A DATABASE FOR DUTCH TRANSPORT INFRASTRUCTURE PROJECTS AND THEIR RESULTS

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A database for Dutch transport infrastructure projects and their results

Thesis report

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PREFACE

I still remember my first thoughts when prof. Hertogh told me about a research project that he was planning to facilitate. It had something to do with databases, explanative parameters and qualitative data. Matters I then considered to be none of my business. Ironically enough I found myself starting this graduation research 9 months ago and, even more ironically, I really enjoyed the subject of study from the start.

Especially the political and societal relevance of the topic appealed to me and I am very glad that I was able to get an insight in the world of the project teams that are responsible for the performance of Dutch infrastructure projects. Very important in introducing me to this world were AT Osborne and Neerlands Diep. Via their far reaching networks I was able to meet very interesting interview candidates and colleagues that each gave me their unique view on a database, their projects and their profession in general. Their input really encouraged me to finish my thesis and join them in practice!

Finishing this thesis would however be impossible without the supervision of my graduation committee. I am grateful for the help and input that each of the committee-members offered me. Marcel, you kept me focused on the broader aims of the database, Marian your guidance in the methodological jungle is really appreciated and Martijn, your input on project performance and project management was really valuable. Olaf, despite being on a distance for a while, you kept on emphasizing the need for a like this database. In the last place I want to thank Joost for his late night e-mails with valuable input on nearly all aspects.

It was a pleasure to me,

Thomas Neijenhuis, *Delft, November 2014*

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SUMMARY

Infrastructure projects and their results have been studied for a long time. Major reasons to study them is to unravel the mechanisms that lead to "better" projects. When the Dutch infrastructure sector is concerned, we do not exactly know how well our projects perform. In order to facilitate research on this topic, adequate recording of Dutch infrastructure projects and their results is desirable. This will help to learn from previous projects and improve the results of future projects. This thesis investigates in what manner a database is a useful and feasible means for the recording, explaining and learning of Dutch transport infrastructure projects. The main research question that follows from this objective is:

What are the possibilities and limitations for a database on project results of Dutch transport infrastructure projects and why?

The research that was carried out to answer this question comprised five phases. The first phase was used to identify concepts that are relevant in recording the results of projects by means of a literature study. The second phase aimed to gather insights on the current ways in which project teams use data in their projects. Besides it aimed to map the desires and concerns of project practitioners regarding a database on infrastructure projects. Phase three, comprised the design of a data gathering procedure on basis of the obtained input. The fourth phase concerned the testing of this procedure on three projects. The last phase is a discussion and conclusion on the findings.

Phase I – Identification of relevant factors in recording project results in literature

In our literature study, it showed off that the applied management approach should be attuned to the presence of contingency factors in a project in order to increase the likelihood of successful project results. An ex-post evaluation of the management approach and the properties of projects might help us explain why a particular result has been realized. Recording of the management approach and the properties of projects is therefore desirable.

The properties to lay down should comprise the inherent characteristics of the project itself and the environment with which the project is to interact. This distinction is necessary as a project managers and decision makers are (partially) able to steer and define the characteristics of the project at its start. They however have no, or at most indirect control, over the external environment.

A last factor to record is the project result itself. Before recording can start, it is important to pick success criteria with which uniform judgments about the project result can be made.

Phase II – Identification of database purposes and elements to record according to practitioners

Knowing the relevant factors, we started the empirical part of our research by interviewing 16 project practitioners, mainly from ProRail and Rijkswaterstaat, to get insights of the current practice and to map desires and concerns of practitioners regarding a database.

Project teams of ProRail and Rijkswaterstaat know three mechanisms with which data is recorded: progress reports, the project database (Rijkswaterstaat only) and specialist database. Via these mechanisms data is gathered on: scope, costs, planning, risks stakeholders and management dilemmas. This data is being used mainly for reporting on progress of individual projects or for knowledge development within one specific specialism.

Learning and knowledge sharing in practice happen in five distinct ways: (1) direct contact with colleagues, (2) coaching other team members, (3) attending lectures, presentations and conferences, (4) using standards and procedures in carrying out the work and (5) using the same project team for multiple projects. After analyzing these five forms, it appears that knowledge sharing mainly concerns the exchange of existing knowledge and the retrieval of knowledge from expert systems. The creation of new knowledge does not regularly take place in practice, which indicates the need for an explanative database.

The second part of the interviews concerned the desires and concerns of the interview candidates with regard to the database that we intend to develop. When questioning the desires, it appeared that next to a database on the results of infrastructure projects, also a database that unbolts best practices is desired by the interviewees. Although support for both databases was about equally strong we chose to stick to the intended plan of developing a database on project results, but on basis of our findings we recommend ProRail and Rijkswaterstaat to investigate how they can better unbolt their best practices for project teams.

The project practitioners mentioned 23 specific elements of projects that are worth recording. After analyzing the 23 individual aspects, they were grouped in the six categories: (1) planning, (2) costs, (3) contract, (4) project characteristics (incl. scope and complexity), (5) risks and (6) project results. In setting up the database we had to ascertain that each of these categories would be included in the design.

In a similar fashion, we identified six concerns that the interviewees have regarding the database and that potentially limit the possible database designs, which can be grouped as data related concerns and organizational concerns. The data related concerns are: (1) a lack of uniformity of the data, (2) subjective data and (3) a lack of relevancy of collected data. The organizational concerns are (4) the required workload to gather the data, (5) confidentiality of (especially financial) data and (6) an unsuccessful implementation.

Altogether, our findings from the first and second phase have given us sufficient information to design a draft version of a data gathering procedure that can be used in filling the database.

Phase III – Designing a data gathering procedure

The third phase comprised the actual design of a data gathering procedure. Before we could precisely indicate what data is worth gathering, we set up a conceptual design of the database. In its essence, the concept is made up of three different parts: (1) a snapshot part, (2) a change event part and (3) a project characteristics part.

The snapshot part allows us to indicate the result of the project by confronting the expectations at the outset of the project with what has been realized at the end of the project. In order to confront the expectations with the

realized, we make use of what we call snapshots. Per snapshot we record data on the expected or realized time, costs and scope performance of the project. Next to taking a snapshot at the start and end of a project, we proposed to take an extra snapshot halfway the project at the transition of the planning to the realization phase. With this extra snapshot we are also able to indicate the result of both the planning and design phase.

The change event part is used to indicate how the differences between the two snapshots have arisen. The total difference in either the time, cost or scope can be attributed to the occurrence of several individual change events. Our database will require the recording each of these change events, as well as their consequences on time, cost and scope of the project. When all change events of a project are recorded and put in a chronological order, we can reconstruct a "movie" that runs from the project start (the first snapshot) to project completion (the third snapshot).

The project characteristics part requires the recording of characteristics of the project other than time, cost and scope. Once the database is completed and the data is analyzed, these project characteristics are expected to have explanatory value in concluding upon the realized project results.

Phase IV – Evaluating the data gathering procedure

Once we finished the data gathering procedure, we verified if it was possible to find all the required data on three road projects of Rijkswaterstaat. For these three projects we tested if it was possible to: take the three desired snapshots, explain the difference between the second and third snapshot by using change events (so the realization phase only) and gather all data on the project characteristics.

Throughout testing, it appeared that the data gathering procedure contained two weaknesses that require further investigation or discussion. The first weakness has to do with the degree of detail with which the scope of the project and the change events should be mapped. A higher degree of detail increase the workload of filling in the procedure while it can be discussed which degree of detail is desirable. The second weakness has to do with the lacking of a clear and appropriate indexation method for financial figures. This makes it hard to compare cost figures of snapshot with each other as they are indicated in differing price levels. It is therefore hard to indicate the financial result of a project.

Phase V – Conclusions and recommendations

Despite the two weaknesses, the data gathering procedure has appeared to be a promising method to come to a database for Dutch infrastructure projects. The procedure is considered to be technically feasible although we acknowledge that this conclusion is bound by the fact that we only tested it on a selective sample of road-related MIRT-projects of Rijkswaterstaat and that we have only verified the mapping of change events in the realization phase of our cases.

Further testing and a gradual expansion of the procure will be required before the database can concern data on the Dutch infrastructure projects in general. Additional activities are also required to determine how the database should be set-up in an organizational sense. Especially finding an owner for the database is considered essential to safeguard that the database becomes meaningful and will be implemented in practice. It is therefore recommended to focus on these organizational aspect before developing the database any further. Potential owners that we have identified are the executive organizations of the Ministry of Infrastructure and Environment (ProRail and Rijkswaterstaat), independent knowledge platforms in the infrastructure sector (such as Neerlands Diep) and scientific institutions (such as the TU Delft).

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1 INTRODUCTION

1.1 INTRODUCTION TO THE RESEARCH TOPIC

This research investigates the possibilities to set up a database for Dutch transport infrastructure projects, in which projects and their performance can be recorded. Such a database should contribute to improved project results and will be a means that allows learning from past projects. Through research on the recorded data, it intends to contribute to an improved project management in infrastructure projects.

At present, infrastructure projects and their results cannot always be considered successful. Flyvbjerg et al. (2003) and Cantarelli (2011) examined the performance of infrastructure projects with respect to cost and planning. Both Flybjerg et al. (N=258, projects from differing countries) and Cantarelli (N=78, Dutch projects only) concluded that on average, projects exceed their initial budgets and initial planning. Although project success is more facetted than cost and time prognosis only, their studies indicate that project teams and public clients struggle to be successful in all aspects of a project.

The challenge that results from their conclusion is to find ways in which we can increase the chances on a successful project result. Solving this challenge is not straightforward, as infrastructure projects are often complex and depend on factors that cannot be fully controlled. Insight in the factors that affect the success of projects could contribute to more successful projects. These insights can be obtained by comparing relevant data of multiple projects. To facilitate an adequate comparison, this data has to be recorded in a structured and uniform manner. Once the database contains data of a considerable amount of projects, it will contain all relevant data for a study on the realization of project success and will allow for the development of practical applications in future projects.

Recognizing the societal and scientific relevance of a better project recording, Neerlands Diep[1], TU Delft and AT Osborne joined together and decided to facilitate an explorative and design-oriented study to the possibilities for a national database of infrastructure projects. This report describes the outcome of this study and is also a part of the graduation thesis for the master Construction Management and Engineering of the TU Delft.

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[1] Neerlands Diep is a collaboration between ProRail, Rijksvastgoedbedrijf, Rijkswaterstaat and the 4 largest Dutch municipalities in which they offer a platform to their (senior) public space project managers to develop and share their knowledge so that public (infrastructure) projects and its management are further professionalized. (Neerlands Diep,2014)

1.2 EXPLORATION OF THE PROBLEM

A database on infrastructure projects is not particularly a new idea. As mentioned in the introduction, Flyvbjerg et al. and Cantarelli have for example gathered a considerable dataset on the time and cost performance of infrastructure projects. Similarly, other scholars, such as Odeck (2004), Lee (2008) and Singh (2010), have gathered data on the (cost) performance of infrastructure projects. With these various datasets already available, it can be questioned which problems a new database is about to solve and which additional value it will have in relation to the existing databases.

The first reason to investigate a new database on infrastructure projects is that most of the currently known datasets and scientific studies on infrastructure projects and their results only limitedly explain why certain patterns in project results are found. The biggest problem in creating a dataset with explanatory value is that it is relatively difficult to show 'why' a project has a certain result. Concluding 'that' a project has a certain result(Verweij and Gerrits, 2013, Siemiatycki, 2009) is generally considered to be easier, but even so a difficult and major undertaking(Nijkamp and Ubbels, 1999, Dantata et al., 2006). Often academic researchers find themselves bound by the availability of relevant reports and data due to their position outside the governing and project process (Siemiatycki, 2009). When these outsiders are compared with insiders, such as government auditors or project team members, Siemiatycki states that these insiders are provided with access to data that far exceeds that of outsiders. After a comparative study, Siemiatycki concludes that insiders and outsiders identify different causes of bad project performance. In order to come to an expanded understanding of the patterns, causes of and cures for bad project performance, the combining of the unique strengths of the insiders and outsiders should be encouraged.

As mentioned in the introduction, this research is set up as a collaboration between Neerlands Diep, TU Delft and AT Osborne. This creates an opportunity to overcome the 'traditional' division between outsiders and insiders. Thereby we have a (unique) opportunity to combine the strengths of both groups and come to explanative findings.

A second reason to investigate a new database, is that the amount of, and the comprehensiveness of, initiatives that enhance learning on projects in the Dutch infrastructure sector is limited. Research of the Dutch Knowledge Institute for Mobility (Kennisinstituut voor Mobiliteitsbeleid, 2009) has revealed that learning from realized projects does not have much attention from Dutch policymakers and project practitioners and considers this a missed opportunity to improve project performance. The same publication therefore propagates a more frequent and structured use of ex-post evaluations of these projects, in order to improve the quality of future decision making and infrastructure projects. Besides, it highlights the importance of saving data of these individual evaluations for a meta-evaluation once data of multiple projects has been gathered.

The two above reasons justify investigating a new database on infrastructure projects, since such a database can be valuable in both a scientific and practical way. When this new database is developed, it will help to solve the following problem:

> ### PROBLEM STATEMENT:
> *Project data on public transport infrastructure projects is only limitedly recorded and the data that is recorded is limitedly explanative for the realized result. Hereby opportunities to learn from previous projects are missed. This hinders the improvement of project results and thereby societal benefits.*

1.3 RESEARCH OBJECTIVE AND RESEARCH QUESTIONS

As has become clear, investigating the possibilities for a database on infrastructure projects and their performance is desirable to enhance learning and improve project results. However, what data is relevant to include in such a database is not self-evident, nor is it straightforward who will eventually collect, store, own and analyze the collected data. Our research objective can therefore be stated as follows:

> **RESEARCH OBJECTIVE:**
>
> *The objective of this study is to improve the results of Dutch infrastructure projects by investigating in what manner a database is a useful and feasible means for the recording and learning from yet realized and ongoing Dutch transport infrastructure projects.*

To achieve abovementioned objective determined what factors are relevant in the realization of a project result, decided what data should be gathered in order to allow for learning and advised how the required data can best be gathered and stored. Designing and testing of a data gathering procedure was also part of this study. These different research activities allowed us to answers the set of research questions that we have formulated:

> **MAIN QUESTION:**
>
> *What are the possibilities and limitations of a database for project results of Dutch infrastructure projects and why?*

As this main-question is too large to answer in one go, we have split it up into sub-questions sub-subquestions that each provide a part of the answer to the main question. Together the sub-questions provide all knowledge to answer the main-question.

> **SUB-QUESTIONS:**
>
> 1. *What factors of projects are relevant to record for an explanative database on projects and their results according to literature?*
>
> 2. *What are unfulfilled knowledge needs and applications that the database can serve according to project practitioners?*
>   - a. *What data is currently recorded by infrastructure project teams and for what reason?*
>   - b. *Which ways of knowledge development and learning are currently used in practice?*
>   - c. *Which database purposes are considered most valuable by project practitioners?*
>
> 3. *What data must be recorded to serve the most valuable purpose and knowledge need?*
>
> 4. *What factors hamper the recording of this data and what effects do these limitations have on a database?*
>   - a. *What challenges and potential limitations do project practitioners foresee?*
>   - b. *In what way can be dealt with these challenges in a database design?*
>   - c. *What additional challenges arise after testing the database design in practice?*
>
> 5. *In which configuration is a database on Dutch infrastructure projects feasible and meaningful?*
>   - a. *What is a feasible technical design for the database?*
>   - b. *How should the organizational process around the database be set up?*

The research questions denote that this thesis has a major focus on determining the data that is to be recorded. To a lesser extent the thesis also addresses organizational aspects that are relevant in setting up and implementing the database. Organizational aspects are however only considered in as far as they influence the data that is to be recorded or the feasibility of the database as a whole. So it does discuss how this database is relevant for various actors but it does not consider the more strategic and political process towards alliances and promises to actually gather the data. Also IT-related aspects, which are also relevant for an adequate functioning of the database, are left out of this research.

A second remark regarding the scope of this thesis is on the infrastructure projects that we consider. The basic presumption of this research is that we strive to develop a database for all Dutch transport infrastructure projects from any certain cost-size (for example €20 mln as used by Cantarelli (2011)). The reverse side of this presumption is that we are considering a large domain, which makes it difficult to keep the research valid and the database workable. When research aspects are considered, especially the internal validity of our research is at stake (Verschuren and Doorewaard, 2010). The workability is threatened as the practical burden that comes with considering projects of all kinds of natures, types, clients and reporting structures might be too high. At the outset of our research it was therefore clear that a certain degree of delineation would be necessary in this thesis, but determining how to delineate was then not evident.

The main problem in delineating at the outset is that research to this topic in the Dutch context is rather new, by which we lacked insights on how our delineating choices would affect the feasibility and potential value of the database. Instead of delineating at the outset, we choose to delineate "on-the-go". Thereby we made use of the insights that we gained and the (data driven) opportunities that came by throughout our study. Throughout this report we will describe how our various methodological choices have delineated our research domain and how these choices must be interpreted in relation to the broad aim of realizing a database of all Dutch infrastructure projects.

1.4   RESEARCH APPROACH

This section presents the strategy and methods we have used to obtain answers to our research questions. Before we do so, we will first describe the conceptual model that we have used in this research. This conceptual model has been set up to provide guidance throughout the research and visually represents how the various concepts that we have studied relate to each other. The various research activities that we have carried out can be linked to this model.

1.4.1   The concept of a database

Figure 1 shows the conceptual model that we have developed, which connects six distinctive concepts. The heart of this model is the actual database that eventually has to be set up. According to Ponniah (2003), a database is "an *ordered collection* of *related data elements* intended to meet *the information needs* of an organization and designed to be *shared* by multiple users".
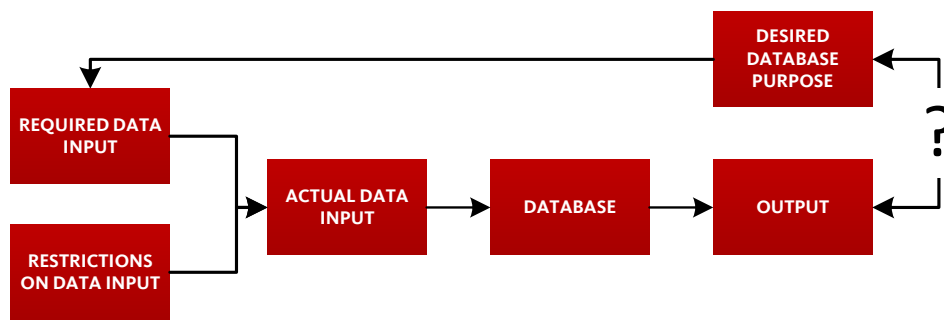
With this definition, two other elements of our model can be identified: (1) input and (2) output. Data input is required in order to build up the ordered collection. If the right data has been collected, the database allows to generate the output that serves the information needs of an organization. Thus before setting up the database, it needs to be determined which purposes the database must serve in order to fit the database output to the information needs. On basis of these purposes it can then be determined what data should be collected. Notice that we have thereby identified the fourth and fifth concepts of the model.

When connecting the first five concepts it seems that we have a foolproof cycle that allows us to construct any database that we like. The truth is however that various types of hindrance can occur in the gathering of the desired data. Thereby the output that the database can deliver and the purposes the database can serve are limited. An example of potential restrictions on the data input was already mentioned in the problem exploration, which is the labour-intensiveness to collect all relevant data (Dantata et al., 2006). Other restrictions that are imaginable are the subjectivity or confidentiality of the data that is to be collected.

1.4.2 Research strategy

According to Verschuren and Doorewaard (2010), three dimensions describe the nature of a research that is carried out. A research focuses mainly on: breadth or depth, quality or quantity and empiricism or existing literature and data.

Concerning depth or breadth, our study focuses on breadth. In order to achieve our objective, we have tried to consider all potential manners in which a database can be valuable. Besides, we intended to gain an overall view on the desires concerning a database on Dutch infrastructure projects. Although we intended to keep the study as broad as possible, it has appeared inevitable to delineate this research, mainly due to a lack of available research time. Throughout this thesis we therefore substantiate the delineating choices that we have made and reflect upon the effect that these choices have had for the broad character of this thesis.

Although the database might allow for a quantitative meta-analysis on project data once it is filled, this research, that has a qualitative nature. This exploratory study focusses on the data which is (potentially) relevant for improving project performance and the mechanisms that influence a project's outcome.

The third dimension is linked to where the answers to the research questions will be found, in the field or in existing sources. The first part of this study, related to the first sub-question, will have a rather theoretical nature. The later, and majority of, research activities however focus on practice. We aim to collect desires and views from project practitioners and we want to develop a procedure that is to be tested in practice.

On basis of these three dimensions of our research, we have further developed our research strategy and decided upon the specific research activities of this thesis.

1.4.3 Research activities

Figure 2, provides an overview of the research activities that have been carried out (red-boxes) to find answers to our sub-questions. Each research activity provided interim results (blue-boxes) that were required to carry out the succeeding research step. Together, all activities and interim deliverables provided the knowledge to answer our main question and conclude and recommend on the possibilities and limitations for a database of Dutch infrastructure projects. In the rest of this section we will introduce the research activities of our first four phases. A more specific elaboration of the applied research methodology of each activity is presented in the chapters that correspond to the research phases.
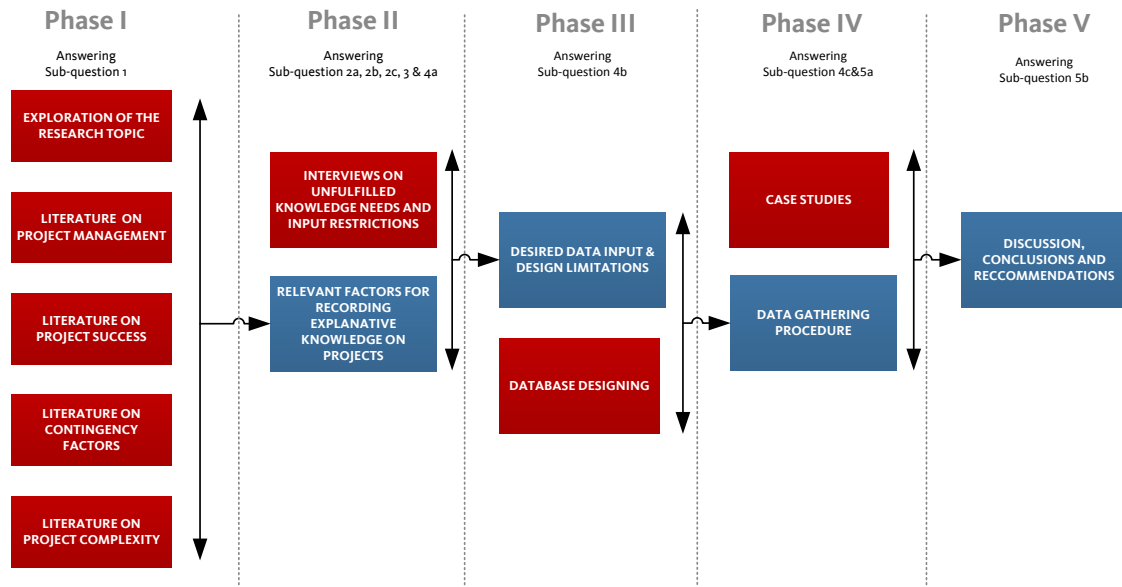
Figure 2 – Research framework

Phase I – Literature study on project performance

The first research activity is a literature study on the factors that are relevant in the realization of infrastructure projects and their successes. From an exploration of the literature, carried out before this research, it appeared that the concepts of project complexity and contingency theory, project management and project success are relevant concepts for a database with explanative value. Chapter 2 will present a more comprehensive description of each of these concepts and the relevancy of them for a database on project and their results. After these findings have been presented, we are able to answer our first sub-question. The knowledge that we have gained with this literature study will help us to define data that that is relevant for registration in a database.

