warning Dijken IJsselmeer and Markermeer)</td>
<td>Donar (water wet storage system data)</td>
</tr>
<tr>
<td>LOBITHW calculation (for water level forecasting in Lobith)</td>
<td>RHINE ALARM MODEL (calculation for emergencies)</td>
</tr>
<tr>
<td>AQUALARM (automatic water quality monitoring network)</td>
<td>MEUSE ALARM MODEL (calculation for emergencies)</td>
</tr>
<tr>
<td>Fairway information system (system for shipping purpose)</td>
<td>Arcview (for generation and digitization of maps and publications on the Internet)</td>
</tr>
</tbody>
</table>

Table 25: Interfaces connected to BC2000

**Internal architecture of BC2000**

The operation of BC2000 is broadly divided into three parts.

1. Import of data / information in the information BC2000.
2. The manufacturing and processing of data to information using the functionality of BC2000, if necessary supported by models.
3. The distribution of the information to various media, such as the Internet, various models or information systems, teletext and transmission to persons and / or agencies by e-mail.

The overall effect of BC2000 is shown in the Figure 81
Usage of BC2000
The paragraphs below provide information about the usage of BC2000. This information is distinguished in form of the schematic overview shown in Figure 81 (i.e. input, output/production and distribution).

1. Daily reporting on the water
Information on the water in a river is vital for shipping. This has to do with the height of bridges, the maximum draft of vessels, the navigation conditions and the application of regulations.

Input: water of about 70 stations in the Netherlands, Germany (Rhine), Belgium (Meuse) and Austria (Danube).

Output: information about the water on the Rhine in Germany and the Netherlands, the Meuse in Belgium and the Netherlands and the Danube in Germany and Austria. Also, the change in water levels compared to the previous day is reported. The communications on the water may be supplemented with information on drainage, bridge heights, expected water levels, least depths identified, regimes of Dutch and other Western European waterways and information on the dams on the Lower Rhine, Lek and Meuse.

Distribution: The water information is distributed on teletext, the Internet, and e-mail. Furthermore, the data is also available at the inland shipping information and communication system (BIC) as well as at the shipping reports and water levels service (BOS) that can be accessed via BIC.
2. Notices to Shipping

**Input:** Shipping messages from various waterway managers such as State water boards, provinces, municipalities and water boards.

**Output:** Information coverage to shipping such as: daily information on restrictions / limitations on the Dutch and other West European waterways, changes to the buoys, rules and operation times of locks and bridges and other information for inland waterway may be important.

**Distribution:** The shipping messages are sent daily via e-mail to fairway information system users (i.e. fairway managers and other stakeholders). Also, the information can be published on the Internet. Furthermore, the navigation messages are made available at the inland shipping information and communication system (BIC) as well as at the shipping reports and water levels service (BOS) that can be accessed via BIC.

3. Ice coverage

**Input:** Ice encodings of 33 national ice centers.

**Output:** the Information Center provides information on inland ice occupation. Such information is also important for navigation purpose as it provides information on ice occupation in relation to access to the seaports. The ice messages are provided in text and graphics (ice map) form.

**Distribution:** The ice message information is made available daily. The information is published as a teletext, at the inland shipping information and communication system (BIC), at the shipping reports and water levels service (BOS) that can be accessed via BIC, on the Internet and through e-mail that is sent to Fairway information service users (fairway managers and other stakeholders).

4. Flood information for the large rivers

The flood coverage comes into effect when very high tides are expected along the major rivers.

For the Rhine, this applies when a water level reaches 14 meters NAP and when is expected to increase to over 15 NAP meters at the Lobith. For the Meuse this applies when the water level at the Borgharen reaches 43.80 meters NAP and when is expected to exceed 44.10 meters NAP. Apart from providing high water and precipitation data, BC200 also facilitates the provision of flood messages during high water situation.