Phase II – Interviews on desired applications and input restrictions

In order to (partially) answer the second, third and fourth sub-question, interviews were held amongst project team members, project controllers and portfolio managers of ProRail and Rijkswaterstaat. These interviews were carried out to identify the database purpose and the corresponding data input. Besides, they were held to identify potential challenges or restrictions in setting up a database. The applied methodology as well as the results and an analysis of the results are presented in chapter 3 of this thesis.

Phase III – Designing a data gathering procedure

After it has become clear what data is to be laid down in the database and where the data can be collected, the actual database needs to be built. As this study has an explorative nature, we have not yet constructed a fully operational database for final use. Instead, we have developed a procedure that prescribes what data of each project should be gathered on basis of our findings from literature and the interviews. In designing this procedure we constantly had to check if and how our desired input conflicted with the challenges and potential restrictions that we found. So this third phase allows us to answer the research question 4b. The concepts that underlie the procedure as well as the procedure itself are presented in chapter 4.

Phase IV – Case studies

The last activity of this research is the verification of the data gathering procedure. This verification has taken place by testing the procedure on three infrastructure projects. The major aim of this research step was to check if (1) all necessary data is indeed available and (2) the database functions technically right and allows for recording of the data. In this way we are able to answer the questions 4c and 5a. The exact methodology that has been applied in studying our cases is described in further detail in section 5.1, the rest of chapter 5 concerns the results and analysis of the results.

Phase V – Discussion, conclusions and recommendations

Together, all our research activities deliver the input to answer sub-question 5b and the main question of this research. The last phase will be used to come to our overall conclusions and look back at the research that we have carried out. This phase will not contain a research activity as such, but has considerable value for the thesis as a whole. Reflection upon the research will also be part of this phase.

1.5 STRUCTURE OF THE REPORT
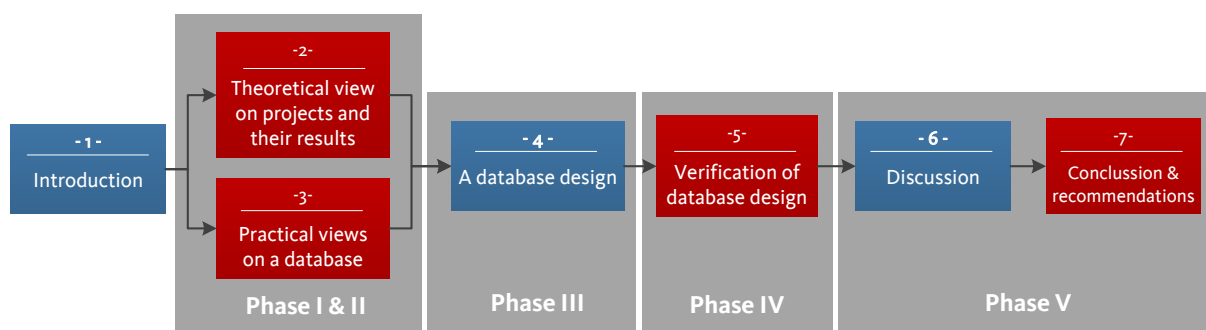
Figure 3 - Outline of the report

Figure 3, presents an outline of this thesis report. The second and third chapter are devoted to an analysis of possibilities for a database. The second chapter mainly concerns the relevant theoretical aspects and how we will deal with them in our design. In contrast, the third chapter describes the relevant aspects according to project practitioners.

In chapter four, insights from practice and theory are brought together in a draft design of the database. This design does not comprise a fully operational technical database set-up but is limited to a description of the data that is relevant to record per project and the description of a procedure to gather this data.

The fifth chapter describes the findings of our case study. In these case studies we have tested if it is possible to collect all data that our procedure asks for and verified if the concepts that underlie this procedure work in practice.

In the sixth chapter, our findings and the value of these findings for the eventual realization of a database are discussed. In the first place we will concern two organizational topics for adequate implementation (1) the database owner and (2) the way in which data should be collected. Although we did not specifically study these two topics, we will discuss potential ways in which a database can be set up on basis of the experiences and insight we have gained with our research activities. In the second place the discussion focuses on the limitations and relevance of our findings.

2 THEORETICAL VIEW ON PROJECTS AND THEIR RESULTS

From a first exploration of the problem (section1.2) it got clear that current large-N databases of infrastructure projects hold only a limited amount of explanative knowledge. Since we are aiming to develop a database that does contain this explanative knowledge, we need to consider which data we need to record per project before we can explain its result. The present chapter describes the relevant concepts that have been identified in a literature study, so that we are able to answer sub question 1:

1. *"What factors of projects are relevant to record for an explanative database on projects and their results according to literature?"*

Figure 4 shows how this literature study is relevant for the development of a database on infrastructure projects. The blue part indicates which part of the conceptual model is considered in this chapter.
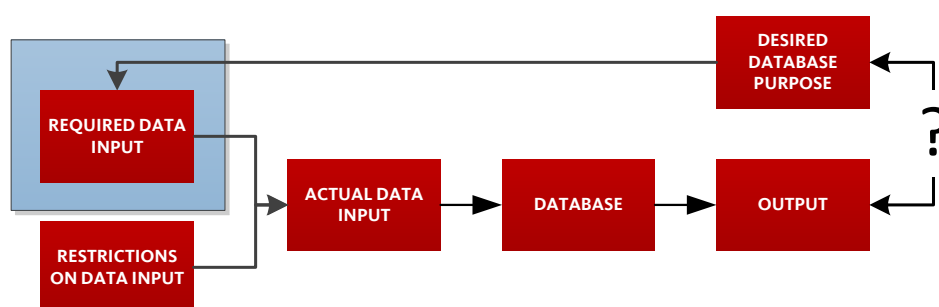
Subsequently this chapter considers: general characteristics of projects and their management (2,1), the ambiguousness of project success (2.2), project complexity and the elements that contribute to it (2.3) and the relevance of a contingent project management approach (2.4) and a conclusion (2.5).

As can be seen, this theoretical part of our research has explicitly focused on the database content. Due to a limited amount of available time, theory on knowledge management in organizations and the technical options in database design, are not considered in this explorative study. A further investigation of these topics and their effect on the database is advised in successive research.

2.1 PROJECTS AND THEIR MANAGEMENT

This section is a general introduction to projects and their management and indicates the most striking features of projects.

2.1.1 Projects and project management

Ever since mankind has started to civilize, it has undertaken project-like activities. Ancient constructions as pyramids, aqueducts and fortresses could not have been completed without a certain degree of planning and systemic ordering of design and construction activities. On basis of trial-and-error, a range of best practices was developed to maximize the chances of success in delivering these constructions. These best practices have dominated construction and engineering processes up to the 1950's. Since then more and more skills, tools and techniques became available to control the achievement of the project's objectives. The process of applying these skills tools and techniques is nowadays known as project management. (Munns and Bjeirmi, 1996, Project Management Institute, 2008)

Along with the origination of project management came the awareness that the clusters of unique activities that were managed could be named projects. Changing views on projects and project management, evolving from a continuous development of project management as a profession and scientific field, however hindered the formulation of a generally accepted and ageless definition of "project". The most recent definition of Turner (2008) is however illustrative for the contemporary notion of the term project:

> *"A project is a temporary organization to which resources are assigned to deliver beneficial change."*

When comparing Turner's definition to other recent ones, it can be concluded that most formulations indicate that (Bosch-Rekveldt, 2011):

> *"A project is characterized by its temporary character, in which a (unique) scope of work is undertaken, within certain constraints and for a particular reason"*

2.1.2 The temporariness of projects

From both definitions follows that the temporary character plays an important role. This temporariness implies that projects have a beginning and an end. In the typical process that bridges the project's start and end, several distinctive phases can be identified; the project lifecycle phases (Project Management Institute, 2008).

The typical lifecycle of a project consists of four sequential phases, Figure 5 (Turner, 2008, Jugdev and Müller, 2005, Munns and Bjeirmi, 1996). The phases are distinctive from each other due to the differing natures of activities that are carried out per stage. Also the groups of stakeholders that are involved in a phase differ. Usually projects start with a feasibility stage in which a client's problems are identified and possible solutions to the problem are investigated. Once the client has picked a preferred solution, the project moves to the next phase; the planning and design phase. In this phase the client's project team and the commissioned contractors undertake all preparatory activities so that the project can be actually constructed in the succeeding realization phase. When production is completed, the turnover phase starts. In this phase, the project team transfers the resulting product to the public client, by which the project has come to an end (Jugdev and Müller, 2005).

Besides these four stages, that we refer to as the project life cycle, two additional phases are described in literature: the utilization phase and the closedown phase. In the utilization phase the realized project is put to use and throughout the closedown stage the product is dismantled. Although scholars agree on the existence and importance of these two additional stages, they are ambiguous in the classification of them. Some scholars, such

as Munns and Bjeirmi (1996), state that the utilization and closedown phase should be integrated in the project life cycle. In their view there exists only one life cycle that is made up of six stages and which ends after the closedown phase. Others, (Jugdev and Müller, 2005), claim that there are two, partly coinciding, life cycles. These are the described four phase project life cycle and a new six stage product life cycle. This product life cycle, is made up of the four phase project life cycle plus the utilization and closedown phase. In this research it is chosen to distinguish two different life cycles, those of projects and those of products, Figure 5. The term project life cycle thereby refers to the phases in which the project team has been actually involved in the project, whereas product life cycle describes the phases in which the client is involved.
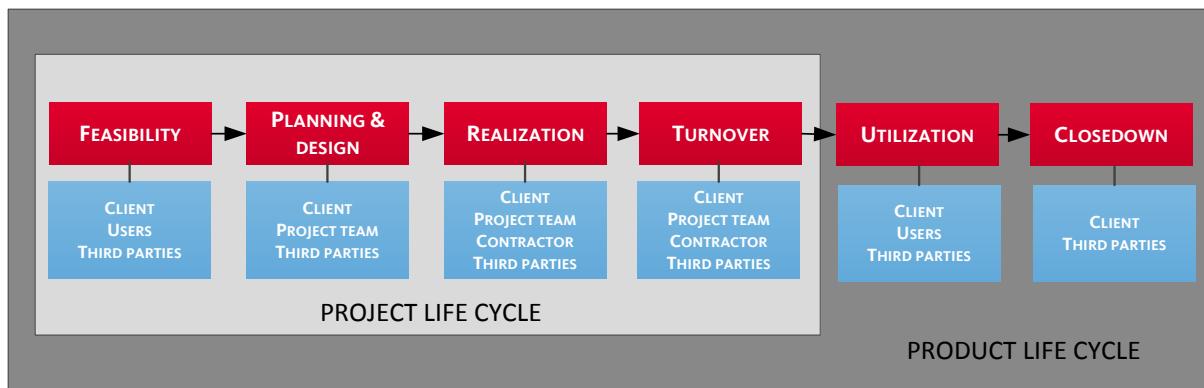
Figure 5 – Project and product life cycle phases

2.1.3 The uniqueness of the task and the team

A second important characteristic that follows from the definitions of a project is that projects have a certain degree of novelty. This novelty comes about by two aspects: (1) a unique scope that is undertaken, which concerns the question *what is done?*, and (2)a temporary organization that is specifically set up to realize that particular project, which concerns *who is doing it*? A combination of the scope and the experience embedded in the particular organization that carries out that project makes some projects more unique than others. A higher uniqueness, and hence lack of experience with the particular task by the members of the project team, requires a larger planning effort from the project team (Conchúir, 2010) to overcome the uncertainty that is induced by the novelty of the task (Turner, 2008). Reducing this novelty by sharing experiences between project teams can therefore be advocated so that the required planning effort can be limited and the efficiency of the project team increases.

2.2   THE SUCCESSFULNESS OF PROJECTS

The ultimate objective of reducing the uniqueness of projects is to increase the likelihood of a successful project outcome. When we talk about the success of a project however, matters get ambiguous really quickly as success appears to have "*multiple dimensions, means different things to different people and is time dependent*" (Shenhar et al., 2001). Some degree of uniformity in the definition and interpretation of success is however indispensable when we want to learn from projects and their results. This section will explain why it is hard to assess project success in a uniform manner and how the successfulness of project management differs from that of projects and the project as a whole.

2.2.1 Success criteria

For a long time the result of a project on the three dimensions of the golden triangle, being cost, time and quality, have exclusively served as the criteria to measure a project's success (Turner and Zolin, 2012, Atkinson, 1999, Westerveld, 2003). According to this definition of project success, we would have to judge any project as successful if it has stayed within its budget and schedule targets even if it does not satisfy and serve the needs of its client and users in any way. Likewise it is imaginable that we would have to asses a project that has run over budget and schedule, but does satisfy and serve its client and users, as a failure by the definition of success. As these examples show, the golden triangle as only success criterion might lead to doubtful classifications and is therefore often considered as incomplete (de Wit, 1988, Atkinson, 1999). To get a more nuanced view on success, additional criteria are needed. In current literature (Westerveld, 2003, Atkinson, 1999, Bourne, 2005) it is widely acknowledged that the satisfaction of involved stakeholders should be added, if not exclusively used, to assess the success of a project. As a consequence of adding stakeholder satisfaction as a success criterion, two questions need to be answered: *Who are those involved stakeholders?* and *When are they satisfied?*

2.2.2 Different perspectives on success

According to Munns and Bjeirmi (1996) and Westerveld (2003), five main types of stakeholders can be identified that are typically involved in projects: the client, the project team, the users, contractors & suppliers and third parties. A further breakdown of these groups can be made by splitting up the client in an owner and project executive, users in consumers and operators and contractors & suppliers in senior suppliers and other suppliers (Turner and Zolin, 2012). For now however the five general groups of Westerveld and Munss & Bjeirimi will suffice. Figure 5 displays the life-cycle phases in which these stakeholder groups are usually involved.

In contrast to identifying "*Who is involved*" less univocal answers can be given to the second question "W*hen are stakeholders satisfied?*". The elements that make a stakeholder satisfied are namely dependent upon local circumstances of the particular project (Westerveld, 2003) and the strategic objectives of that individual stakeholder (Shenhar et al., 2001, Eweje et al., 2012). As these objectives can differ with the different perspectives that are present in a project, the success criteria for the project as a whole can even turn out to be contradictory and competing for one project (Jugdev and Müller, 2005, Westerveld, 2003, van Loenhout, 2013). This all makes it "*impossible to generate a universal checklist of project success criteria that is suitable for all projects*" (Westerveld, 2003). Success of a project can therefore only be defined in its local context.

2.2.3 Time dependency of project success

A last difficulty that makes project success intangible is the time dependency of the success perceived. If for example a road widening project has been realized according to budget, schedule and specifications, it is likely to be regarded as successful by the commencing client directly after completion of the road. When after some time it appears that the project does not lead to the expected decrease in the amount of traffic jams or additional road safety, which was the basic objective to commence the project, the perceived success will soon vanish.
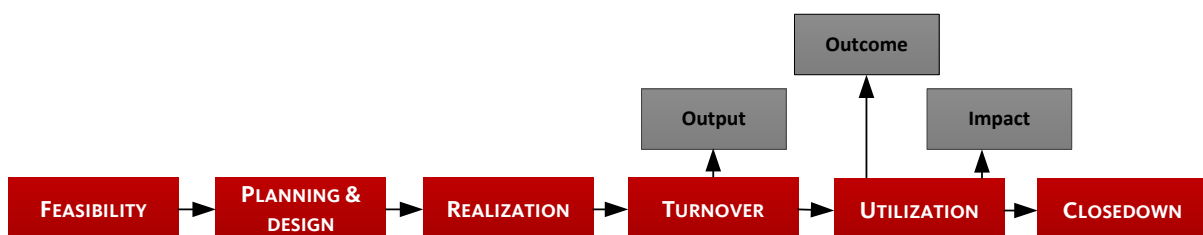
According to Xue et al. (2013) the total result of projects manifest in three different levels: output, outcome and impact. Each of these result levels displays itself in different time frames and contributes to the success of a project as whole. The first level, the project output, manifests directly after a projects completion and concerns the actual asset that has been produced; *is the project delivered according to the specifications and constraints?* The project outcome, as second level, concerns the functionalities that are gained by the project and can be assessed several months after completion (Turner and Zolin, 2012); *does the asset allow for the planned use?* Several years are however needed to assess the impact of the project result, which deals with the strategic objectives that underlie the project; *did it make the world, or our position in it, any better?* In determining the success of a project, all three of Xua's result levels should be considered to come to a nuanced judgment on a project's success.

2.2.4 Success of the project, the product and its management.

From the above it gets clear that project success is more than adhering to the golden triangle. Purely using the golden triangle to assess project success leads to comparable findings but also to pronouncements that might be narrow minded. Alternative criteria, in the form of satisfaction of stakeholders, provide room for a more complete evaluation of a project's success but often comes at the cost of comparability and uniformity of the outcome. Although the limited comparability, the use of these alternative success criteria is generally advocated in literature. The question we should ask ourselves is what value is still to be attached to the golden triangle. "*To determine the golden triangle's place within the project management theory, a distinction needs to be made between project success and project management success*" (van Loenhout, 2013).
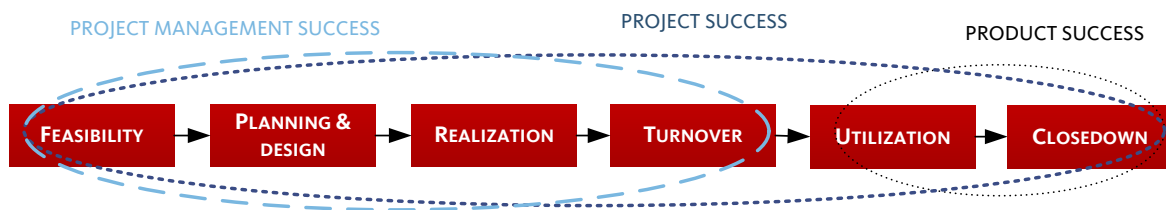
Figure 7 - Life cycle phases in relation to types of success

In that light project management success can be considered as a "*subset of project success as a whole*" (Munns and Bjeirmi, 1996) and is said to focus solely on the project's process and a project team's short-term objectives (Collins and Baccarini, 2004). Therefore it can be measured against the traditional gauges of performance, being cost, time and quality (Jugdev and Müller, 2005). A second subset of project success is product success. Product success, as in Collins and Baccarini (2004), in contrast to project management success, focuses on a project's overall objectives and deals with the effects of the project's final product. The satisfaction of diverse stakeholders and the degree to which the product has contributed to the strategic objectives of these stakeholders seems to be the best measurement criteria for project success. Figure 7 shows how the types of success relate to each other and which life-cycle phases are considered in each definition.

For a project to be entirely successful, it needs to be managed successfully and have resulted in a successful product. Table 1 is a schematic wrap-up of this section, that shows how the used success criteria, the relevant timeframe and the involved actors differ for the two subsets of project success. In recording the results of projects in a database, we need to be aware that various criteria exist with which these results can be expressed. In designing our database we will have to carefully pick the criteria that we are going to use.

PROJECT SUCCESS		
	Project Management Success	Product Success
Criteria	Golden triangle	Satisfaction & strategic objectives
Timeframe	Short term (Output)	Mid & Long term (Outcome & Impact)
Actors	Project Team & Client	Client & Users

Table 1 – Differences between Project Management Success and Project Success

2.3 PROJECT COMPLEXITY

Knowing how to judge and describe the result of projects and project management, our next step focuses on the factors that influence the likelihood of a successful project result. An often mentioned factor in that sense is the interaction between the complexity of the project task and the approach that project managers take to respond to that (Thomas and Mengel, 2008, Vidal and Marle, 2008, Williams, 2005, Hertogh and Westerveld, 2010). Especially in the last decade there has been an increasing notion on the importance of complexity in the domain of project management research (Bosch-Rekveldt, 2011). The current section will therefore provide an introduction to the concept of complexity. First we present complexity from a theoretical viewpoint and explain that complexity comprises two dimensions: detail and dynamic complexity. Secondly we present two frameworks that allow to render a complexity footprint of a particular project. These are the practitioners view developed by (Hertogh and Westerveld, 2010) and the TOE-framework by Bosch-Rekveldt (2011). In each section we will conclude upon the relevancy of the view for a database of infrastructure projects.

2.3.1 Theoretical view on project complexity

We start this section with the notion that the concept of complexity is not exclusively bound to the project management domain (Thomas and Mengel, 2008). Instead, the concept is adopted from complexity theory, which can be applied in all disciplines that deal with systems that can be considered complex (Reitsma, 2003). The most important property of complex systems is the inability to explain and predict the behaviour of these systems albeit the individual components that make up the system are known (Reitsma, 2003). This property also takes an important place in the definition that the philosophy scholar Edmonds (1999) has given of complexity:

"Complexity is that property of a model which makes it difficult to formulate its overall behaviour in a given language, even when reasonable complete information about its atomic components and their inter-relations is given."

When considering this definition it is noticeable that complexity is a property of a model. This means that complexity is not an attribute of the factual reality but only a perception of the people who are dealing with this reality. Due to differing perceptions, and hence different models, "*A situation 'complex' for one manager can be seen as 'simple' by another*" (Hertogh and Westerveld, 2010). The classification of simple or complex can differ per manager, as the ability of managers to oversee the amount of atomic components and their interrelatedness and their ability to deal with the overall behaviour of the considered system differs. So due to varying competences, experiences and viewpoints, different interpretations of complexity might be faced by different members of project teams (Bosch-Rekveldt, 2013).

Detail-complexity

A first aspect that contributes to perceptions of complexity is the, yet mentioned, amount of components and the interrelatedness of these components in the system. Hertogh and Westerveld (2010) refer to this as 'detail-complexity' but in literature also the terms 'structural complexity' (Williams, 1999, Bosch-Rekveldt, 2011) and 'complicatedness' (Rogers, 2008, Glouberman and Zimmerman, 2002) are used. Often detail-complexity will explain why larger projects are more complex, simply because there are more components (including actors) that have to be managed. The intuitive feeling that an increase in size and component makes a project more complex however does not always hold true. The variety of these components and their interrelations is also important. In Figure 8 two possible configurations in which a bath room floor can be tiled are shown. The left configuration consists of 264 (complete) tiles, while the right one is made up of 89 tiles. When only considering at the amount of components, the left figure would be far more complex, but due to the variety in tiles and their relations the right figure is obviously more complex. Therefore Hertogh and Westerveld (2010) noted that a task will be more complex as the **description** that is required to describe the components of a project and their interrelatedness is longer. So it is not about the number of components only.
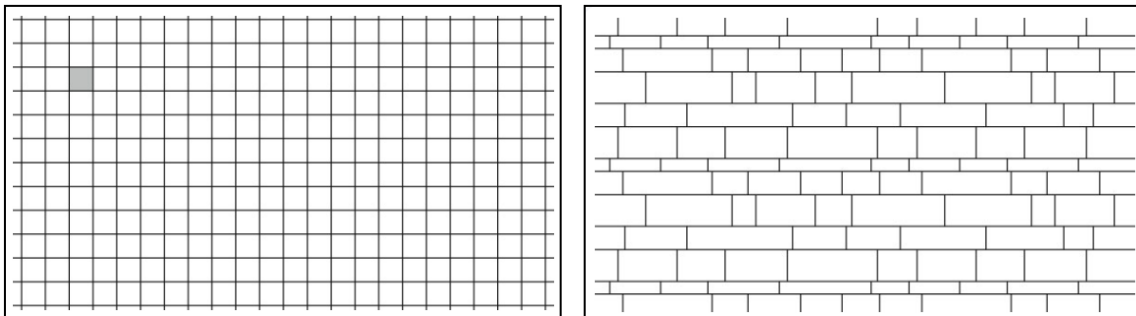
Figure 8 - Two tiling configurations

Dynamic-complexity

Next to detail-complexity, complexity is also made up of dynamic-complexity. Dynamic-complexity is the difficulty to describe a system's behaviour. Infrastructure projects tend to be dynamically-complex as the projects have the potential to evolve over time via self-organization and co-evolution and since the outcome of complex projects can only be limitedly understood and predicted (Hertogh and Westerveld, 2010).

This potential for self-organization and co-evolution hinders project managers to fully control the course of their project and implies the use of other management strategies for complex projects than for simple (traditional) projects. For understanding why a different management approach might be desired we will look at the origin of this self-organization in projects. Regine and Lewin (2014) describe the self-organization as follows:

"Complex projects are composed of a diversity of agents (stakeholders) that interact with each other, mutually affect each other, and in so doing generate novel behaviour for the project as a whole. But the pattern of behaviour we see in these projects is not constant, because when a project's environment changes, so does the behaviour of its agents, and, as a result, so does the behaviour of the project as a whole. In other words, the project is constantly adapting to the conditions around it. Over time, the project evolves through ceaseless adaptation".

Due to the unknown feedback that will inevitably succeed after any policy or management action in the project, managers of infrastructure projects cannot draw their attention exclusively to the execution of their projects in complex projects. With increasing complexity, managing the stakeholders around the project should take a more

prominent role. According to Hertogh and Westerveld (2010) the management approach of complex projects should therefore be more focussed on "interaction" instead of f "control". Also De Bruijn et al. (2003) highlight the importance of managing the process surrounding the project in order to successfully realize changes in a complex environment.

Wrap-up on complexity theory

Overall it can be concluded that complexity follows from the structural set-up of the project (detail-complexity) and the way that it is embedded in and interacting with its external environment (dynamic-complexity). Especially in the beginning of projects, (political) decision makers and project managers have a certain ability to steer and frame the complexity by the decisions that they make regarding the scope and the organization of the project. Once the project is in place however, the applied management style should be adapted to the occurring types of complexity. The chosen management style appears to be conditional for the achievement of successful project results (Hertogh and Westerveld, 2010).

Before the most suitable management strategy can however be picked, it is important to understand the occurring complexity of the project. A database of projects might in that sense be a helpful source of reference that assists managers and other decision makers in choosing the most suiting strategies by using past experiences of projects that have comparable characteristics.

To allow for this, we need to question ourselves which characteristics are relevant to record and contribute to the overall complexity of projects. Therefore the next sections present two frameworks that can be used to map what makes a project complex.

2.3.2 Two frameworks to map project complexity in practice

In the previous section we have answered the question "what is complexity?". This section focusses on the question "what characteristics of a project make it complex?" This is done in order to allow for a footprint of complexity, so that the complexity of projects can be mutually compared. In doing so, we will present and compare the "practitioners view" described in Hertogh and Westerveld (2010) and the "TOE-framework" from Bosch-Rekveldt (2011).

The practitioners view

In their dissertation Hertogh and Westerveld have studied complexity in the view of the management and implementation processes of large infrastructure projects (LIPs). Part of their work comprised the development of what they call the "practitioners view". This view was developed since "*it is of great importance to know what makes the management and organization of LIPs complex for the project managers involved*". On basis of interviews, their experiences and discussions with practitioners, six types of complexity were distinguished.

1   Technical complexity – arises when difficult or unproven technology is used and when technical uncertainty is high. The use of unproven technology can be favourable when it has promising characteristics. It can for example be cheaper, more durable or quicker in its implementation than conventional technology and hence lead to a better project result. Its reverse however is that we do not fully know its characteristics and behaviour, which makes that unproven technology contributes to complexity. Technical uncertainty for a large part deals with the effect of the site conditions on the technology to be used. It is sometimes hard to get full information on the properties of the physical location. This increases the chance that the 'wrong' technology is planned, which requires changes throughout project execution. Often these changes lead to considerable cost and time effects.

2   Social complexity – concerns the conflicts of interests and how to deal with them. Due to the impact that infrastructure projects have on its environment, many stakeholders try to interfere in the decision - making process of the project in order to defend their interest or to hitch on the project for the sake of their own objectives. The constant interaction that takes place between the project team and its stakeholder environment, with objectives and perceptions that can be conflicting, makes it hard to control the project according to the original plan that was set up and predict how the project will develop.

3   Financial complexity – deals with the value that has to be created at the cost of money. The complexity deals with the division of value and costs amongst stakeholders and the development of costs and value throughout a project's planning and execution phases. Especially when costs and value are shared unequally among stakeholders and when the perceived cost and value differ from that planned or realized, a project becomes financially complex.

4   Legal complexity – arises when laws are changing, non-existent or conflicting, when legislation influences the content and processes of the project and when legislation restricts the operational space of the people involved in the project. The non-existence or conflicts in legislation provides room for stakeholders to claim their "right", which often interferes with a peaceful continuation of the project once that occurs. An overkill of procedures and regulation hinders project team members to effectively do their work. In such cases there is the risk that regulation will be (unconsciously) violated by team members, which might result in other consequences.

5   Organizational complexity – refers to the difficulties to set up an organization that is able to adequately deal with the complexities of the project. Finding the right personnel, using the right processes and finding the right contractors is often difficult as there are many options that are not by definition 'good' or 'bad'. Besides the internal structuring, organizational complexity also refers to the division of responsibilities and duties between the project organization and the commencing client.

6   Time complexity – is the last element that contributes to the complexity of an infrastructure project. The typical duration of an infrastructure projects life cycle is rather long, often over 10 years, which gives room to the development of new insights, technologies and changing urgency throughout a project's life cycle. All these changes cannot be foreseen on beforehand and changes have to be implemented on the go.

Having identified these six dimensions of complexity, a complexity scan of a project can be made, which indicates in which aspects a project is complex. To get to a complexity scan of projects, interviews need to be conducted among project team members, so that the research can distribute a certain amount of over the six types of complexities per interview. Hertogh and Westerveld divided 10 points per interview. The total complexity score for the project was then generated by summation and scaling of al complexity scores of the interviews. Using the individual scores of their five cases, an average view on complexity in LIPS could be generated, Figure 9. This average view shows that social, technical and/or organizational properties of the project contribute largely to the entire complexity of LIPs.

Average views of complexity

Legend: ■ Technical ■ Social ■ Financial ■ Legal ■ Organizational ■ Time

Technical	Social	Financial	Legal	Organizational	Time
0,2	0,33	0,14	0,05	0,19	0,08
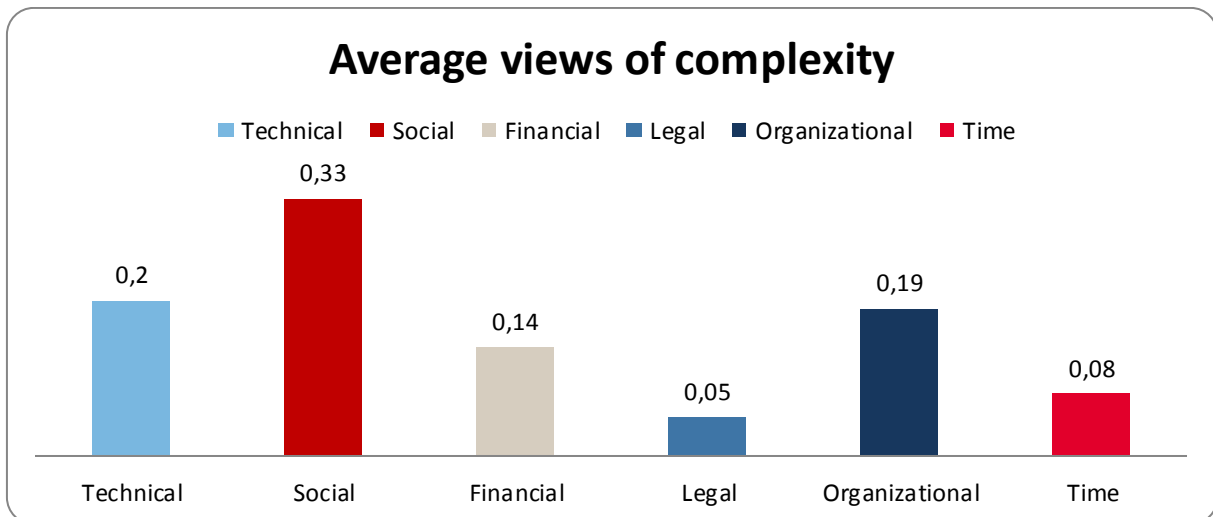
Figure 9 - Relative importance of complexity types in 5 LIPs (Hertogh and Westerveld, 2010)

The TOE-framework

Like the practitioners view, also the TOE-framework has been developed as part of a dissertation. In 2011, Bosch-Rekveldt obtained her doctorate with a study on the adaptation of front end management activities on project complexity in order to improve the performance of projects. This study was not particularly carried out for the infrastructure domain but focused on the Dutch process industry instead. On basis of a literature study, she identified 40 elements of projects that contribute to the complexity of a project. Succeeding case-studies revealed that practitioners consider 49 elements to contribute to complexity in their projects. After analyzing, comparing, grouping and evaluating all the elements from literature and the case-studies, a final list of 47 unique elements, classified as contributing to technical, organizational and external complexity, remained, Table 2.

FINAL ELEMENTS OF THE TOE-FRAMEWORK					
1	T	number of goals	25	O	number of different nationalities
2	T	unaligned goals	26	O	number of different languages
3	T	unclear goals	27	O	presence of JV partner
4	T	uncertainty in scope	28	O	overlapping office hours
5	T	quality requirements	29	O	size of project team
6	T	project duration	30	O	incompatibility of different project managment method and tools
7	T	size in CAPEX			
8	T	number of locations	31	O	lack of trust in project team
9	T	newness of technology (world-wide)	32	O	lack of trust in contractor
10	T	number of tasks	33	O	organizational risk
11	T	variety of tasks	34	E	number of external stakeholders
12	T	dependencies between tasks	35	E	variety of external stakeholders perspective
13	T	uncertainty in methods	36	E	dependencies on external stakeholders
14	T	interrelations between technical processes	37	E	political influence
15	T	conflicting norms and standards	38	E	lack of company internal support
16	T	lack of experience with technology	39	E	required local content
17	T	technical risks	40	E	interference with existing site
18	O	project schedule drive	41	E	weather conditions
19	O	resource and skills scarcity	42	E	remoteness of location
20	O	lack of experience with parties involved	43	E	lack of experience in country
21	O	lack of HSSE awareness	44	E	internal strategic pressure
22	O	interfaces between different disciplines	45	E	instability project environment
23	O	number of financial resources	46	E	level of competition
24	O	number of contracts	47	E	risks from environment

Table 2 - Overview of elements in the TOE-framework

To come to a complexity footprint in practice, the TOE-framework can be used as a basis to assess the complexity of an engineering project. For all of the elements an individual scoring has to be given by one or more team members. It is argued that the resulting complexity footprint reveals in front-end where complexity might be expected throughout the project and provides input for the project team to take adequate measures to deal with it.

In succession of this research in the Dutch process industry, Bosch-Rekveldt has also investigated the project complexity for large Dutch construction projects (Bosch-Rekveldt, 2013). This later research revealed that three additional elements might potentially be added to the 47 elements of the initially developed TOE-framework. These new elements are: (1) soil conditions, (2) operational safety and (3) project history. Further research is however necessary to prove their relevance. Other conclusions that are drawn in this successive research are on the elements that most contribute to project complexity in infrastructure projects. Compared to other sectors, the project duration, site availability and construction logistics and remoteness of the location appear to be of specific interest for construction projects.

Wrap-up and discussion on complexity frameworks

When both frameworks are compared, it is noteworthy that the three most dominant complexity dimensions of the practitioners view (Technology, Organization and Social) are also present in Bosch-Rekveldt's framework. This means that, when recording data on projects and their results, at least the technological, organizational and social/external characteristics of projects should be recorded. Their recording is desirable as these three aspects largely influence the complexity of projects and are thereby influence the management actions that are required.

What also follows from the comparison is that the TOE-framework is more detailed and operationalized and might therefore address more specifically were complexity is to be expected and where management attention or actions are required. One of the problems in the application of the TOE-framework, but also the practitioners

views, is that there is no indication of reference with regard to the assessment results. This makes it hard to apply the framework in practice, as it is hard to interpret the findings and to take suiting management actions. Albeit complexity is subjective and depending upon the view with which one views the project. Setting up a benchmark of projects, their management and their complexities might help practitioners to interpret their results relative to those of others and support them in taking the right management decisions. A database of Dutch infrastructure projects can therefore be supportive to these frameworks if it contains data on some, or all, aspects the contribute to complexity. In our further database design it must become clear how feasible it is to record data on all elements or if clustering or selection of them is required.

2.4 CONTINGENCY APPROACH FOR PROJECTS

The main conclusion that was drawn from studying project complexity is that due to varying types and degrees of complexity different management approaches are favorable. In a broader theoretical context, the desired adaptation of the project management style to the complexity that is actual present in the project should be positioned in the school of contingency theory (Söderlund, 2011). In this section we will give a brief introduction to contingency theory and investigate if there are other factors that influence the management approach to be followed. Like complexity, such other factors might potentially be of interest for a database on projects and their results.

2.4.1 Contingency theory

Where contingency theory has initially been developed by organizational scholars in the 1960's for use in organizational management only, the theory has been extended in later years for use in innovation and project management too (Howell et al., 2010). In the view of contingency theory, situations where the applied project management fits to the characteristics of the particular project have the largest prospects for success. The basic idea of contingency theory is therefore that "*a project's structure and management practices should be tailored to suits its context*" (Howell et al., 2010). More specifically the theory is built on the assertion that "*different external conditions might require different organizational characteristics, and that the effectiveness of the organization is contingent upon the amount of congruence or goodness of fit between structural and environmental variables*" (Shenhar et al., 2001).

Important to note is that a contingent, or also named situational, approach can be contrasted by the "one-size-fits-all" approach that is implied in the "traditional" project management practices (Shenhar et al., 2001, Müller and Turner, 2007, Mulder, 2012). The accumulation of prove that these traditional methods are only limitedly effective and helpful in achieving project success (Mulder, 2012, Flyvbjerg et al., 2003, Cantarelli, 2011) has given momentum to scholars to investigate which type of management should be applied under which circumstances. In the upcoming section we will therefore focus on the characteristics, or contingency factors, that are relevant in picking the right strategy.

2.4.2 Overview of contingency factors

In this section we will shortly present and compare five publications that identify contingency factors that stipulate the project and thereby the management to be applied. For each of the publications we will explain what their authors imply for the management of projects.

The first publication that we consider is "On Uncertainty, Ambiguity, and Complexity in Project Management" of Pich et al. (2002). In their publication they state that most project teams apply an instructionist approach in the management of their projects. This instructionist approach is "*sufficient as long as information about the state of*

the world and the payoff effects of actions is adequate". In various situations information is inadequate, which means that uncertainty is present. Two causes, contingency factors, are presented for this inadequacy, **ambiguity** and **complexity**. Ambiguity arises when too little is known about the state of the world or the causal effects of the pay off. Complexity is defined as the inability to analyze the effects of actions on the pay off because of too many interacting parameters in the transition. The aim of their paper was to come up with alternative management strategies in situations of uncertainty where the instructionist approach won't do, learning and selectionism are presented as alternatives.

Also Williams (2005) notices that traditional project management strategies as prescribed by the bodies of knowledge, as PMBok or PRINCE 2, do not always lead to the desired project result. On basis of a literature study, he concludes that a higher degree of complexity, made up of structural complexity and uncertainty, and **pace** in projects reduces the effectiveness of "conventional project management". In that sense a tailored and contingency approach is promoted for complex and time pressured projects. In such situations; *"the project should not be fully preplanned", "a more cooperative management style is needed"* and *"it should be accepted that the external environment influences the project plan"* (Williams, 2005). Noteworthy is that complexity in the definition of Williams includes uncertainty while complexity is part of uncertainty in the view of Pich, Love & De Meyer.

Aiming to unravel the impact of pre-construction planning on project performance for the US electrical construction industry, Menches et al. (2008) have identified five contingency factors, that influence the pre-construction planning by the contractors. On basis of 12 projects it was concluded that *"better planning that takes into account the characteristics of the project can increase a project's chances for successful performance".* The project characteristics that they identified on basis of a literature study and three workshops that prescribe the degree of required pre-planning in the projects were: **size**, initial uncertainty, bid accuracy, **existing relationships** and **type of construction and award**. A remark is made regarding the factor "bid accuracy". In their research projects and project performance are viewed the perspective of the contractor, for the (financial) success of a contractor it does matter how exact the bid has been prepared. As comparable cost estimation procedures are used in public clients project teams, this factor is less relevant in the present research.

Howell et al. (2010) have developed a framework that relates contingency factors to actual project management strategies. A literature study delivered them five factors: uncertainty (including ambiguity), complexity*, **team empowerment, criticality** and urgency. According to the authors both the themes of team empowerment and criticality are said to be new in contingency theory. With team empowerment the authors refer to the degree to which the organization can organize and process itself within the power that they have and the limitations that are imposed upon them. The term criticality is used to describe how much is "at stake" in the particular project. Urgency is used to refer to what Pich et al. call pace. To assist in picking the right management strategy, Howell et al. have developed the framework that links management strategies to the uncertainty and the effect of consequences of sudden changes. In total three management strategies are presented: plan driven, emergent and problem structuring. Whereby the plan driven approach is to be used when uncertainty is low and the problem structuring approach is to be used when uncertainty is high.

The last researched study in the light of contingency factors is the study of Heupers (2011). In this study he investigates the contingency factors in order to apply Situational Method Engineering for project management purposes. On basis of a literature study of 16 articles from the period 1996-2010 (including the article of Pich, Loch & de Meijer), he comes to a list of 27 contingency factors in which uncertainty and complexity have been mentioned most often. These 2 factors have been mentioned by 11 scholars. Pace, also described as urgency or time, has been mentioned in 8 publications. Also expertise degree, technology, size and interdependencies seem

to influence the required project management strategy as they are mentioned in at least 5 articles. The value that needs to be given to the remaining 20 factors is doubtful as they are only limitedly recognized by researchers as contingency factors. They have at most been mention in 4 of the 16 publications. The management approach that follows from his studies is what he names Situational Project Management Method Engineering (SPMME). The aim of SPMME is to develop a method base that consists of method chunks, so that "*by taking the project characteristics into account appropriate method fragments can be selected from this method base to assemble the best method for the situation.*" This method has largely been based upon the work of Henderson-Sellers and Ralyté (2010).

2.4.3 Wrap up and discussion on contingency factors

In comparing five studies on contingency factors, it is discovered that both complexity and uncertainty are the most important contingency factors. These two factors have been mentioned in all studied publications. Also pace, or urgency, is mentioned multiple times as a contingency factor albeit only in three of the five publications. The other detected factors seem less important as they are only mentioned once or twice Uncertainty, complexity and pace therefore play an important role in determining the most suitable management approach.

When comparing the management approaches that are advised in the occurrence of contingency factors. A uniform pattern can be found in the advice to use a process-based management approach in those situations. In the absence of contingency factors, which are predictive, simple and relaxed environments, the traditional control oriented project management approach is however favorable.

Although contingency theory is valuable by addressing that the applied management approach should depend upon the type of projects. The studied publications are rather general in their advice. None of the publications is specific enough to help managers and decision makers of infrastructure projects in identifying situations and degrees of uncertainty, complexity or time pressure. It is also unclear when to "switch" from the traditional approach to the process approach. This information is however desirable as it will help project managers and decision makers in deciding to adjust the properties of the project or assist them in picking the right management approach.
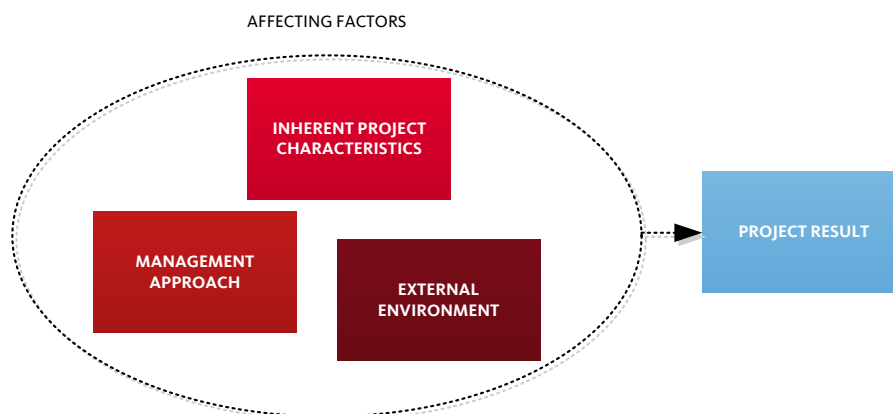
Figure 10 - Three factors that together affect project results

This implies the following for a database: in order to provide such guidance in future, more specific and evidence based data should be gathered by which a decision support tool or method can be developed. This data should be able to link management styles, properties of projects and the project results in order to investigate their mutual dependence. These properties should comprise the inherent characteristics of the project itself as well as

the environment with which the project is to interact. This distinction is necessary as a project managers and decision makers are (partially) able to steer and define the characteristics of the project at its start, but they do have no, or at most indirect control, over the external environment. Once data is gathered, research can be done to the interrelatedness of these factors, so that managers know how to attune their projects in such a way that they are most likely to lead to successful project outcomes. Figure 10 shows for which factors recording is desired and how they relate to each other.

2.5 CONCLUSIONS

In this section we will answer the sub question that was stated in the beginning of this chapter:

1. What factors of projects are relevant to record for an explanative database on projects and their results according to literature?

Our literature study showed that the applied management approach should be attuned to the presence of contingency factors in a project in order to increase the likelihood of successful project results. An ex-post evaluation of the management approach and the properties of projects might help us explain why a particular result has been realized. Recording of the management approach and the properties of projects is therefore desirable.

These properties to lay down should comprise the inherent characteristics of the project itself as well as the environment with which the project is to interact. This distinction is necessary as a project managers and decision makers are (partially) able to steer and define the characteristics of the project at its start, but they do have no, or at most indirect control, over the external environment.

Recording the properties of projects is however not very easy. Albeit being specifically developed for the mapping of the properties that contribute to complexity, the practitioners view of Hertogh and Westerveld (2010) and the TOE-framework of Bosch-Rekveldt (2011) might provide a valuable starting point. In that case we should at least register several technical, organizational and external elements of projects. To get a minimal view on the properties of the considered project. Recording more elements of their frameworks is however favourable as it will enrich the dataset and allow for more specific research.