5. Alerts dyke managers at IJsselmeer area

BC2000 is used to alert dike managers around IJsselmeer area when storm is predicted around the lake. Such information is used initiate surveillance of the dikes along the IJsselmeer lake.

Apart from the above mentioned usage, BC2000 is also to provide information on low water coverage, provide information about chemicals spill in water, bathing water information and water temperature reports.
7. C2000

About C2000

Communication among relief agencies during emergency situation is vital. Cancellation of communication between relief agencies can be disastrous. C2000 is a new digital communications network that has been developed to support communication between the police, fire, ambulance and Royal Military. It replaces the approximately one hundred obsolete analog networks for emergency services previously used. Through these analog networks was multi-disciplinary communication (between different emergency themselves) very difficult.

C2000 is designed so that even under the extreme conditions in the air remains. It aims at allowing a social worker, anywhere in the Netherlands, ability to communicate and promotes the safety of civilians and aid workers in emergency situations.

C2000 is initiated by the Ministry of Interior Affair however the construction of the C2000 network is outsourced to TetraNed. Different parties are participating in TetraNed including Getronics, KPN Telecom and Motorola. Together this consortium is responsible for the construction of the network and the equipment. The network consists of 400 communication masts and all the necessary exchanges.

Types of communication supported by C2000

The fundamental idea of the C2000 system is that all communication is covered through a central communication point. There are 25 central emergency control rooms that cover up the “Geintegreerde Meldkamer Systeem” (GMS). Each emergency room covers a safety region in the Netherlands. In these emergency rooms representatives of each relief service operate together. Like in a hub-and-spoke network all communication goes through these central headquarters. C2000 supports, however, a wide variety of types of communication.

The five different types of communication possibilities are listed below (Hennis, Lagerweij et al. June 2006). The numbers in Figure 82 correspond with the listed descriptions. The numbers in Figure 82 correspond with the listed descriptions.

1. Direct mode operation
   The DMO enables users to communicate directly with each other through mobile devices without using the C2000 network.

2. Air Interface
   Communication between mobile devices can also take place by using masts or mobile stations which communicate with each other through electromagnetic waves. The used standard is TETRA. Besides the use of mobile devices, all used emergency vehicles have built-in C2000 equipment. Air communication is possible up to a height of 1200 meters.

3. Inter System Interface
   Different TETRA networks can be connected to each other through the Inter System Interface. This is important for international communication.

4. Gateways
   C2000 can also be connected to external networks like the telephone network and data networks. The gateways of C2000 are responsible for this feature.
5. Peripheral Equipment Interface

The Peripheral Equipment Interface makes communication between a mobile station and a PC (laptop) possible.

![Figure 82: A sketch on the concept of C2000 (BZK March 2006)](image)

**Equipment**

The C2000 equipment is produced by Motorola. During the fall of 2004 the first TETRA terminals were bought, which go under the name of Motorola MTP700. This device enables voice communication and, into a lesser extent, data communication (Motorola 2001). In the meantime a new model is launched by Motorola, which proves to be a great success in the UK. Using the device it is possible to exchange incident views, digital maps and specialized graphics. Another advantage is the built-in GPS receiver, which makes it possible for the emergency rooms to plot the location of the user (Motorola June 2006).

**C2000 usage**

As already mentioned, C2000 network supports voice and data traffic between the different emergency services. The extent in which data traffic can be used depends, however, on the used equipment. Next to this there is also the possibility of sending and receiving short text messages. When a user turns on his device, it automatically logs in into the central system. In continuation the operator in the emergency room divides the users in groups based on the situation and authority. These groups can contain emergency workers from different emergency services. In some cases emergency workers receive less information compared to the old situation. While using the C2000 system, emergency workers do only receive messages that are relevant for their own situation, instead of receiving messages that are relevant to the whole discipline. The relevance of information to a certain user group is determined by the controllers in the emergency rooms. However, by the coupling of C2000 to the GMS operators from different disciplines can share information with each other, which can lead to more information generation (BZK June 2006).
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