A last (and apparently trivial) factor to record is the project result itself. The reason why we do mention it here is that various success criteria can be used to conclude upon the result and that result can therefore mean various things. Before we can record the result we need to decide upon the success criteria that we are going to use, so that the same definition of success is used for all projects.

3 PRACTICAL VIEWS ON A DATABASE

The development of a database on Dutch practice does not stand on its own. According to Österle et al. (2011) design-oriented research must lead to original and beneficial applications. An adequate analysis of theory and practice is therefore required. To investigate the current practice, sixteen senior project practitioners of Dutch infrastructure projects have been interviewed. The purpose of these interviews has been two-fold:

1 to gain an impression and overview of the current recording and use of data in infrastructure projects and their back offices

2 to identify which data is desired to fulfil the database purpose in the view of people from practice.

After evaluation of the current practices, the first purpose helps us to formulate the points of departure and the aims of the new database. (Sub-question 2a & 2b) The second purpose provides the input and conditions for the succeeding database design process. (Sub-question 2c, 3 & 4a)

When we recall the conceptual model from the first chapter of this thesis, we can illustrate how the two aims of the interviews contribute to a database design.
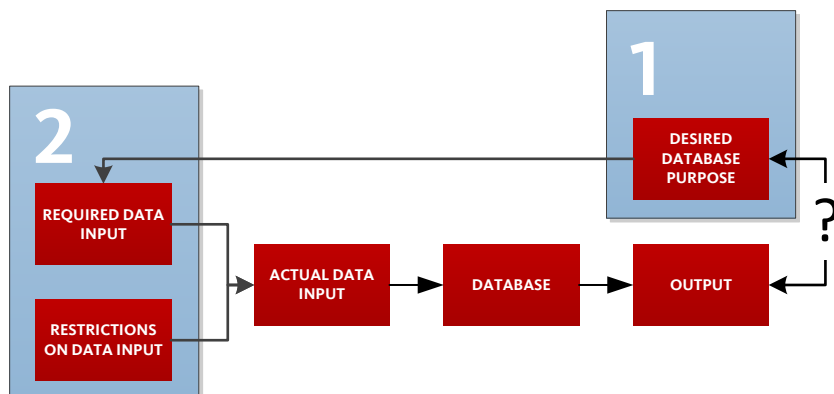

Figure 11 - Contribution of interviews to research aim

The present chapter deals exclusively with the interviews and their results. The first paragraph will first discuss the applied research methodology (3.1), then report on the current registration of data (3.2) and continue with the way in which project teams learn and share their knowledge (3.3). After evaluating the current practices, it will conclude upon the purposes that the database can best serve in practice (3.4) and show which data, in the view of the interviewees, should be gathered in order to serve these purposes (3.5). At last, the challenges and restrictions that are expected in realization of the database are presented (3.6) before the chapter will end with some preliminary conclusions and the answering of sub question 2 and 3 (3.7).

3.1 METHODOLOGY

This section describes the applied research methodology. The entire paragraph is divided in three sections, of which the first section shows why semi-structured interviews are used, the second section motivates and presents the selected candidates and the third section is used to demonstrate the content of the interviews.

3.1.1 Research approach

At the start of this study, it was clear that interaction with people in the field would be necessary to gain insights on, and explore, current data registration and knowledge development activities in the infrastructure sector. The aim of mapping current data recording and knowledge development practices is to ascertain that "*the design-goal really covers the desires of the stakeholders*" (Verschuren and Hartog, 2005). This is relevant as not being informed in this respect increases the probability of developing an artifact (our database) that is not sufficiently innovative. We used research interviews to analyze the current practices and map desires for our database. According to Gill et al. (2008), research interviews suit well to the broad, qualitative and explorative nature of our aim:

"The purpose of the research interview is to explore the views, experiences, beliefs and/or motivations of individuals on specific matters. Qualitative methods, such as interviews, are believed to provide a 'deeper' understanding of social phenomena than would be obtained from purely quantitative methods such as questionnaires. Interviews are therefore most appropriate where little is already known about the study phenomenon or where detailed insights are required from individual participants. They are also particularly appropriate for exploring sensitive topics, where participants may not want to talk about such issues in a group environment."

Of the three possible forms in which research interviews can be held, structured, unstructured and semi-structured (Gill et al., 2008), semi structured interviews were used in our research. Semi-structured were picked since they "*have some degree of predetermined order but still ensures the flexibility in the way issues are addressed by the informant*" (Longhurst, 2010). This is desirable as we wanted to obtain research results that were mutually comparable to some extent but we also want to leave room for the interview candidates to address the topics that they thought were relevant and leave ourselves the option to embroider on theme's, ideas and suggestions that we considered interesting and valuable (Gill et al., 2008). The interviews were carried out in person, this was preferable as the personal interaction contributes to a relation of trust between interviewer and interviewee by which the most valuable answers would be gained (Verschuren and Doorewaard, 2010).

3.1.2 Selection of candidates

Having picked semi-structured interviews as our research method, the succeeding step was to find an adequate group of interview candidates. Selection of our interview candidates has taken place in collaboration with Neerlands Diep. With the aims of the interviews in mind, three criteria were considered relevant in determining the

group of interviewees: (1) their role, (2) the type of projects that they work on and (3) the organization they work for.

Relevant roles and functions

Regarding the function, we first analysed the typical roles that are present in projects. As shown in section 2.1, the roles of the client (incl. policy staff), project team and contractor are relevant in the planning and execution of projects. Of these three roles, we specifically focused on project teams, since compared to the other roles, project teams:

- Have most in-depth inside in the evolvement of projects and should therefore be able to indicate which data is relevant to explain project results

- Are able to indicate which data is currently generated and recorded of their projects and are likely to know how this data is handled in their organizations

- Are relatively easy to approach, and likely to cooperate, via the network of Neerlands Diep

By choosing to interview project team members our selection process wasn't yet completed as we still needed to decide on the specific functions that would be most interesting. After evaluating the typical roles in project teams, interviews among (1) project managers, (2) portfolio managers and (3) project controllers were considered to be most valuable since these three functions:

- are concerned with the general aspects of the project. This gives them a broad view on the course of projects instead of the more narrow and specific view of for example technical or contract managers.

- play major roles in the decision making throughout the project and are therefore likely to have clear views on which data and knowledge will support them in taking adequate decisions. The project manager is thereby assumed to have the most complete view on these needs as it is the highest ranked person in the project organization.

An important remark to make here is that for this first explorative research the consultation of project team members is considered sufficient for the development of a first database concept. In future, when the database is to be further developed, we however advise to also consult clients, and their supporting policy staff, regarding their views. Consultation of them is also relevant since clients also hold decision making powers and might therefore have different needs and desires regarding the database that can support them.

Relevant types of projects

Next to the role and function of our interview candidates, also the type of projects that they work for are relevant selection criteria. Since we aim to investigate the possibilities for a database on the entire infrastructure sector, it was chosen to interview candidates that work on different types of projects. This means that projects differ in size, type of modality (rail, road, waterway), nature (new-built, renovation, maintenance etc.) and structure (bridge, tunnel, station etc.).

Relevant organization

The last criterion in the selection process is the organization that the managers work for. Considering the explorative nature of this research and the broad aim of the database, diversity in the project organizations is favourable. From a practical viewpoint however, this would require a much greater effort in organizing the interviews. Due to limited research time, we decided to mainly focus on the two largest organizations in the Dutch infrastructure sector: ProRail and Rijkswaterstaat. We choose these organizations since they are both related to Neerlands Diep. This means that interviews could be organized relatively easily within their network. A second

reason to work with these organizations is that their portfolio of projects comprehensive enough to covers up nearly all types of possible projects.

Worth noting is that the desires and relevance of a database within ProRail and Rijkswaterstaat not necessarily coincides with that of other organizations that commence infrastructure projects, such as municipalities or provinces. It therefore needs to be validated if the relevancy of the database stretches out to the other organizations and which specific adaptations are required to make it valuable for them.

The selection of interviewees

On basis of these three criteria a lists of potential candidates was been formulated; mainly of managers who work for ProRail and Rijkswaterstaat and who have completed one of Neerlands Diep management programs. Of the in total 18 candidates that have been approached, all initially replied positively. Due to planning difficulties it was decided to cancel 2 of those interviews, so in the end 16 interviews have been conducted. An overview of the amount of interviewees per functions and organization is shown in Table 3. Further specification of interview candidates is given in appendix A.

ORGANIZATION	# PROJECT MANAGER	# PORTFOLIO MANAGER	# PROJECT CONTROLLER
ProRail	6	1	-
Rijkswaterstaat	4	2	2
Municipality Amsterdam	1	-	-

Table 3 - Overview of functions of interview candidates

A remark that must be made regarding the candidates is that the recruitment of the candidates has taken place via the Neerlands Diep network. As Neerlands Diep offers their programs only to ambitious, talented and critical managers only a bias might be present among our interview candidates.

3.1.3   Interview content

As mentioned in the introduction of this section, the intentions of the interview series were twofold. The interviews had to (1) map the current practices of data registration and knowledge development in infrastructure projects and (2) investigate the desires of the candidates with respect to the new database. Together this was to resulted in the requirements for the database. To achieve these goals, an interview protocol has been used that was built around 6 more specific main themes, Table 4.

THEMES OF THE INTERVIEW	
1	Background and personal details of the candidate
2	General vision on data registration and knowledge development
3	Current data registration and application within their organization
4	View on form and aims of a new database
5	View on organizational processes and knowledge building
6	Epilogue

Table 4 - The six themes of the interview

The interviews started with an introduction on the background and personal details of the interviewee to gain an idea of the viewpoint from which the candidate perceives the topic. The second theme, the general vision, was threated after the introduction to make directly and explicitly clear how the candidate perceives a database of

Dutch infrastructure projects. This provided ground to further unravel why a candidate has a particular view on the development of a database later in the interview. Depending on the answers given and the course of the interview the topics 3,4 and 5 were treated, although not necessarily in successive order. In these themes we gathered our actual data. In the epilogue, there was room for candidates to come up with tips regarding the content of the research and interesting people to consult. An exact outline of the interview protocol is included as appendix B.

3.2 INTRODUCTION TO CURRENT DATA RECORDING

One of goals of the interviews was to gain an impression of current data registration within the ProRail and Rijkswaterstaat organization. Thereby we have an indication of the context in which the database has to appear. Throughout the interviews three sources of data were mentioned by the interviewees: progress reports, Rijkswaterstaat's project database and specialist databases. We will introduce them briefly in the upcoming sections. Characteristics of the candidates that we refer to can be found in appendix A.

3.2.1 Progress reports

A large share of data that is available on projects and their performance is currently laid down in so-called progress reports. Within Rijkswaterstaat and ProRail these progress reports are generated three times a year, throughout the planning and realization phase of projects.

The main purpose of those progress reports is to show the advancing of the project to the client and the back office on various aspects of the projects. These reports dwell amongst others on the progress of the project with respect to scope, budget and milestones. Besides they give up to date information on the most threatening risks, interaction with the main stakeholder groups and other potential management dilemmas. In total there are about 12 indicators that are part of the progress reports (candidate 7).

With these reports, project teams are able to communicate yet approved mutations in scope, budget and milestones that the project team and their contractor have decided upon[2]. Since the reports provide a common language to communicate with clients and superiors. Thereby the reports are valuable for managing and organizing their projects. This contributes to a better understanding of the project team's work and dilemmas and thereby helps the team and client in making more effective decisions.

Next to its direct communicative function on the project level, the progress reports also have a function in the back office. In specific situations the back office uses the reports to generate organization wide information on particular developments in the project portfolio. Seen from the perspective of a project manager, as stated by candidates 3 and 15, the back office in some cases is too harsh in the bundling and combining of the project related data. Explicatory lines that they often take up in their reports often fall out in the distillation process while in their view it are exactly these phrases that provide the nuance to correctly interpret and understand the information that is presented in the report.

3.2.2 Rijkswaterstaat project database

An important tool that is specifically used by Rijkswaterstaat in the administration of these progress reports is their project database. The database was initially developed in 2007 for the larger projects of Rijkswaterstaat as a tool and platform to develop and share progress reports according to a predefined format (Rijkswaterstaat, 2013). Since this database stores the subsequent reports, it holds much data on the entire portfolio of projects that are

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[2] **These are the "Verzoek tot Wijziging (VtW)"**

carried out by Rijkswaterstaat. The project database might therefore also be valuable for learning and strategic purposes instead of communication of project progress only.

As the database is relatively new and only a little amount of data was available, these other purposes are still rather unexplored. As the pile of data grows investigating these purposes gets more interesting. Difficulties that, up to now, have hampered a full realization of these functionalities are a lack of uniformity and a lack of a clear process owner who is responsible for the evaluation and the unlocking of the data and the interesting findings (candidate 10).

ProRail on the contrary does not have a centralized location in which the progress reports are stored. Generally the ProRail projects make use of a relative simple predefined spreadsheet that is stored in the project archives (candidate 3). Comparison of the reports is therefore difficult as reports are not centrally stored an much effort is required to gather and compare all the reports.

3.2.3 Specialist databases

Next to the progress reports and the project database, both Rijkswaterstaat and ProRail have specialist databases. These specialist databases are used and developed by experts that are part of the project team. Therefore these databases contain only a specific kind of knowledge that can only be used for one particular expertise. In line with the specific functions and tasks that are known in project teams, interview candidates mentioned the existence of databases on risks, index numbers[3] (for cost), standard planning elements, design guidelines and material standards.

Although most of the interviewed candidates state that they make use of the information that comes from the databases of the experts, they indicate that they do not exactly know how, how often and by whom the databases are updated or revised. They also have a common conjecture that the feedback of what happens in practice towards the databases is suboptimal. A general tendency of project team members to prevail project duties over line duties in their view explains why the continuous improvement and updating of the database by the experts is doubted.

3.3 LEARNING AND KNOWLEDGE SHARING IN THE CURRENT PRACTICE

Throughout the interviews candidates were asked if and how they try to learn from their own work and in which way they share their experiences with others in their organization. These questions were asked to map the needs that a database of Dutch infrastructure projects should serve. The present section will be used to present the five main mechanisms were identified with which managers try to boost learning and knowledge development within their organizations. This section will thereby provide a basis for an evaluation of them in the subsequent section. The learning and knowledge sharing mechanisms that we will subsequently present are:

1 Direct contact with other project teams or colleagues

2 Internal coaching and mastering within the project team

3 Visiting lectures, presentations and courses

4 Using standards, executive documents and procedures.

5 Keeping project teams intact for more than one project

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[3] **Kentallen**

3.3.1 Direct contact with other project teams or colleagues

An often heard form in which project teams organize knowledge exchange is by organizing meetings, discussions or presentations with comparable projects as reference for the work that they are doing. On an individual level meetings are generally replaced by phone calls with experts to find help and answers for particular dilemmas and questions. A good example that shows how this knowledge sharing mechanism works in practice is given by interview candidate 2:

"Before and throughout the project I often, depending on the subject and the complexity of the project, search for information and experiences that we need and that are currently missing in our team. Knowing what we lack, we can actively search for relevant knowledge. In my current project we consciously sought interaction with other Rijkswaterstaat teams to learn about transfer dossiers, as we have to transfer our project to 14 different asset managers in the near future."

In the example of candidate 2, the lack of experience with transfer dossiers, was an important criterion in their search for reference projects. When candidates were asked which criteria they use to come to reference projects, many managers stated that the **project scope** in their view is the most important criterion. Others also mentioned that the **phase** of the project and the **environment** are relevant in making a comparison. According to candidate 3 the environment has to be interpreted broadly as it can mean the physical environment as well as the stakeholder, political and policy environment. This supports the statement of interviewee 14 who states that: despite the totally different scopes, a project as the renovation of the XXXXX can learn a lot from the media policy that has been set up by the YYYYY project as they are both projects with a national prestige.

3.3.2 Internal coaching and mastering within the team

Four managers indicate their role as a master and coach towards their team members as a way in which they try to improve the level of knowledge within their organization. Their hierarchical positions as well as their seniority sets them in the position to do so. Candidate 4 explicitly considers this an important part of his job:

"It for sure is part of my job to improve knowledge within my organization. Therefore I try to propagate my vision on projects within my project teams. Although I don't speak everyone, the impact in the organization is wider than that. There is an unchecked spreading by which people pass-on the for them relevant parts of knowledge to others in the organization."

Where candidate 4 considers his guiding role to be explicitly part of his role, candidate 1&10 on the contrary consider it only to be implicitly part of their job. When we were discussing coaching of the project team by a project manager, candidate 10 said:

"This learning duty that we are now discussing is not explicitly part of my function but just happens on-the-go"

Although only four candidates have mentioned their role as master or coach in the interviews, we expect that this learning mechanism is wider embedded amongst the project management practice. The implicit nature of the mechanism and the modesty that must be set aside to claim to be exemplary are factors that might have prevented managers to mention the internal coaching mechanism.

3.3.3 Visiting lectures, presentations and conferences.

In order to learn both ProRail and Rijkswaterstaat try to share knowledge and ideas by organizing presentations, lectures and conferences on specific topics and for specific audiences. A lot of the interviewed managers recognize and describe them as a learning mechanism and they are generally considered valuable. Due to the

room for interaction and the interchange of visions on the craft of managing projects. Despite their value, several remarks are made that stress the weaknesses of these lectures.

1. A first remark concerns the limited effectiveness of lectures and presentations. Often there is a (partial) misfit between the lecturer and audience as not all information of the presenter is relevant for the people in the audience. Illustrative of the limited effectiveness of the lectures and presentations is a remark that is made by candidate 12, on presentations that are held in monthly project managers meetings at ProRail:

   > *"such lectures do not lead to a structural change or improvement in the way we do our projects. After such a presentation only a few people come up with content related questions. For the most people the topic is not directly relevant or applicable as they are busy with a project with different characteristics. Once they are in a position that the topic has become relevant they are likely to have forgotten what the others have yet learned, so similar mistakes will be made again."*

2. Candidate 3,7 & 14 state that care is needed in organizing lectures and presentations, as lecturers tend to have a double agenda: "*all too often events with the intention of knowledge sharing are spoiled with managers trying to sell their own successes and capabilities*" which does not fit with the intention to learn from each other. In their view such lectures should also focus on bad-practices in order to learn from each other. Since a lot of people do not like to talk about their negative experiences and their own failures, there is a constant threat that these session lose their value.

3. A last condition for the effective use of presentations, is that best practices and lessons learned need to be related to theoretical ideas and thoughts. According to candidate 16 "*linking practice to theory will help to interpret the process that has happened in practice and formulate the lesson that could be learned from it.*" This linking also explicitly shows the reflection that has taken place. In many cases project managers just tend to tell what they have done and how the projects babbled on without finding (theoretical) explanations for the course of the project.

3.3.4 The use of companions, standards and procedures

When questions were asked on the learning power of the organizations Rijkswaterstaat and ProRail throughout the interviews, many candidates mention the standards and procedures that are used within those organizations in the planning and execution of projects. ProRail has developed the "core-process[4]" as their working standard, whereas Rijkswaterstaat works with the "Working companion for construction projects[5]" (WCC).

Both companions prescribe which activities and documents have to be completed by the project team before it can continue with succeeding activities. Working with these standards enhances the uniformity and transparency of the organizations, which makes it easier to check the quality of the work of the project teams (with gate reviews) and to take measures if the desired quality level is reached. Quality checks have to safeguard that correct and complete information is available when important decision have to be made.

When the core process and the WCC are compared, the WCC appears to be somewhat more elaborate, as it is not only a prescriptive standard but also an important source of reference for the project team members. The WCC offers templates, best practices and document overviews, guides and other manuals. Like with the lectures various notions of critique have been mentioned by the interview candidates:

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[4] **Kernproces**

[5] **Werkwijzer Aanleg**

- Both ProRail and Rijkswaterstaat formally have a feedback mechanism which guarantees constant updating and adaptation of the standards, in practice this mechanism appears to be more diffuse. There is a common feeling that the revision of standards is too late and that the opportunities to implement experiences from project teams are not optimally used. This also has to do with a tendency that project duties are considered to be more important than line duties (candidate 10 &14). Another reason is that reorganizations regularly hinder the realization and functioning of feedback mechanisms (candidate 12). Recently ProRail and Rijkswaterstaat have reorganized their organizations. Standards are therefore not always up to date and suiting to desires of the project teams.

- The procedures are in some cases considered as bureaucratic and too large. Bureaucracy is mainly present in ProRail's place as the core process is not flexible enough to suit all project types in practice, (candidate 3 & 11). In the core process all projects are treated in a same fashion while some, tailoring to the characteristics of the projects might be advisable for some projects. Especially for the smaller and more straightforward projects the Core process demands too much documents. On the contrary, the extensiveness of Rijkswaterstaat's WCC often makes it hard to find the right pieces of information or documents (candidate 2 & 9): "*In such case you start to invent and improvise yourselves, resulting in mistakes that others have yet made*". Both organization therefore have the a challenge to unlock the data in a more intuitive and suiting way.

- Some managers warned that the procedures tend to paralyze their team members and serve the intrinsic laziness that is present in any human (candidate 3, 10 & 13). People often tend to blindly follow the standard procedures but that does not guarantee a good outcome. Instead team members need to actively think on which topics are relevant relying on the experiences and creativity that is present in themselves and their colleagues. In the view of the managers freedom encourages and motivates people to do their work right and to justify the work that they have done. According to these managers the standards and procedures are sometimes too stringent and thereby right passes their initial intentions to safeguard a minimum level of quality.

3.3.5 Keeping the project team together

A last mechanism that we identified, is not specifically a learning or knowledge developing mechanism but is a mechanism to make optimal use of gathered knowledge and experiences within one team. Interviewees 3, 11, 12 & 13 have mentioned an example in which they maintain their team in its original formation and try to acquire additional work:

"*Within my team I do not record a lot of data, although there is pretty much repetition in our work. Instead I try to make use of a fixed team and actively safeguard the bundled knowledge within that team. Although data and the lessons we have learned are not explicitly laid down, they are always implicitly among us*" (Candidate 11)

"*Once I have my team, I always try to acquire some additional side-projects. One reason is that we make optimal use of the efficiency that is already present with the team, we do not have to start it all up again. The second reason is that it helps me to keep my people 'fresh'. Especially when they are working for a longer time on one project, people might become stigmatized by the actual developments in the main project.*" (Candidate 3)

It is worth noting that all four managers who mentioned, maintaining the project team as a way to safeguard knowledge, are working for ProRail. There is no reason to believe that this mechanism exclusively happens within the ProRail organization but there might be circumstances that stimulate it. According to candidate 15, a team manager of ProRail, there is a scarcity among certain experts and team functions within the organization. In that sense there tend to be a culture of "*who screams hardest, gets first choice*". Therefore project managers want to

optimally exploit a complete and well-functioning team once they have finally got one as there is high uncertainty on the composition of the next team.

3.4 EVALUATION OF THE KNOWLEDGE SHARING PRACTICES

Our previous section showed that knowledge sharing happens in various forms within the project departments of ProRail and Rijkswaterstaat. The mechanisms that have been described, and the distinction that some the interview candidates made between various types of knowledge sharing, suit well to the types of knowledge sharing that are described by Huysman and de Wit (2003): knowledge exchange, knowledge retrieval and knowledge creation. In this section, we will provide a basic introduction to each of the types and show how knowledge exchange, knowledge retrieval and knowledge creation are facilitated in the two organizations on basis of our findings from the previous section. By evaluating these practices we can conclude upon the purposes that a database on Dutch infrastructure should fulfill. For more in-depth insight and theory on knowledge sharing and (organizational) learning we refer to Huysman and de Wit (2003).

3.4.1 Knowledge exchange

The first type of knowledge sharing is knowledge exchange. According to Huysman and de Wit (2003) knowledge exchange has the purpose of exchanging existing individual knowledge among individual members of the organization. When looking at the mechanisms described in the previous paragraph, it can be seen that this description suits with the direct contact with other project teams as well as the individual coaching that takes place between colleagues. In both mechanisms individuals try to learn from other individuals.

According to Antonova and Gourova (2006) a typicality of knowledge exchange is that it is induced by a knowledge seeker who searches a particular source of information, the knowledge source. The final source does not have to be found within one try but it can also be someone who points the seeker to a new source. A quote of candidate 14 illustrates this seeker-source relationship in knowledge exchange:

"Once you face a particular problem for the first time, you try to find someone who is more experienced with it. This person can be found within your team but also among other colleagues."

Since especially the direct contact between project teams is an often used mechanism, knowledge exchange as a way of learning appears to be very common in infrastructure projects. As many as 13 out of the 16 interview candidates, have mentioned knowledge exchanges as an important learning mechanism. Knowledge exchange thereby by far outreaches the other two forms of knowledge sharing and seems to be fully ingrained in the two organizations. An anecdote of candidate 16 illustrates the deep rootedness of the exchange tendency in Rijkswaterstaat:

"In a discussion on quality management in our organization, some people where propagating to make an overview of the experiences and knowledge of each individual employee. A new colleague, who has been part of the organization since only one year, stated the redundancy of this proposition and claimed that this overview already existed in the form of our address directory: "within five phone calls I have up till know always found the person I needed to speak.""

A particular reason for interview candidates to prefer knowledge exchange over the other types of knowledge sharing is that personal contact is essential in order to learn from other projects according to the interviewees. Besides it is the quickest way to get answers on specific questions and it allows best to describe the specific context of the reference project. Understanding of the context is important as not all lesson can be transplanted directly from one project to the other (Candidate 6,10 & 12).

If knowledge exchange is to be facilitated by means of a database of Dutch infrastructure projects, an important criterion that follows from the interviews is to include contact information of involved people in that project. The more specific distribution of contact information helps knowledge seekers get easier access to knowledge sources than is currently the case. As it will take too much effort to register all team members, candidate 16 suggests including information on the main managers (IPM-roles at Rijkswaterstaat) at various stages of the project. Inclusion of multiple managers is desirable as each specific function holds distinctive knowledge of the project.

Implications for a database

Since knowledge exchange is yet widely incorporated in the organization and a database is not likely to replace the direct contact between teams and colleagues, there is no need to make knowledge exchange as such the main purpose of the database. The inclusion of data that might help to make current exchange mechanisms more efficient, e.g. contact information of involved managers, should however be considered.

3.4.2 Knowledge retrieval

The second form of knowledge sharing that currently takes place within Rijkswaterstaat and ProRail is knowledge retrieval. Compared to knowledge exchange, knowledge retrieval is more supply based as there is a knowledge source present that is waiting to be mined. Generally it is about setting available organizational knowledge, for example in the form of a learned lesson or best practices, to the individual people in the project teams (Huysman and de Wit, 2003). Throughout the interviews, two kinds of knowledge retrieval mechanisms are mentioned by candidates: (1) meetings, presentations and lectures (2) the companions, standards and procedures.

Throughout the interviews it appeared that people are rather critical on the way that knowledge retrieval is currently organized. This might give the impression that people are skeptical on lessons learned and best practices in general. The interviews however clearly indicate that this is not the case. A total of eight interview candidates stated that more and better accessible best practices and lessons learned will help their organization, and themselves, to do their work better. Five of these candidates (2,3,6,10 &11) even suggested that setting available lessons learned should be one of the main functionalities that the database should fulfill.

Implications for a database

The overall impression that was gained on knowledge retrieval in the infrastructure sector is that together the two mechanisms cover up and provide most of the knowledge that is currently present in both organizations, including the lessons learned and best-practices. A threatening problem that is however faced with the current systems is that their effectiveness is rather low. Presentations can have a functional misfit and companions and standards are sometimes too stringent or too large. Both ProRail and Rijkswaterstaat are therefore advised to investigate how they can make the knowledge retrieval mechanisms that are yet present in their organization better suited for the specific needs of project teams. Especially with the improved yet present mechanisms, the need to exclusively devote our new database to knowledge retrieval is limited.

3.4.3 Knowledge creation

The third form of knowledge sharing is knowledge creation. This is the generation of new knowledge in the organization which results from combining existing pieces of individual or organizational knowledge. When in the interviews it was asked how the organizations are trying to learn from completed projects, the impression that was gained throughout the interviews is that knowledge creation is not a top priority in practice:

"Feedback and reflection on what we have realized compared to what we planned to do and the lessons that we learn from them is far from optimal. In general I think that the learning capabilities of our organization are not particularly high. For myself it lasted a while before I got used to that after my work experiences in other organizations" Candidate 15

Although candidate 15 has work experiences outside his present organization and thereby has some reference he is not the only candidate who notices the limited learning capacity of the two organizations. Also candidates 1, 5, 11, 12, 13, 14 & 16 state that the learning and reflective power in the infrastructural sector is rather low.

The impression that was gained is that in the current practice, learning initiatives are often organized in a local situation and for a particular reason. Examples that were mentioned are: a monitoring track after a policy change, the writing of a booklet that describes the learned lessons of a particular project and the recording, and comparison, of occurred risks within one department that does comparable projects. When then questioned why such learning initiatives are not implemented organization-wide various reasons were given why no structural feedback upon delivered performance and reflection and evaluation of the work is present:

1. Project managers and the organizations in general tend to have a main focus on production and realization. As candidate 1 states: *"We're happiest when the cranes are out so we want them to get out as soon as possible, thereby ignoring that cautious preparation and evaluation might pay itself back"*. It is not in the nature of project managers to look back and reflect on the work that they have done.

2. The process of gathering, comparing and analyzing recorded data on projects in order to create new knowledge is rather labor-intensive, according to candidate 14. This makes it hard to combine with our main duties, those of the project. As a lot of manpower is required to learn, the management is deterred to set available resources. It is also very hard to show how these investments pay themselves back.

3. Active pullers promoting and setting up feedback and learning mechanisms are lacking in the organizations. Interviewees 8 and 12 state that this is an important condition for successful learning: *"You need someone who sees the potential and wants to get it organized."* At present, feedback and learning mechanisms are not a top priority of management so people do not work on it. Instead they work on those things that do have priority, which is the execution of projects.

4. It gets harder to reflect on yourself and your organization the longer you work in a comparable situation. *"In the first years I worked for ProRail I regularly wondered the way things work in this organization. Gradually I got used to it and things do not surprise me anymore, in that sense I've become blind for my surrounding organization."* (Candidate 11)

Implications for a database

Knowledge creation, in contrast to knowledge exchange and knowledge retrieval, has not found a prominent place in the everyday practice of ProRail and Rijkswaterstaat. It is not common to collect and analyze loose bits of data and experiences for learning and knowledge development purposes. The interview candidates however acknowledged that a database might be a useful means in the creation of knowledge as it can be a storage place to collect relevant data that can be researched and investigated with means of a meta-analysis.

3.4.4 Conclusion and discussion on knowledge sharing practices

When considering the three types of knowledge sharing, all three types were considered valuable by project practitioners. Two specific kinds of databases appeared desired by practitioners: a database for the spreading of best practices (a knowledge retrieval application) and a database for developing new knowledge by means of a

meta-analysis on entered data (a knowledge creation application). There is no specific preference of the practitioners for one of the two types.

Despite the comparable amount of support for both types of databases, we shifted our focus to the development of a knowledge creating database after the interviews. The main reason to do so is that the need to develop an entirely new knowledge retrieval mechanism is rather low, since there are already retrieval systems in place. A knowledge creating application on the contrary is however not yet developed in practice.

Due to the "complaints" of interviewees about the current knowledge retrieval systems, both ProRail and Rijkswaterstaat are advised to investigate manners that can make them more effective and fit-for-purpose. Possibilities of improvement that have been mentioned by candidates are to make better use of best practices and improve the disclosure of experiences. Only if these improvements appear to be impossible on the current systems, investigation of a new database of best-practices should be considered.

3.5   INTERESTING DATA TO COLLECT

This section is devoted to the data desires and needs of the interview candidates with regard to the database. It presents the factors that are considered worthwhile to register in a knowledge creating database. These factors must allow for a meta-analysis to find general explanations of, and patterns in, projects results.

3.5.1   Relevant factors for a meta-analysis to project results

One of the main questions in designing a database is which data should be recorded and for what reason. The interviews that have been held were partially used to explore answers to this question. Throughout the interviews we asked our candidates the (open) question what aspects they would record in a database and why. From all our sixteen interviews eleven candidates mentioned relevant factors. These relevant aspects of projects were often mentioned literally by candidates but some of them were mentioned implicitly as part of answers to other questions.

Five candidates, of which three of ProRail and two of Rijkswaterstaat, however did not provide clues on relevant aspects. Often a combination of the following three reasons explains why aspects were not mentioned throughout the interviews: (1) the candidate was exclusively supportive to a database of best practices, (2) the candidate was highly skeptical about databases in general and (3) the available interview time has been used to gain input on other topics. Despite these candidates could not directly contribute to determining the relevant factors for recording, they did deliver valuable input on other topics such as the investigation of current practices and potential challenges and pitfalls in designing a database.

#	ASPECT	CANDIDATE								
A.	**Planning**									
1.	time	1	4	8	13	16				
2.	preparation time	6	8							
B.	**Cost**									
3.	total costs	1	4	5	6	8	12	13	15	16
4.	cash flows/cash rhytm	5	8							
5.	reference costs per unit	1	6							
C.	**Contract**									
6.	contract type	1	6	12	16					
7.	contract mutations incl. scope	6	15	16						
8.	procurement type	6	15							
9.	cuts in contracts	12								
10.	compliance (documents)	15								

#	ASPECT	CANDIDATE					
D.	**Project characteristics**						
11.	scope	1	6	8	13	14	16
12.	project characteristics	4	8	13			
13.	type of project	5	8	14			
14.	state of areal	5	8	16			
15.	context/circumstances	6	12				
16.	personel	4	13				
17.	physical situation	5	16				
18.	stakeholder environment	5	16				
19.	complexity	13	15				
20.	location	15					
21.	stem data	15					
E.	**Risk**						
22.	risk	4	6	8	9	12	14
F.	**Project result**						
23.	performance/succes	6	8				

Table 5 - Overview of mentioned aspects that are relevant for a database of Dutch infrastructure projects

In the overview of mentioned aspects, Table 5, a total 23 different aspects can be recognized that were mentioned by the candidates. After analyzing them, they were grouped in 6 distinctive themes. Both, the themes and individual aspects will form an important basis for the actual database since project management experts consider them useful in the creation of project management knowledge. Although the mentioned aspects and themes provide an important basis, not all of them will automatically be incorporated in the final database design. Some selection will take place so that the aspects that tend to: overlap with others, are too hard to objectively record or are not relevant enough will be filtered out. In the upcoming chapter, chapter 4, it will be presented how the database is designed and which aspects and elements are integrated in this design.

3.6 CHALLENGES FOR DATABASE DESIGN

Throughout the interviews many candidates gave general tips and suggestions that are helpful in realizing a database on Dutch infrastructure projects. Often these tips and suggestions are induced by the difficulties and challenges that were foreseen in the practical implementation of the database by the interview candidates, in total nine challenges were identified:

1   **Workload I** - Try to make use of present data and mechanisms as much as possible; do not try to start from scratch. (candidate 7)

2   **Uniformity** - Be aware that the present standards allow for different interpretations. Present data on project is therefore not always evenly uniform. (candidate 9 &13)

3   **Subjectivity** - Data on projects is very often subjective and ambiguous, depending on the perspective that one takes. (candidate 12 & 14)

4   **Workload II** - Limit the burden upon the project teams, prevent that it becomes a must do, but make it a win-win instead. (candidate 3 & 11)

5   **Confidentiality** - Confidentiality might become an issue, especially when financial and market information is concerned. So a mechanism must be designed how to deal with that. (candidate 7,14 & 15)

6   **Implementation I** - You need a clear puller or client, to get your initiative implemented. (candidate 8 and 12)

7   **Relevancy I** - The data that you want to collect should depend upon the demands and problems that the client phases. Otherwise it is hard to decide the relevancy of data. (candidate 5,7,8 &10)

8   **Relevancy II** - The term Dutch infrastructure projects, is rather general. A further specification and delineation will help to make it more concrete. (candidate 8 & 15)

9   **Implementation II -** Try to consider a database as a lively document; start with a compact version and see how it needs to develop. This will prevent a lot of unnecessary work and it will make the database as concrete as possible. (candidate 6)

When analyzing the nine challenges it shows off that some of the challenges are more concerned with organizational issues while others are more dealing with the data itself. Two groups of challenges can therefore be determined:

DATA-RELATED CHALLANGES		ORGANIZATIONAL CHALLANGES	
A. Uniformity	(# 2)	D. Workload	(# 1&4)
B. Subjectivity	(# 3)	E. Confidentiality	(# 5)
C. Relevancy	(# 7&8)	F. Implementation	(# 6&9)
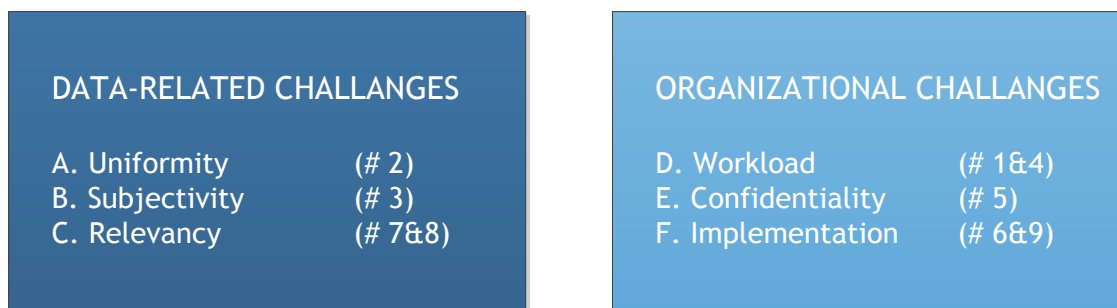
Figure 12 - Overview of data-related and organizational challenges

In the next chapter, in which we are actually designing the database, we need to show how these challenges have actually affected the database design or the feasibility of a database of Dutch infrastructure projects

3.7   CONCLUSIONS

In the current chapter we have mapped the present data registration practices within ProRail and Rijkswaterstaat and investigated desires and concerns regarding a database of Dutch infrastructure projects. Thereby we have found answers to the sub-questions 2a, 2b, 2c, 3 and 4a of our research.

2a. What data is currently recorded by infrastructure project teams and for what reasons?

Within infrastructure projects, teams generally record and use data for two purposes: for progress reports and for the development and maintaining of specialist databases.

Progress reports generally contain data on the scope, budget, milestones, risks, stakeholders and management dilemmas. These reports are made every four months and are used in the communication between the project team and the client and organizational staff of the executive organization. Rijkswaterstaat develops and stores their reports in the central project database. ProRail reports are generally stored in the project archives.

The specialist database purpose concerns the gathering of data in a specialist field as a companion for future work. Databases on risk, costs, planning, design guidelines and material standards are mentioned by our interviewees.

2b. Which ways of knowledge development and learning are currently used in practice?

Five ways of knowledge development and learning are currently present in practice by project practitioners. These are: (1) direct contact with colleagues in which knowledge is exchanged, (2) coaching and mastering of unexperienced team members by experienced team members, (3) the attending of lectures and conferences on the sector, (4) the use of standards and procedure that provide a companion for organizing the work and (5) keeping the project team together for a longer time, to prevent that gained knowledge and experiences dilute. When analyzing them, three of these ways can be classified as a knowledge exchange mechanism: direct contact, coaching and maintaining the project team. Two of the ways are a knowledge retrieval mechanism: attending lectures and using standards. No way of knowledge development was identified that can be categorized as knowledge creating.

2c. which database purposes are considered most valuable by project practitioners?

The interviews with project practitioners have shown that two types of database are valuable for the project practice. In the first place this is a database that unlocks best-practices and general project management knowledge. Secondly it is a database that is used for recording of objective project data that can be reflect on the projects and analyze their course once data for multiple projects is entered. Both types are considered to be about equally valuable by the project practitioners, eight candidates have indicated the potential value for each of the two types. There is no indication that one type is more desired within ProRail than within Rijkswaterstaat and vice-versa. Although we must make a remark that a database on best practices is also a valuable purposes of the database, the interviews confirm that our initially intended database purpose in which we record data to enhance learning and research is considered valuable for the current practice.

3. What data must be recorded to serve the most valuable purpose and knowledge need?

Project practitioners indicated 23 aspects of projects that are worth recording for investigation of projects and their results. Six categories of data were defined after analyzing the 23 aspects: (1) planning, (2) costs, (3) contract, (4) project characteristics (incl. scope and complexity), (5) risks and (6) project results. Data on each of these categories should be recorded in the database that is to be developed.

4a. what challenges and potential limitations do project practitioners foresee?

In total nine challenges have been mentioned throughout the interviews, due to partial overlap or limited recognition they are grouped in six main factors that potentially threaten a successful database: (1) the required workload to gather the data, (2) a lack of uniformity of the data, (3) subjective data, (4) confidentiality of (especially financial) data, (5) a lack of relevancy of collected data and (6) an unsuccessful implementation. These potential limitations will determine the design space in which the database has to arise.

4 DATABASE DESIGN

The current chapter is used to present a first design of a potential database. The main keynotes with which we start this design process are the:

1. Elements which are relevant to record according to our interview candidates (section 3.5) and theory.

2. The challenges and potential limitations (section 3.6) that restrict certain kinds of data to be recorded.

By combining these keynotes, we get an overview of the data that can actually be gathered in practice. Next to defining the actual data input, the design process also comprises the development of a method to record this data. We will therefore present a procedure by which this data can be collected and describe how this procedure deals with the challenges of the interviews. (Sub-question 4b)

Figure 13 highlights how the design process relates to our eventual aim; presenting in which manner a database can be useful and feasible for the recording of data on infrastructure projects in order to learn.
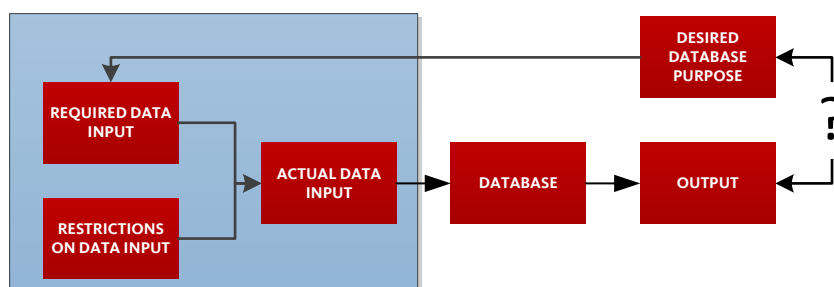
Figure 13 – Relevance of the design process for research aim

In the current chapter, we describe the substantive steps that have been taken in the design process. First we present the concepts that underlie the data recording method. Then we will describe which impact these methods have on our definitions of project result and infrastructure projects. In the third and last section, the conceptual design is substantiated in to a practical design, by means of three procedures. These procedures dictate how the data, that is to form the actual database input, can be recorded.

4.1 THE CONCEPTUAL DESIGN OF A DATABASE

The major aim of the database is to contribute to new and additional insights in the realization of infrastructure project results. Achieving this aim is not particularly straightforward. According to (Verweij and Gerrits, 2013), the desire to discover generally applicable findings on project results tends to conflict with the ambition to do right to the individual context and characteristics of projects. While especially these context and characteristics are often used as an explanation for the results of individual projects. This means that we need to find a structure that allows for the recording of case-specific elements as well as generic elements. With this structure we can then explain the results of individual projects following the logic of causality and discover patterns and similarities among projects and project results. Only if we facilitate both, we can provide the necessary nuances, conditions and insights that are required in general conclusions on the realization of project results.

4.1.1 Conditions to finding general explanations of project results

Figure 14 shows that we can come to general explanations on infrastructure project results when three conditions are met. We need to (1) measure the result of an individual project, (2) explain the individual result and (3) collect this information from various projects. The upcoming sections will explicate which concepts and schematizations will be used to meet these three conditions.
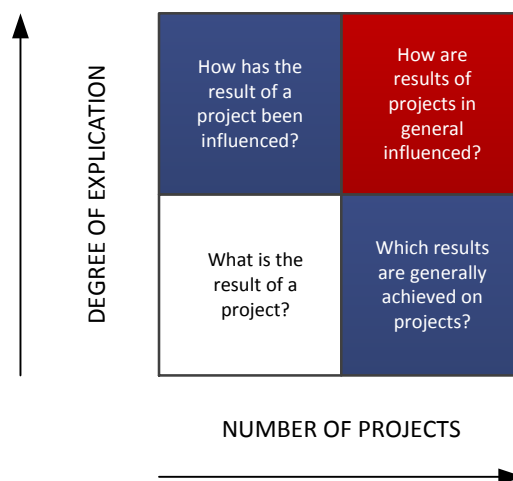
Figure 14 – Conditions for finding general explanations of project results

4.1.2 Concept to map the result of a single project

The most basic schematization of a project result is a comparison of the realized project at completion with the projects promises at the project start, as is shown graphically in Figure 15. It is in fact a comparison of two snapshots of the project and the resulting question to answer is: "How do these snapshots differ?".

As perspectives upon the snapshots might differ, various answers to this question can be given. Criteria are therefore needed by which we can express the (expected) result of a project in a uniform and reproducible way. Also the moments in a project's lifecycle at which snapshots are to be taken need to be determined unambiguously, so that (about) the same snapshots are compared when replicated.

In section 4.2, where the practical design of the database is presented, will be shown which criteria and moments are advised for the database and motivated why these are the most suitable.
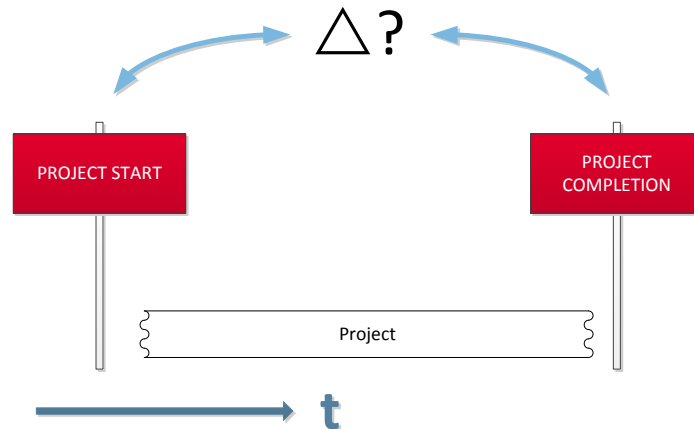
Figure 15 - The project result is comparing two snapshots

4.1.3 Concept to explain the result of a single project

With the project result recorded, a next step is to explain them. Explaining a project result comes down to identifying events, developments and activities that have forced the project team to deviate from its initial plans and led to differences between the two snapshots. For each event and activity, which we will call "change event", we can try to identify and classify its cause and consequence on the project result. By putting all change events in the chronological order, we can reconstruct the "movie" of the project, which shows how the project has developed from its prognosis at the start to the realized result at completion. In a more abstract way, the project result can be defined as the sum of the consequences of occurred change events.

In the practical interpretation of this concept, the most important challenge will be to come to a uniform and reproducible classification of change events and their causes. Section 4.3.2 will show a stepwise procedure by which change events can be defined. This procedure includes properties, such as causes and consequences to each of the events.

4.1.4 Concept to come to general explanations of results

When the "movies" of various projects have been reconstructed we can start with our eventual aim; the search to generic patterns that describe and explain the results of infrastructure projects in general. In order to do so, various (sets of) projects need to be compared with each other.

This report will not exactly prescribe how these differences and similarities should be investigated once the data has been gathered, mainly because the appropriate research will depend on the portfolio of projects that is considered and the intentions of the research. On the other hand, this thesis does present two strategies that could be used to come to insights on the realization of project results and shows how the concepts of our theoretical model and data we propose to gather are relevant for both strategies.

To start with, the theoretical model of Figure 2 is recalled. This model shows that particular configurations of the three affecting factors (project characteristics, exogenous factors and project management) lead to particular project results, but also points out that we do not know which combinations of factors lead to particular results. Data on the three affecting factors and project results can be used to map their mutual coherence via two types of reasoning; backward reasoning and forward reasoning, Figure 16.
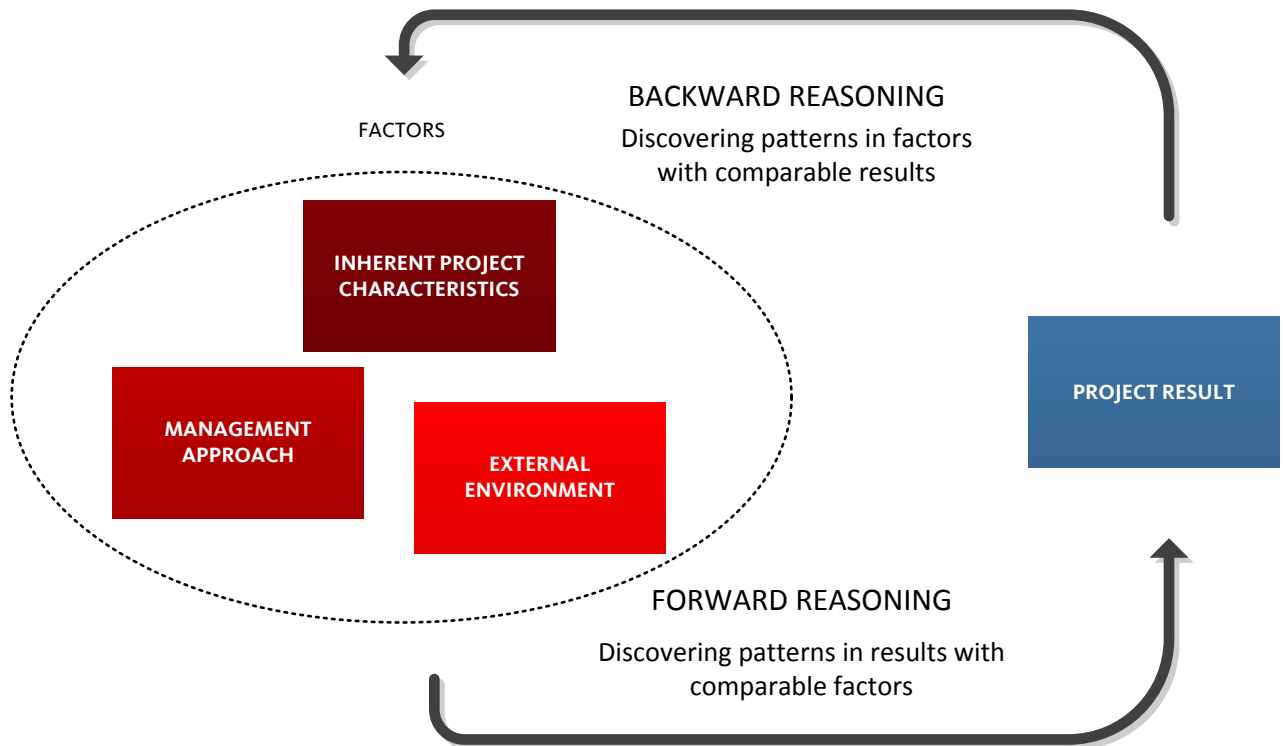
In the case of backward reasoning, projects with (partially) comparable results are grouped and research is done on the conditions and factors that have led to these comparable results. Using backward reasoning it can for example be discovered that projects with good results generally have a long preparation time and have only limited changing demands from clients compared to projects with bad results.

Exactly opposite of backward reasoning is forward reasoning. With forward reasoning a certain condition is picked and investigation takes place to the results that occur when that particular condition is sufficed. An example of this is that we group all projects that have faced changing demands by the client. If all projects with changing demands from the client are considered and confronted with all projects that did not have changing demands, we might conclude that projects with changing demands generally have worse results than projects without changing demands.

Note that the above examples are mainly mentioned to show the principle of forward and backward reasoning. They are not meant to lay down a precedent with regard to the content of any relations between affecting factors and project results. It is not expected that relations between affecting factors and project results can be discovered as simple and univocal as in the set examples. In reality, the relations are expected to be more complex and intertwined, which requires cautiousness of the researching parties in the drawing of conclusions. Despite this challenge, it is believed that the existence of a database on infrastructure projects contributes considerably to the possibilities of researching parties and helps to unravel relevant relationships between (possible) affecting factors and the project result.

The sections 4.3.2 and 4.3.3 will be used to propose methods with which change events and project characteristics can be recorded in a uniform and structured manner. Before these methods can however be presented, additional delineation of the project to be included in the database and the definition of the project result is needed.

4.2 ADDITIONAL DELINEATION OF PROJECTS AND RESULTS

The current section will be used to prepare our conceptual database design for use in practice by further delineating two important concepts of the thesis: project results and infrastructure projects.

4.2.1 The golden triangle as criteria for the project results

To allow for the recording of projects in a database, criteria need to be picked with which the differences between the expected and realized result can mapped. As can be recalled from the literature chapter, various indicators for results are known within the project management literature. In this research time, cost and scope (the three elements of the golden triangle) have been picked as the indicators for the project result. In theoretical terms, the project result is defined according to the criteria of project management success instead of project success. Various reasons support this decision, at first there are three theoretical reasons:

- The balance between the expected time, cost and scope is the most important criterion in political decision-making

- Project and portfolio managers mainly steer their projects with information on time, cost and scope (candidate 4 and 7)

- Realized time, cost and scope are commonly used in scientific publications to refer to the results of projects (a.o. Flyvbjerg, Cantarelli, Bosch-Rekveldt) by which we suit up with academic standards.

There are however also three practical reasons to choose for this definition. These reasons have emanated from the challenges that have been mentioned throughout the interviews, section 3.6:

- Current project documentation and data gathering have a main focus on the monitoring of a project's costs, planning and scope development during the planning and realization phase. By mainly focusing on these criteria throughout these phases, nearly no additional data has to be gathered. This matches the advice to re-use existing data (challenge 1)

- As only limited additional data has to be gathered, the burden upon project teams will also be limited (challenge 4)

- Limited additional data gathering also matches with the advice to start with a compact version of the database. (challenge 9) Once the database is in use and has proven its value, an expansion by facilitating more functionalities, and thereby by gathering more types of data, might be considered.

4.2.2 Delineation of infrastructure projects to MIRT-projects

In the first chapter of this thesis we pointed out that infrastructure projects are projects that produce a road, rail, bridge or tunnels and that cost a certain amount of money. As this domain is too broad to treat in this research have to delineate the term infrastructure projects.

The interviews were revealed that a further delineation would be advisable as the current definition allows for the study of a broad range of projects such as maintenance, replacement, upgrading, extensions and new built projects (challenge 8). In the view of the interviewees these should be divided into two groups and treated as such. In the first place there are the projects that aim to maintain an infrastructure network appropriate for operation. In the second place there are projects that lead to changes and modification of the current networks. Next to the nature of the works the types of projects can be distinguished by different kinds of decision-making. Modification projects are subject to a public and political decision making process, while decision-making for

maintenance projects happens mostly within the operating agency. The differing decision-making gives the two projects an entirely different nature.

One of the conditions that ensues from our database concept is that projects that we record must allow to take comparable and recognizable snapshots. Comparability means that the snapshots of two different projects are evenly detailed. Recognizable means that anyone with a particular interest in infrastructure projects should be able to easily detect the moment at which a snapshot should be taken. The more variety in types of infrastructure projects and decision-making structures, the harder it will be to suffice this condition.

In order to keep this research workable and valuable delineation of the broad infrastructure domain was required. A suggestion for delineation was given by interview candidate 15 who advised to specifically focus on MIRT-projects[6]. Snapshots can then coincide with the formal MIRT-related decision-making moments. An additional advantage of considering MIRT projects only, is that it is relatively easy to take an extra snapshot of the project. It is logical to this snapshot between the planning and the realization phase, at time of the project decision. For MIRT-projects, this project decision coincides with the route decision[7] if the route law[8] is applicable for the project that is considered. The chronological order of the decision-making moments, the project phases and the snapshot is presented in Figure 17.
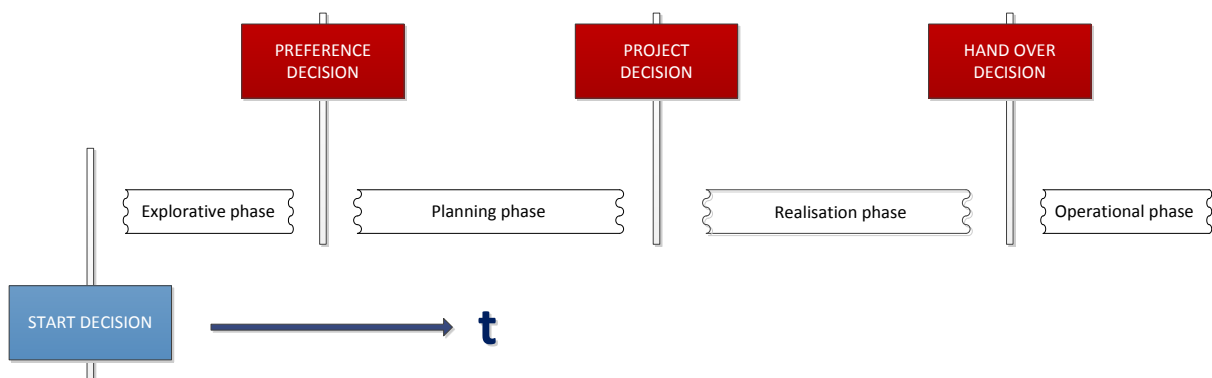
Figure 17 - 4 MIRT decision-making moments of which 3 are suitable for a snapshot

Although the workload increases when an extra snapshot has to be taken, there are two main reasons that justify this choice:

- An extra snapshot will allow to do research to the relative importance and the interrelatedness of the planning and realization phase with the total project results. This research is desirable as both literature, Cantarelli (2011), and the interviews, section 3.5, provide clues that project budget overruns tend to have their origin in the planning phase, but there is currently only little proof available. Likewise, other relations between the phases can be investigated with the extra snapshot available.

- Project teams of MIRT-projects generally do not stay intact throughout the entire project. If the project would only be evaluated at the end, it will be hard to identify all change events and explain the differences, since not all team members have been involved in the project since its beginning. By adding an additional snapshot, the project can be evaluated half way and it is more likely that team members do

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[6] MIRT-projects are part of the MIRT-program – the spatial investment program of the Dutch state. A more elaborate and specific introduction to MIRT projects is provided in appendix C

[7] Tracébesluit

[8] Tracéw et

have the knowledge to explain potential differences between the project start and the project at the project decision.

Choosing to shift our focus to MIRT-projects has the drawback that replacement and maintenance projects, as well as many municipal projects, will not be considered in this research and the first database concept. Although this limits the domain of the database in first instance, this does not mean a database will not concern other types of infrastructure projects in future. For now we however follow the advice that has been given throughout the interviews to start compact and further develop it in future.

4.3 A PRACTICAL DESIGN OF A DATABASE

After all preparatory activities, the core of the thesis has been reached; a proposal for the data that must be entered in the database for each project. In order to do so, we make use of three procedures. The first part of this section is used to present a procedure, with which snapshots can be mapped, then it will be shown how change events can be described and the last part comprises the characteristics that should be entered in the database.

4.3.1 Procedure to map snapshots

With the criteria for the project result defined and having determined when the snapshots will be made, the two theoretical conditions are sufficed. The remaining question is how snapshots can be unambiguously and uniformly recorded in practice. This paragraph describes a step-wise procedure that prescribes which data should be recorded in order to make snapshots. The snapshot procedure consists of three parts. In subsequent order it will be described how time, cost and scope are to be recorded.

Capturing time

The easiest and most objective criterion to map is time. The planned duration of the project, as well as the in between milestones, are often mentioned as exact dates, months or quartiles in (formal) documents and by project team members.

In total, 7 milestones have been identified that call for registration, Table 6. Identification of these milestones has taken place via a study of various MIRT-related documents and via the interviews, as described in section 3.5. Recording data on more milestones than the three formal MIRT-decisions is desirable, as it provides a more detailed insight on the course of projects. With more dates present, a better detection is possible of the phases and steps that slackened or speed up projects.

TIME		
Required activity	**Possible options**	**Unit**
Entering the dates of expected or realized planning milestones for possible options	Preference decision	[dd-mm-yyyy]
	Draft track decision	[dd-mm-yyyy]
	Contractclose	[dd-mm-yyyy]
	Track decision	[dd-mm-yyyy]
	Start realisation	[dd-mm-yyyy]
	Opening	[dd-mm-yyyy]
	Decharge	[dd-mm-yyyy]

Table 6 - Overview of milestones for which data input is required

An important remark is that project team members tend to work with various kinds of schedules. Examples are probabilistic schedules, deterministic schedules within the team and deterministic schedules agreed with the

client. The planning that is considered in the database is the formal planning that client has agreed upon, as this planning comprises the milestones with which political decisions are formally taken.

Capturing costs

Mapping the costs of projects in a database demands a somewhat different approach than the mapping of time. While a planning can be easily split up in separate milestones, a similar approach is not straightforwardly applicable for costs. Instead of trying to uniformly break down the project and attribute costs to certain components or labor, this framework considers the three most relevant total costs only, Table 7.

COST			
Required activity	**Possible options**	**Unit**	**Remark**
Entering budgetted or realized costs	Project budget	[€*10^6]	Mentioned amounts are indexed to the database pricelevel
	Ministerial funding	[€*10^6]	
	Contract sum	[€*10^6]	

Table 7 - Overview of cost types for which data is desired

The project budget is the total amount of money that is set available by the project clients. There is explicitly referred to clients in the plural form, as the ministry of Infrastructure and Environment does not have to be the exclusive sponsor of a project. Often, municipalities, provinces or water boards also partially fund the project in order to get add-on of the scope realized. To map the relative contribution of the Dutch government to the entire project, the ministerial funding should be recorded separately. The last type of costs is the contract sum. Mapping the development of the contract sum is an important indicator for the quality of the contract and the stability of the project scope.

Relevant for all three cost types is that they need to be indexed to the price level that is used in the database.

Capturing scope

The third, and last, criterion to map is the project scope. Compared to the mapping of cost and time, mapping scope is a more complex and tricky matter. To do justice to all unique characteristics of the project, the scope needs to be decomposed to smaller parts to obtain enough detail in the recorded data. In this section a five step procedure is described that can be used for the mapping of the scope of infrastructure MIRT-projects.

In this procedure four colors are used to indicate what data or input action is required for specific steps in the procedure. The colors that are used are displayed in Table 8.

Define field
Optionfield
Insert field
Conditional input

Table 8 - Possible data input options

The blue colored background indicates a define field. With such a field, elements and objects that are related to a particular project can be defined in the database. For example a certain structure. To these objects, properties can be assigned with either the purple or the orange field. The purple color indicates an option field, which means that one option needs to be selected from a predefined list of answering options. In our example we then for example have to choose between the options viaduct, aqueduct or ecoduct being properties of the aforementioned structure. The orange field requires the insertion of an answer or value albeit in a predefined unit when desirable. In our example, this can be the name of the structure, but also the dimensions of the structure in

meters. The red text indicates a conditional input option. The entering of data in a conditional field is only required if a certain condition is sufficed. Entering a sailing class is only useful when the property aqueduct is assigned to a structure.

The first step in defining the scope is determining the main modality that is served in the project. This modality can either be road, rail or waterways, Table 9. Depending upon the chosen modality, the content of the succeeding procedure will differ, but the concept by which the scope can be recorded is comparable for all three types of modalities. The modality road will serve as example. Note that the background of the cell modality is purple; one of the three options needs to be picked.

SCOPE						
Required activity			Possible options	Unit	Condition	Remark
Step 1	Modality					The chosen modality determines the content of step 2
Defining modality			Road	[-]		
			Rail	[-]		
			Waterway	[-]		

Table 9 - Overview of possible scope modalities – Step 1

With the modality defined, the second step is to define the class of the project. Defining the class, from a given list of options (Table 10), is necessary, as some scope components and structures are only applicable to particular classes only. An example of this is that roundabouts do occur in the Dutch N-road network but are not present in the A-road network. By defining a class, conditions can be put on the answering options in later steps. The answering option "roundabout" can for example be excluded from the list of possible structures on an A-road project.

SCOPE						
Required activity			Possible options	Unit	Condition	Remark
Step 2	Class					
Defining classes			A road	[-]		
			N road	[-]		

Table 10 - Overview of possible scope classes - Step 2

With step three and four, we reach the core of the scope identification process. Every project, whether rail, road or water, can be modelled as a gathering and combination of stretches and structures. We need to identify the stretches and structures are present in the project and assign properties that describe the scope that is present in each stretch or structure. Because the possible properties that can be assigned to stretches differ from those of structures, stretches and structures are treated in two different steps. Step 3 will concern the stretches, step 4 will deal with structures.

SCOPE						
Required activity			**Possible options**	**Unit**	**Condition**	**Remark**
Step 3b		Type of construction				Determining the projecttype by taking dominant type of stretches
Attribute properties to every defined stretch			surface level	[-]		
			half deepened	[-]		
			deepened	[-]		
			land tunnel	[-]		
			tunnel	[-]		
		Type of intervention				Determining the projecttype by taking dominant type of stretches
			construction	[-]		
			expansion	[-]		
			renovation	[-]		
			replacement	[-]		
			removal	[-]		
		Road lay out new				
			main lanes	[#]		
			rush hour lane	[#]		
			hard shoulder	[#]		
			acceleration lane	[#]		
			deceleration lane	[#]		
			combined lane	[#]		
		Road furnishing				
			Sound baffles left	[m]		Heigth
			Sound baffles right	[m]		Heigth
			Dynamic Traffic management	[-]		
			Street lightening	[-]		
		Road lay out old			Only applicable for expansion and removal projects	Amount of new scope can be determined by substracting road make up new with road make up old
			main lanes	[#]		
			rush hour lane	[#]		
			hard shoulder	[#]		
			acceleration lane	[#]		
			deceleration lane	[#]		
			combined lane	[#]		

Table 11 - Overview of properties of stretches - Step 3

The first part of the third step is the listing and naming of all the stretches that are present in a project. A stretch is defined as: a piece of road in which the properties of the road are constant and in which no structures are present. For road projects this means that stretches border to structures or to pieces of road with different properties, another stretch.

Table 11 displays the five main types of properties that are relevant in the description of stretches. The first two properties, the type of construction and the type of intervention, are assigned by picking one of the options. The third property, the road lay-out, is mapped by filling in the amount of different lanes that are present. The fourth property concerns the furnishing that is present on the stretch.

A fifth property of stretches is conditional; this condition applies to all stretch with the property "expansion" and "removal". For those stretches, input on the old road lay-out is desired. In the case of an expansion project we can then determine the scope that is realized on that stretch by comparing the old road lay-out with the new one.

SCOPE						
Required activity			**Possible options**	**Unit**	**Condition**	**Remark**
Stap 4 a		Structure				Including structures that are part of acceleration- and deceleration lanes and junctions
Defining structures			Structure id	[-]		
Stap 4b		Structure type				
Attribute properties to every defined structure			Bridge	[-]		
			Viaduct	[-]		
			Aquaduct	[-]		
			Ecoduct	[-]		
			Round about	[-]		
			Level road juntion	[-]		
		Type of intervention				
			construction	[-]		
			expansion	[-]		
			renovation	[-]		
			replacement	[-]		
			removal	[-]		
		Dimension new			Only for bridges, viaducts, aquaducts and ecoducts	
			Span (length)	[m]		
			Width	[m]		
			Headway / clearance	[m]		

Table 12 - Overview of properties of structures – Step 4

For structures, a comparable procedure as for stretches is used. So first we start with identifying all structures in the project and then we give it an id and certain properties. The first two properties are assigned by picking one of the presented options. The properties concern the type of structure that is considered and the type of intervention that will be carried out in the project. The third property is a conditional property that is used to investigate the dimensions of certain structures.

SCOPE					
Required activity		**Possible options**	**Unit**	**Condition**	**Remark**
Stap 5	**Other**				These scope elements are optional and can be added/activated
Other scope components		To demolish building	[#]		
		Facade improvement	[m2] & [#]		Register both the total facade size and the amount of dwellings
		Environmental compensation	[m2]		
		Area development	[m2]		
		Soil decontamination	[m3] or [m2]		
		Waterstorage	[m3] or [m2]		

Table 13 - Overview of other optional scope components – Step 5

The last step, step 5, is used to identify and map all other scope elements that are part of the project scope but are not primarily related to the infrastructure functionality itself. Often these are spatial development measures to compensate for hindrance or disturbance that the infrastructure function has brought to the direct project environment, Table 13.

When the fifth step has been completed, only one step remains to get an overview of the entire project scope; putting together a list of all different stretches, structures and other scope components.

Wrap up

In this paragraph a method has been presented with which we can map the time, cost and scope of projects in a uniform and objective manner. The activities that were described will have to be carried out in order to come to a snapshot. It is expected that these snapshots are sufficiently detailed to detect differences when multiple snapshots are compared. This detection of differences is highly relevant in order to map the change events and construct the movie between two succeeding snapshots. The next section will be used to present a method on how to deal with change events.

4.3.2 Procedure to map change events, their causes and consequences

As mentioned in section 4.1.3 the registration of change events is useful in explaining project results because the project result can be considered as the sum of the consequences of the occurred change events. In this section a stepwise procedure is presented that describes which data should be entered in the database for each occurred change event.

The first input that is required is the change event itself, in the form of an event id, Table 14. To this id, properties can be attributed that together describe the change event. To start with, a description is required which shortly elucidates the change event and its nature. The verbal description should be such detailed that a well-informed project insider knows what change event is considered. The last entry in this step is the date at which the change event approximately happened. All change events can then be put in chronological order so that the "movie" of the project can be completed.

CHANGE EVENTS				
Required activity		**Required input**	**Unit**	**Remark**
Step 1	Change event			
Defining the change event		Event id	[-]	
		Short description of *what* has changed and *why*	[-]	Maximum amount of characters to be determined
		Date	[dd-mm-yyyy]	

Table 14 - Overview of required input for defining change events – Step 1

After an event and a description of the event and its nature are inserted in the database, consequences are to be attributed to the event. Registration of the consequences takes place along the three same criteria as with which the project result is defined: cost, time and scope.

Table 15 shows which input of cost information is required, in case the change event had any cost consequences. Most importantly, this is information about how the change event affected the project budget and the contract sum. Additionally, it is about the division of the costs or benefits of the change event among the project team or other parties. In general, the preferred unit by which cost information is entered is Euros, or a percentage of the budget. If detailed cost information lacks, it can still be indicated if the change event has led to a cost increase or a cost saving.

CHANGE EVENTS					
Required activity		**Required input**	**Unit**	**Remark**	**Bugs/problems**
Step 3 a	Cost consequence			Consequences can be positive,	
Assigning cost consequences		Project budget	[€]	neutral or negative, step not	Not all cost figures might be
		Contract sum	[€]	required if consequence is neutral	present, if not possible to determine
	Cost bearer				them indicate effect as +, 0 or -
		project	[€]		
		additional funding	[€]		

Table 15 - Overview of required input of cost consequences per change event – Step 3A

For those change events that have speeded up or slowed down the project, data on the time consequences should be entered. In the first place it should be indicated if the event had a positive or negative effect on the planning. If the consequences of the effect are so large that the event directly influenced the (future) milestones, it should be indicated how these have been affected.

CHANGE EVENTS

Required activity		Required input	Unit	Remark
Step 3 b	**Effect on planning**			Consequences can be positive, neutral or negative, step not required if consequece is neutral
Assigning time consequences		Positive		Not all change effects have a direct effect on the milestone planning, so therefore indicate effect as + or -
		Negative		
	Old milestone planning			
		Draft track decis	[dd-mm-yyyy]	
		Contractclose	[dd-mm-yyyy]	
		Track decision	[dd-mm-yyyy]	
		Start realisation	[dd-mm-yyyy]	
		Opening	[dd-mm-yyyy]	
		Decharge	[dd-mm-yyyy]	
	New milestone planning			
		Draft track decis	[dd-mm-yyyy]	
		Contractclose	[dd-mm-yyyy]	
		Track decision	[dd-mm-yyyy]	
		Start realisation	[dd-mm-yyyy]	
		Opening	[dd-mm-yyyy]	
		Decharge	[dd-mm-yyyy]	

Table 16 - Overview of required input for time consequences per change event – Step 3B

The last criterion for which data should be entered is scope, Table 17. As there is no predefined unit by which scope can be expressed, changes to scope will have to be reported via a verbal description. For each change we can then indicate which stretches or structures are influenced. The last step we need to take is to indicate whether the scope increases or decreases with the change. Since two types of scope exist in infrastructure projects, we need to split this step up. The change event can either lead to a change in the contracted scope, the scope of the project or both.

CHANGE EVENTS

Required activity				Required input	Unit
Step 3 c		**Project scope**			
Assigning scope				Positive	[-]
consequences				Neutral	[-]
				Negative	[-]
		Constract scope			
				Positive	[-]
				Neutral	[-]
				Negative	[-]
		Effect on scope		Short description of *what* has changed	[verbal]
				Affected stretches	[stretch id's]
				Affected structures	[structure id's]

Table 17 - Overview of required input for scope consequences per change event – Step 3C

The very last step in the mapping of change events is the adding of links that provide further and more detailed information about the change event, Table 18. This fourth step thereby not directly contributes to the gathering of relevant research data in the database. Instead, it is a step that facilitates future researchers or other database users.

CHANGE EVENTS			
Required activity		**Required input**	**Unit**
Step 4	**Documentation**		
Adding links to further		Documentname	[-]
information		Archival location	[-]

With the fourth step completed, all relevant data on an individual change event has been gathered. This procedure should be repeated for all change events. The result for the project will then be a list of change events, their causes, their consequences and links to additional information.

Although identifying causes of change events for multiple projects in itself is already valuable for the domains of project management and project control, even more value can be gained if we know how causes are stimulated by the characteristics of project. Therefore in the next paragraph a procedure will be proposed with which we can map the most important characteristics of an infrastructure project.

4.3.3   Proposed procedure to map project characteristics

After having presented methodologies that together allow for the recording of projects and their result, the procedure in this section is meant to link the project result to the circumstances that it has been contingent upon. We will therefore propose a set of parameters that is to be recorded, that will eventually help to discover how the project results relate to the inherent characteristics and the external environment of projects.

As can be recalled from section 2.4.2 the main contingency factor of projects, is project complexity. In the TOE framework of Bosch-Rekveldt et al. (2011) elements have been listed that together contribute to the complexity of a project. These elements can partially be used in our database to map the characteristics of our projects. We cannot use all of the elements as:

- ▪ The framework leaves too much room for subjective data input. This makes it hard to compare characteristics of one project with those of another.

- ▪ The framework is too elaborate as is has been designed for use in the international process industry whereas the database considers Dutch infrastructure projects only. Therefore, various elements are not applicable to our database.

The most important and relevant elements have been selected for use in our database. The classification of elements as contributing to Technical, Organizational or External complexity, is considered valuable in describing project characteristics. In the upcoming sections we will per type of complexity describe which elements have been selected for registration in the database. The selection of these elements has also been based on the aspects that were considered relevant by the interview candidates, Table 5 in section 3.5.

Technical characteristics

The main technical characteristic of the project that has to be mapped in the database is the project scope. An elaborate description of the project scope has however already been entered in the database when snapshots are taken. The inserted scope description also already contains information on various other aspects of the TOE-framework, such as the number of tasks, the variety of tasks, the dependencies between tasks and the magnitude of the scope. This description can be reused in defining the technical characteristics of the project, so no new data needs to be inserted.

Organizational characteristics

When organizational aspects are considered, various suggestions have been made by the interview candidates, mostly about the interaction between the project team and market parties. Also the internal organization and the project personnel are considered worth registration, according to some of the interviewees. Therefore, organizational characteristics can be entered via a two-step procedure. The first step is about the interaction with market parties and the second step is about the internal organization, see Table 19 and Table 20 respectively.

ORGANIZATIONAL CHARACTERISTICS				
Required activity			**Required input**	**Remark**
Step 1	**Contracttype**			
Defining the market interaction			DBB	
			D&C	
			DBFM	
			BOT	
	Procurement type			
			Dialogue	
			Public procedure	
			Non-public procedure	
			Private procedure	
	Contractor/consortium			
			Contracted parties	Insert all entities that are contracted or part of the contracted consortium

Table 19 - Overview of required data input on market interaction

ORGANIZATIONAL CHARACTERISTICS						
Required activity			**Required input**	**Unit**	**Condition**	**Remark**
Step 2	**Project team set-up**					
Defining internal organization and team			Partners in a joint projectteam		If applicable	
	Organization and team					
			Amount of project team members	[hrs]		Project team members
			Share of external labour in team	[%}		Hired labour to support the project team
	Management team information					
			Names of project management team members			
			Name of portfolio manager			

Table 20 - Overview of required data input for internal organization

External characteristics

Both the interviewed candidates and the TOE framework consider various categories of external characteristics. The two most striking characteristics are the physical environment and the stakeholder environment.

The physical location largely concerns the location of the project and the properties that are present at that location. The most important step is therefore to enter the location of the track in the database. In most cases, a start and end location will indicate the track course. Secondary information about that location can then also be entered such as the soil conditions and the presence of cultural or natural heritage.

EXTERNAL CHARACTERISTICS				
Required activity			**Required input**	**Condition**
Step 3	**Location**			
Defining the physical environment			Place of track start	
			Place of track finish	Not applicable if point infrastructure
	Soil type			
			Peat	
			Clay	
			Sand	
			Loam	
	Heritage			Select if applicable
			Cultural	
			Natural	

Table 21 - Overview of required data input for physical location

According to Bosch-Rekveldt et al. (2011), the amount of stakeholders and the variety of stakeholders perspectives are well recognized as elements that contribute to the complexity of a project. Also some of our consulted interview candidates have mentioned stakeholders as interesting to register. Therefore it is proposed to make a stakeholder analysis part of the database input. The most important step is to identify and define the stakeholders that are relevant in the view of the project team. For each stakeholder the methodology of Hillson and Simon (2007) can then be executed. This means that for every stakeholder, its power, attitude and interest are defined. A potential problem with inserting a stakeholder analysis in the database is that the identification, as well as the attribution of properties, is subjective which means that care is require when the stakeholder settings of different projects are compared.

EXTERNAL CHARACTERISTICS				
Required activity			**Required input**	**Bugs/problems**
Step 4	**Stakeholders**			Stakeholders are identified from a project teams view; as this view might differ per project manager subjectivity might become a problem
Defining the stakeholder environment			Stakeholder id.	
			Power	
			Attitude	
			Interest	
	Stakeholder type			
			Government	
			Semi- Public	
			Business	
			Interestgroups	
			Inidividual	

Table 22 - Overview of required data input for stakeholder environment

4.4 CONCLUSIONS

In coming to the design of the data gathering procedure, two keynotes were given at the start of the design process

- The data desires that have to be incorporated in the design

- Challenges and potential limitations to the design solution

In designing our data gathering procedure particular choices have been made to deal with these challenges, we can therefore answer the sub-question:

4b In what way can be dealt with these challenges in a database design?

In order to cope with these challenges, we had to further delineate some of our concepts. The first concept to delineate was project result. As is presented in section 2.2 various criteria can be used to determine if the result of a project is successful or not. Data that is currently recorded by project teams, and therefore is relatively easy to gather, tends to merely focus on time, cost and scope and (occurred). Hence we define project result according to the criteria of project management success in order to limit the *required workload* in data gathering. Starting "simple" also increase the chances of a *successful implementation*.

The second delineation concerned the term Dutch infrastructure projects. This definition comprises a wide range of possible projects including renovation and maintenance projects. Due to the diversity in these projects it is difficult to indicate for whom results are *relevant*. Secondly the diversity in projects also brings a variety of data and decision making processes. This threatens the *uniformity* of the data that is to be gathered. Instead of concerning Dutch infrastructure projects in general, our focus will shift towards so-called MIRT-projects.

5 EVALUATION OF DATABASE DESIGN

The previous chapter has been used to present a first draft of the data that should actually be gathered for a database of Dutch infrastructure projects. Defining the procedures to gather this data does however not guarantee an adequate working of them. Evaluation of these procedures will be the topic of the present chapter. Three projects have been investigated so that we could:

1. Verify whether the actual data input (as defined by the procedures) could be found and recorded in a concept database.

2. Optimize the data gathering procedures by eliminating bottlenecks and restrictions that have been found throughout testing.

This step thereby contributes to the answering of the research questions 4c and 5a:

4c   *What additional challenges arise after testing the database design in practice?*

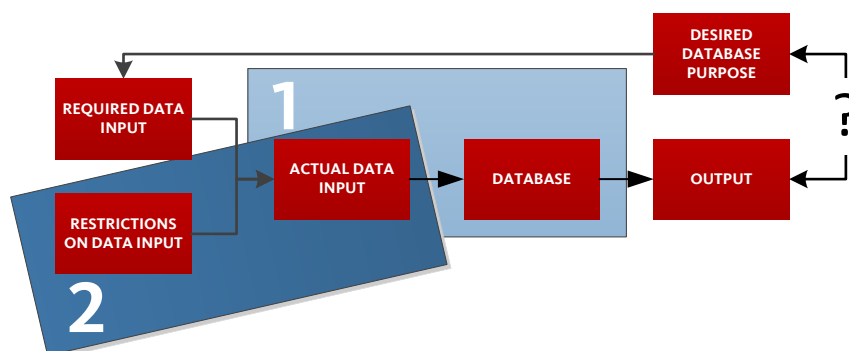5a   *What is a feasible technical design for the database?*

Figure 18 - Relevance of case-studies for research aim

In this chapter we first describe why, and which, cases have been used to investigate our design. Then we will give a short introduction to the three cases we have studied (5.2) and present our case study result (5.3). In the succeeding sections, an evaluation of the proposed procedures is described. Subsequently we will treat the feasibility of taking snapshots (section 5.4), the recording of change events (section 5.5) and the gathering of project characteristics (section 5.6). The chapter ends with a conclusion in which the sub-questions 4c and 5a are answered.

5.1 METHODOLOGY

5.1.1 Case studies as research strategy

Knowing that we want to evaluate the applicability of the procedures in practice, a suiting research strategy has to be chosen. According to Yin (2003), five typical research strategies exist; experiment (1), survey (2), archival analysis (3), history (4) and case studies (5). Each of the strategies uses a different way of collecting and analyzing of empirical evidence.

The appropriate strategy can be chosen on basis of three conditions that apply to the studied phenomenon. These are: the type of research question (1), the extent of control the researcher has over the studied event (2) and whether the studied event is contemporary or historical (3). Table 23 shows under which conditions a certain research strategy can best be used.

Strategy	Form of Research Question	Requires Control of Behavioral Events?	Focuses on Contemporary Events?
Experiment	how, why?	Yes	Yes
Survey	who, what, where, how many, how much?	No	Yes
Archival analysis	who, what, where, how many, how much?	No	Yes/No
History	how, why?	No	No
Case study	how, why?	No	Yes

Table 23 - Relevant situations for different research strategies - taken from Yin (2003)

In our situation we are studying the applicability of the procedures in infrastructure projects. It is evident that we are not able to control the project environment in which we test our procedures. It is also clear that we focus on a contemporary phenomenon as we intend to investigate projects that have been recently completed. The research question that we pose has a "how and why" nature, since we want to understand how the data input can be gathered from project environments and why certain data input is not appropriate for recording. On basis of the three conditions, case studies are the most appropriate research strategy.

5.1.2 The case study set up

Setting up a case study design will guide us through our research. In designing our case study we will use the approach as described by Yin (2003). First we will focus on five components that need to be defined at the case study outset and then we will motivate which type of case study we will carry out.

The first part of designing a case study is to state:

1 Case study questions

2 Propositions, if there are any

3   Unit(s) of analysis

4   Logic that links the findings to the propositions

5   Criteria to interpret the findings.

In our case study, we mainly focus on our sub question 4c: *"What additional challenges arise after testing the database in practice?"* The main proposition that underlies this question is that the first draft of the procedure does not exactly live up the expectations that we have. Formative evaluation of the design with a case-study is helps us to identify potential improvements and weaknesses in the design (Verschuren and Hartog, 2005). Since this design comprises of three sub-procedures that should each function before the procedure as a whole functions, we have three separate units of analysis that we want to conclude about. These are the snapshots procedure, the change event procedure and the project characteristics procedure.

For each of these procedures we want to test and verify whether they work and how they behave in practice. Concluding about the degree to which something "works" is rather subjective however. To keep our findings as objective and reproducible as possible we will try to verify the procedures in a structured way and report on them likewise. Beneath we will describe the line of reasoning that will be used in reporting on the case study.

In evaluating the design we will consider the design from two viewpoints: a strategic and an operational one. This leads to two types of additional challenges that we might detect in the procedures:

1   Weaknesses in the concepts

2   Practical adaptations

Weaknesses in the concepts have a strategic nature are relevant for concluding whether the conceptual design of the database works. These are potential threats for the explanative value of our database. Practical adaptations have an operational nature. Implementing these adaptations leads to a better connection of the procedures to the project practice. This makes the procedure more efficient.

Weaknesses in the concepts can be split up in improvable and non-improvable weaknesses. A weakness is classified as improvable if the required adaptations to the procedure do not lead to a loss of functionalities of the procedure. For each weakness we will therefore describe why it is a weakness to the concepts, which adaptations of the procedure we propose and why these adaptations do not affect the functioning of the database. In contrast, there are also non-improvable weaknesses. A weakness is non-repairable if it limits the contemplated functioning of the database and no adaptations can be proposed. Like with improvable weaknesses we will report on the backgrounds of the weaknesses, state why the weakness cannot be repaired and describe which impact it has on the functioning of the database. Depending on the total amount of improvable and non-improvable weaknesses that we find and the degree to which they limit the data that we can register, we can conclude whether the procedure is a feasible design and answer our sub-question 5a: *What is a feasible technical design for the database?*

Also practical adaptations can be subdivided, in either the adding of relevant elements or the removal of non-relevant elements to the procedure. In our reporting we will describe how this improves the procedure and contributes to better connection with the project practices.

A last note to mention is that we will mainly focus on the failures and shortcomings in our procedure and do not explicitly report on the parts of the procedure that function appropriately, as we assume that most parts of the procedure will.

With the aims of our case-study defined a next step is to define the type of case study that is carried out. Yin (2003) distinguishes four different types of case study designs, Figure 19.
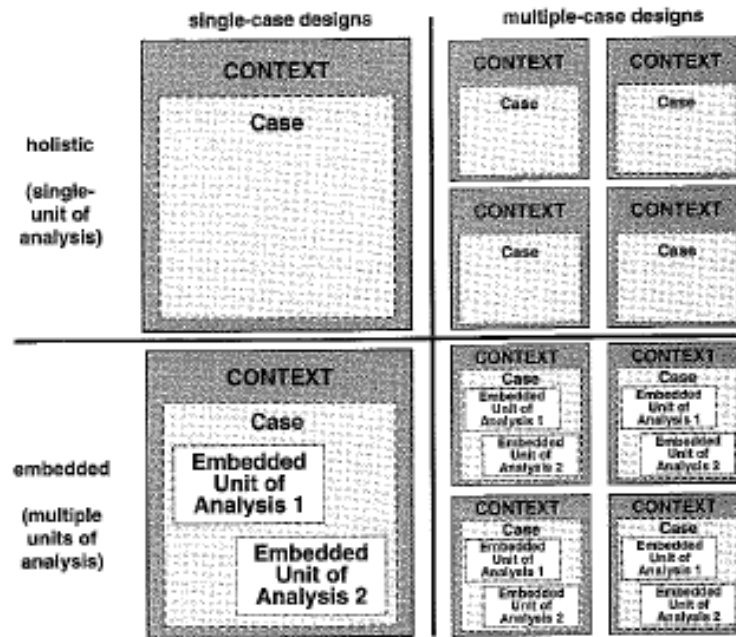

Figure 19 - Basic types of designs for case studies – taken from Yin (2003)

As shown in Figure 19, case studies can be typified by two conditions; embedded vs holistic and single vs multiple cases. Earlier in this section, we already described that we want to study the functioning of the three different procedures for infrastructure projects. We thereby see that we have multiple and specific units that we want to analyses and that we are designing an embedded case study.

Since we are in the possibility to study multiple projects, we will opt for a multi case study design as multiple case studies are generally preferred over single case studies (Yin, 2003). Replication the study on more than one case contributes to the validity of the findings. By contrasting the results of the various cases which each other, we are better able to conclude on the generalizability of our findings

The amount of cases that we study has been determined on basis of the effort that was expected per case and the total amount of time and resources that were available for the research. After considering both aspects, it has been chosen to study three cases. The next section will describe which project are selected as our cases and for which reasons they have been picked.

5.1.3   The selection procedure of cases

In selecting our cases, five conditions were important. By combining these conditions, a select pool of suitable projects was obtained from which our cases could picked. Eligible projects had to:

1   Comprise the realization of infrastructure

2   Have a budget larger than €20 million

3   Be part of the MIRT-program

4   Be completed

5   Be carried out recently

The first three conditions follow from how we defined the research domain of this thesis. The latter two conditions are newly added. The fourth condition is relevant since we want to test the functioning of the three procedures. For two of those procedures, the change event and snapshot procedure, project completion is a requirement. The fifth condition has a more practical nature. For an adequate case study the availability of data and information is important. When a project is in its very last phase, or has been recently completed, information is still complete and accessible by the involved project staff. The longer it has however lasted before the project was completed, the more difficult it will be to get access to relevant data and information. On basis of these five conditions the selection process of our cases took place.
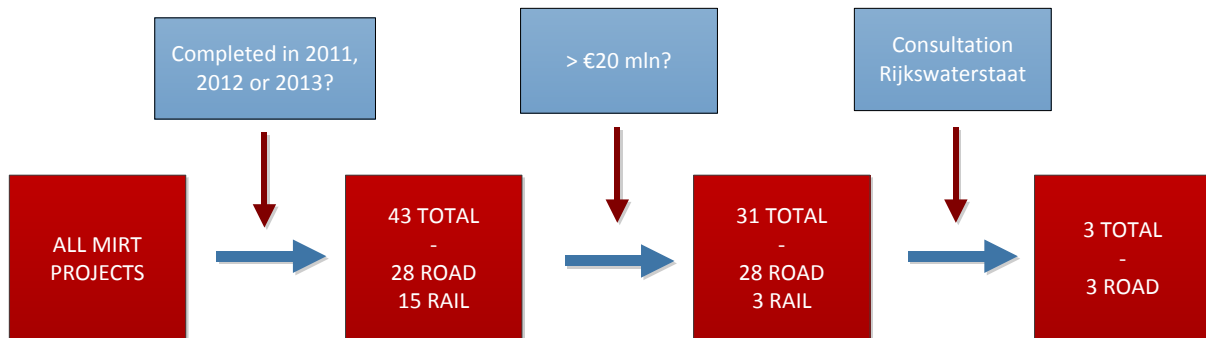
On basis of the MIRT-project books (Ministerie van Infrastructuur en Millieu, 2011a, Ministerie van Infrastructuur en Millieu, 2012, Ministerie van Infrastructuur en Millieu, 2013)a list has been made of all infrastructure projects that were completed in 2011, 2012 or 2013. In total, this list comprised 43 infrastructure projects, of which 28 were road-related projects and 15 were rail-related projects. When the budget criterion was applied to this selection, the selection decreased to 31 projects. This new selection still consisted of 28 road-related projects, but only comprised 3 rail projects. The rail related MIRT-projects that fell out of the selection comprised the realization of small train stations (8 projects) and minor adaptations or extension to the current network (4 projects).

The large difference in the amount of appropriate road and rail projects that ensues from our conditions has put us at a crossroad. We could either adapt our conditions to get a better balance between rail and road projects in our selection or we could accept that our case-study would focus on road projects solely. We choose to further delineate the research by focusing on road projects. Two reasons justify this choice:

1   Interview candidates have advised to start with a small and more specific database. Starting small will make it easier to get the database operational and linked to an owner. Once this database has proven its value for a specific type of projects in practice, it might be implemented and adjusted for other project types too.

2   Limiting the research to one type of project, limits the organizational effort that is required to get access to our cases. Instead of introducing our plans and ideas twice, within ProRail and Rijkswaterstaat, we can limit ourselves to one introduction. This leaves more time for the actual research work.

To get to three cases, we first limited our list off 28 possible cases to a shortlist of ten projects. Diversity within the pool, topicality of the project and representativeness of the project were the main criteria to select the ten projects of the shortlist. Then Rijkswaterstaat was consulted, combining our criteria of diversity, topicality and representativeness with the judgment of Rijkswaterstaat on the availability of team members for consultation and

the relevance of projects for our research. This lead to the final selection of three cases: a new built highway (A74 Venlo), a highway extension including a fixed 1 km bridge (A50 Ewijk-Valburg) and a road upgrade including a maneuverable bridge (N50 Ramspol-Ens).

5.1.4 The case study content

The main aim of the case study was, as is just described in the previous section, to verify whether our procedures work. This means that we checked whether there were any threats to intended functionalities of our concept by applying the three procedures to each of our three cases in practice. For each of the cases we therefore tried to:

1. Compose three snapshots, in which each of the snapshots reports on the time, cost and scope of the project at that moment.

2. Map all relevant change-evens of the realization phase, which is between the second and third snapshot

3. Record the organizational and external project characteristics.

In fact we tried to make a first start with the database, by gathering all relevant data for first three projects. The only striking deviation from what actually will have to be gathered once the database is in use, is that we only mapped the change events of the realization phase and not of the planning phase of the project. The main reason to do so is the availability of information.

When setting up the case studies it was clear that the availability of information and data would be low for complete projects. In the first place because of limited (explicit) recording of changes and design choices throughout he planning phase of Rijkswaterstaat projects in general and in the second place because knowledge of than project team members has been forgotten or disappeared due to the long period that is present between the planning phase of the cases and the present.

It has been considered to also study three cases that have only just started their realization in order to verify the working of the change event procedure in the planning phase. A lack of available research time has made us decide to focus on complete projects and the realization phase only. Note however that we did try to complete the first snapshots of the cases that we study, we only did not try to explain the differences between the first and second snapshot.

5.1.5 The case study evidence

The last preparatory step, before we will start reporting on the actual case study, is to describe the strategy that we have used in order to gather our evidence on these three cases and conclude upon the adaptations that are desirable to the procedures. This section will shortly describe the three main sources of the evidence in our case study and state how these sources contributed to our findings.

At the outset of the case study, publicly available documents on the internet were our most important source. For all three cases we have obtained the formal decision that have been taken by the minister, these are the ministerial position[9], the draft route decision and the route decision. Next to the decisions themselves, studied the reports that contained the supporting information. Other documents that we've read are various (local) newspaper articles, websites of involved actors and political correspondence and records. In first instance the main aim of these publicly available documents was to orientate ourselves on the case and in later phases these sources

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[9] Standpunt van de minister

have been used to check and verify the data from our other sources so that we were certain that the right data was entered in the procedure.

Next to the publicly available documents we also studied non-publicly available documents of the project team. Access to these documents was desired, as the publicly available documents did not contain all information that was required in the procedures. The most important documents that have been studied per case are the: implementing order[10], scope change forms, project justification reports and stakeholder overviews. These documents have been the major source of data with which the procedure was tested.

The last sources that we have used were interviews. For each project a series of three interviews were planned with a project team member. For two of the cases, these were the project controllers and for one project it was the contract manager. The aim of the interviews was threefold: (1) the interviews had to lead us to the relevant project documents, (2) the interviews were used to verify our interpretation of the documents with the team member before we entered the data on the considered project in the procedure and (3) the interviews were used to check the generalizability of our findings, by checking if our findings from a particular case are recognized and conferment in the view of the project team members of the other two cases. Throughout the series, the focus of the interviews shifted from the first to the second and third aim.

5.2 A SHORT INTRODUCTION TO THE SELECTED CASES

In the present section, we will show a brief outline of the cases that we have studied. Per project we will roughly state the scope of work and highlight the most striking features. This description of the project is relevant for a correct understanding of the conclusions at the end of this case study, since our findings on the procedures are dependent on the circumstances that we have tested them.

5.2.1 A50 Ewijk-Valburg

The first of three cases is the project A50 Ewijk-Valburg. This project aims to improve congestion problems on the highway A50 and connecting highways. In its totality, the A50 is an important connection for North-South oriented road transport in the eastern part of the Netherlands. Due it's crossing of the A12, A15 and A73, the A50 also plays an important role in West-East related transport between the interchanges of Grijsoord (near Arnhem) and Ewijk. In two separate projects, additional capacity between Ewijk and Valburg (A73-A15) and Valburg and Grijsoord (A15-A12) will be realized. The project A50 Ewijk-Valburg focusses on the Southern and largest part of this corridor, Figure 21.

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[10] Uitvoeringsbesluit

When the minister in 2005 decided to commence this project, it became clear that the track would be extended from a 2x2 configuration to a 2x4 configuration. For adequate implementation, various adaptations to the interchanges of Valburg and Ewijk are included in this project, as well as the realization of an additional bridge over the river Waal.

Besides its function in the intended 2x4 configuration, the inclusion of the additional bridge also faced a secondary purpose. Due to the bad condition of the present bridge, with a 2x2 capacity, renovation of this bridge was urgently required. Renovation however means a partial or total closing of the bridge for traffic, which would cause severe congestion if no alternative would be present. The additional bridge would therefore also be required for the temporal situation in which the present bridge is renovated and taken out of use. In May 2013 the main part of the work was completed and the additional bridge was opened, albeit configured for the temporary situation. Renovation of the old bridge is expected to be completed in 2015 which means that after then the final situation can be realized and the project can be finished.

5.2.2 A74 Venlo

The second case we consider is the realization of highway A74 near Venlo. The main purpose of this project is to improve the processing of traffic between the Netherlands and the Southern German regions, including the Ruhr area. This aim is reached by realization of the new highway A74, which connects the Dutch highway A73 with the German highway 61. A second aim that is achieved by this project is a limitation of the burden upon the local road system of Venlo. For a long time, local road have been used as a shortcut between the highway A67 and highway 61. `
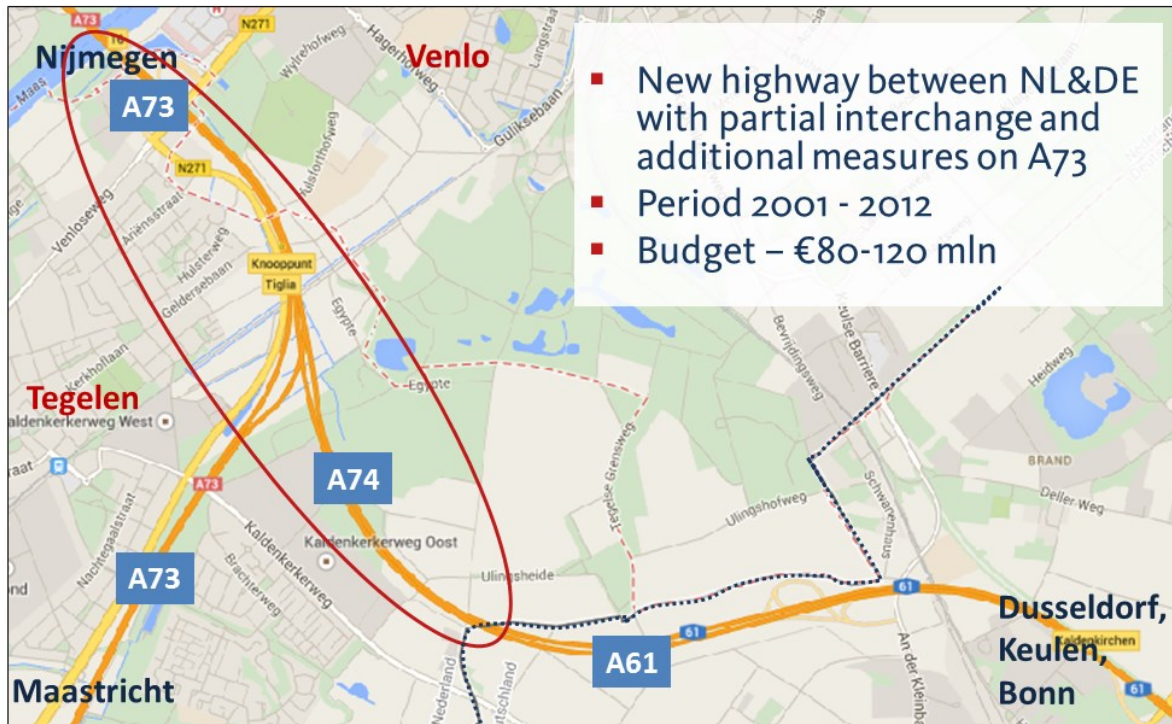
Although the aims of the project were clear from the outset, a long lasting discussion has been held on the best solutions to achieve this aim. For a long time two alternatives have been considered, a Southern route connecting the A73 and 61, and an Eastern route connection the A67 and 61. This Eastern route was to be located between Venlo and the German border. In 2001, the then minister de Boer, choose for the development of the Southern alternative and commissioned a draft track decision. Due to various delays the draft track decision got completed in 2009 instead of the planned 2004. Once the draft track decision was completed, the project continued in a normal fashion and the new road was opened in April 2012.

The scope of the project included the realization of 2,5km new build 2x2 highway on the Dutch territory and the realization of the partial interchange with the highway A73. Various structures were built in the interchange but also across the road for the transfer of local traffic and fauna. Besides, measures had to be taken to limit additional noise nuisance in Tegelen and Venlo due to increasing traffic amounts on the highway A73.

5.2.3   N50 Ramspol-Ens

The project N50 Rampsol-Ens completes our case study. The N50 highway is the main corridor between the South-western part of the province Friesland and the Noordoostpolder and the Southern and Eastern parts of the Netherlands. In contrast to the other two projects this project was initiated to increase the road safety and to improve the technical state of the bridge over the Ramsdiep. Increasing the capacity was of this road was initially of minor importance in this case.

A first statement on the project was presented by the minister in 2005. The scope then roughly included the realization of a new 2x1 road located about 150 m west of the old road, a split level crossing with the N352 and a 7 m high new bridge for the trough going traffic. The old bridge was to be downsized to a service road that could be used by cyclists and slow traffic. In 2007 however, this statement was replaced a revised statement on basis of progressing insights and reactions from stakeholders. Various changes to the scope were made. Instead of a 2x1

road layout, a 2x2 layout was proposed facilitate an expected growth of traffic intensity. The 7 meter height of the bridge increased to 13 meters to limit the amount of bridge openings and congestion on the road. This bridge would also facilitate the service road for cyclists and slow traffic so that the old bridge could be demolished. After the statement has been presented for the second time, the project prospered and the new bridge was opened in May 2012.

Figure 23 - Map of N50 Ramspol-Ens

5.3   CASE STUDY RESULTS

This section focuses on the data that we have gathered from our cases. We will present the result by means of various examples that demonstrate how the procedures are able to fulfill their purposes. In subsequent order we will focus on the snapshot, change event and project characteristic procedure.

Important to note is that in some examples the projects has been anonymized due to confidentiality of some parts of the data. Appendix D provides more in-depth an non-anonymized results.

5.3.1   Results of the snapshot procedure

The first procedure that we consider is the snapshot procedure. The main aim of the snapshot procedure is to map the result of the projects by confronting the expectations, that were present in advance of an activity, with the outcome that has been realized after the activity was completed. The examples that we present in this section demonstrate that the procedure is able to fulfil this aim. In subsequent order we will focus on the development of time, cost and scope expectations.

Time

As addressed in section 4.3.1, the procedure demands to record planned and realized milestones of projects every time a snapshot of the project is taken. In the first place these milestones are important to map the course and the result of the projects. In the second place the developments of the milestones provide an important indication of the phases in which a project has lasted longer or shorter than initially expected. By specifically knowing the phases of acceleration or deceleration we can find explanations for them more easily.

EXPECTED AND REALIZED DRAFT ROUTE DECISION				
Project	Moment S1	Expected S1	Realized S2	Difference (yrs)
A50 Ewijk-Valburg	10-2005	Q3-2006	3-2009	+1 ½
A74 Venlo	11-2002	Q3-2003	12-2009	+5 ¼
N50 Ramspol-Ens	10-2007	Q2-2008	11-2008	+½

Table 24 - Overview of expected and realized milestone draft route decision

Table 24 shows a first example of time related data of the three cases. This table presents the expected moment of completion of the draft route decision for the three case (expected S1) at the time of the first snapshot (moment S1). The same table also shows the moment at which the draft route decision has actually been taken (realized S2) and the result for this milestone (difference yrs).

What can be seen from this table is that all three projects faced a delay in their draft track decision. Especially the delay that A74 Venlo faced is considerable. The rejection of an earlier draft route decision in 2004 had a large contribution to this delay.

EXPECTED AND REALIZED OPENING							
Project	Moment S1	Expectation S1	Moment S2	Expectation S2	Realized S3	△ Total (yrs)	△ Realization phase (yrs)
A50 Ewijk-Valburg	10-2005	2011	4-2009	2014	3-2013	+1 ¼	-¾
A74 Venlo	11-2002	2007	2-2010	Q4-2011	4-2012	+4 ¼	+¼
N50 Ramspol-Ens	10-2007	2012	6-2009	Q3-2013	11-2012	0	-¾

Table 25 - Overview of expected and realized milestone opening

A second example of a milestone is presented in Table 25. This table shows how the expectations regarding the date of opening have developed throughout the project. By comparing the date of the actual opening (Realized S3) with the expectations at the start (Expectation S1) the project result with respect to time can be formulated (△ Total). In line with the results for interim draft route decision milestone, it can be seen that all projects have had a delay.

Interesting to note is however that the projects have either slightly accelerated, or just faced a limited delay, throughout the realization phase (△ Realization phase, being the difference between Realized S3 and Expectation S2). It can be concluded that in the realization phases the project teams succeeded well in realizing the time expectation that were set. The political pressure for timely completion, that was especially present in the A50 and A74 project due to the relations with the renovation of the old bridge and the opening of the greenery exhibition Floriade 2012, have had influence on this.

Although we have only mentioned the draft route decision and the opening, comparable figures can be generated for other milestones in the project. Thereby we can get an overview of the time performance of projects in general and the time performance of projects in certain project phases specifically.

Cost

Like for time related data, the main aim of mapping cost figures is to determine the cost result of the project. With an indication of the cost performance, we have a starting point to investigate which factors have contributed to that particular result. Due to confidentiality of the cost-figures we cannot go into very much detail about the cost performance of the three projects in this section. In the (confidential) appendix D more detailed insight and explanation of the cost performance is presented.

PROJECT BUDGET DEVELOPMENT			
Project	Expected S1	Expected S2	Realized S3
A	100%	217%	156%
B	100%	103%	107%
C	100%	118%	131%

Table 26 - Overview of non-indexed cost performance relative to initial expectation

Although being anonymized, Table 26 shows that the data of our procedure allows us to indicate the cost result of projects by comparing the project budgets at the various snapshots. Important to note, for a correct understanding of the cost figures, is that the budgets were not indexed. With project durations ranging from 5 to 10 years, about 7-17% of the overrun can be explained by inflation. When considering the three projects and the share of the cost uplifts that can be explained with the indexation figures we can indicate that;

- Project A has had a rather tumultuous course. After a major budget uplift in the planning phase it managed to reduce their costs reasonably throughout the realization phase.

- Project B can be considered exemplary when costs are concerned. The project has had a stable cost development throughout both the planning and realization phase, and therefore has achieved a good cost result.

- Although Project C has reached a better final cost performance then project A, their course is however different as the budget has constantly been under tension in both the planning and realization phase.

CONTRACT SUM DEVELOPMENT		
Project	Agreed S2	Realized S3
A	100%	153%
B	100%	123%
C	100%	110%

Table 27 - Overview of non-indexed contractor reward relative to initial contract

Next to project budget, other cost figures are also helpful in identifying how project costs have developed. Table 27 for example shows the final contract reward relative to the initially agreed contract sum.

- Project A indicates that considerable changes have taken place in the contract. When this is combined with the data that we had of the development of the project budget, we get the indication that there was much uncertainty about the project course at the moment of snapshot 2 due to the contradicting development of the project budget and the contract sum.

- Project B shows a project that has faced contractual mutations, but since the total budget uplift was limited, it indicates that the budget reserves were sufficiently high to cope with the additional works.

- For project C the contractual uplift was limited, but the budget rise was considerable. This indicates that changes and events beyond the contractual scope have largely caused the budget uplift.

With use of the examples, we illustrated that our procedure is capable of indicating the cost result of projects and that combining the data provides the first (and very rough) indications for potential explanations of the result.

Scope

The third aspect for which we gathered data with the snapshot procedure is scope. Compared to time and cost related data it is harder to present uniform and comparable overviews of the scope of three projects all together. Instead we will therefore present three examples that indicate how the final scope deviates from the initial expectation. Thereby we demonstrate that our procedure is suitable to detect differences between the scope that was initially expected in snapshot 1 and the scope that was realized at the end of the project in snapshot 3. The first example that we consider comes from the project A50, Figure 24.
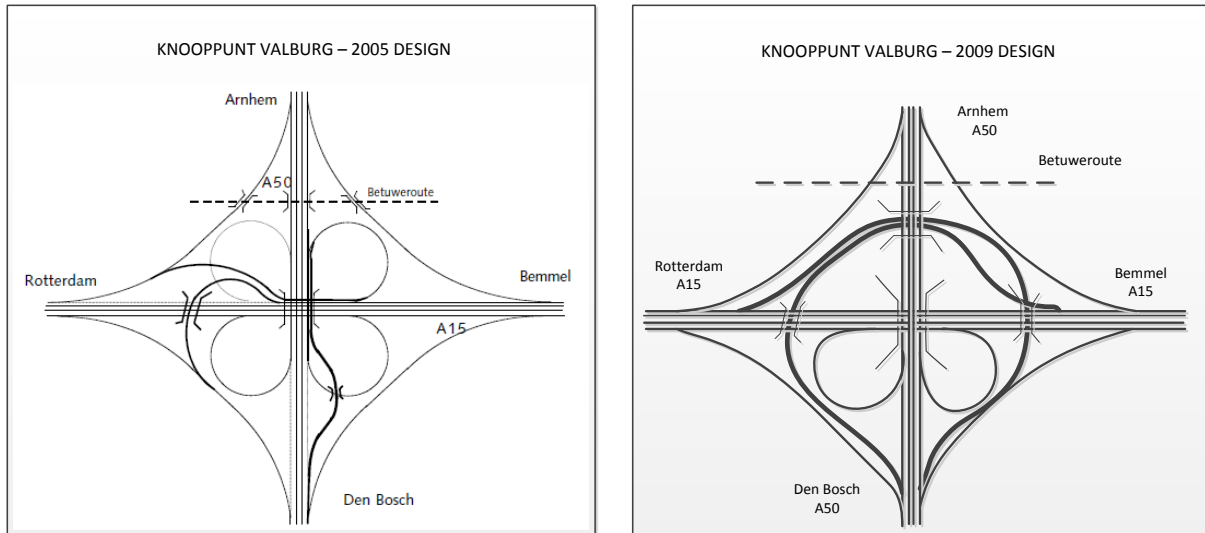

Figure 24 - Scope change in Valburg interchange identified with S1 and S2

The left figure indicates the layout of the interchange Valburg as was initially planned at snapshot 1. Throughout the planning phase it however appeared that another layout (right figure) would better fit the traffic demands for a comparable amount of costs. Therefore the decision was taken to alter the scope, so from snapshot 2 the scope is designed as a "clover-turbine-interchange"[11].
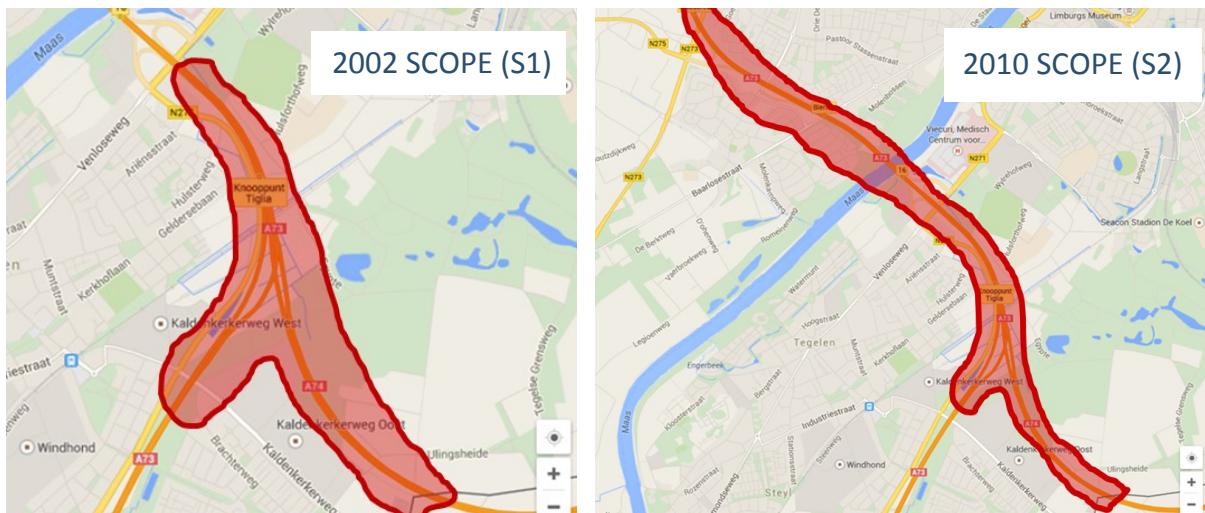

Figure 25 - Scope extension for sound barriers A74 Venlo identified with S1 and S2

The second scope example comes from the project A74 Venlo,

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[11] Klaverturbineknooppunt

Figure 25. The left picture shows the initial scope of this project in 2002, the total considered track had a length of about 3 km then. The map on the right shows how this scope has extended in the planning phase of the project, instead of 3km, the total road-length increased to 6,5 - 7 km.mThe extension of the scope is mainly caused by additional sound barriers that appeared necessary, to absorb additional noise nuisance along the highway A73 that will occur due to the realization of the highway A74. In our snapshot this difference is visible as extra stretches are added for the second and third snapshot
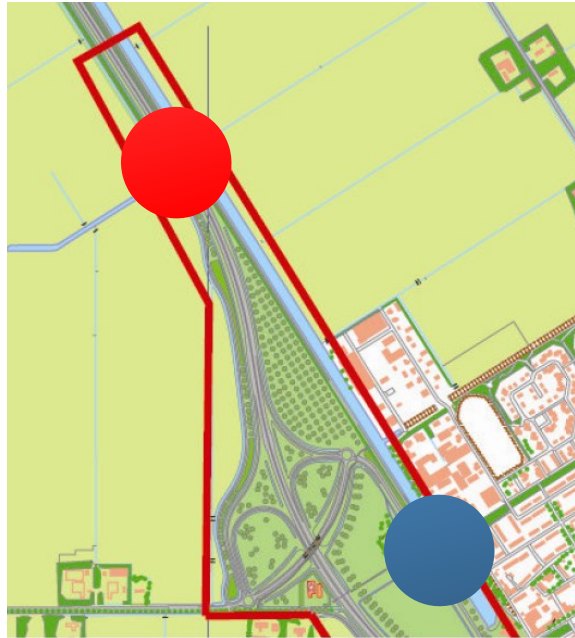

Figure 26 – Locations of scope changes in N50 Ramspol –Ens identified with S1, S2 and S3

A last example that demonstrates that the snapshot procedure allows to detect developments in the project scope comes from N50 Ramspol-Ens. The two dots in Figure 26 refer to locations where changes have taken place in the scope.

The first change, which showed off by comparing snapshot 1 with snapshot 2, is located under the blue dot. At this location the local roads of Ens connect to the access road of the N50. Initially this connection was designed as a crossing but later on it appeared that design did not meet traffic safety and circulation requirements. To meet the requirements, the crossing was replaced by a roundabout.

The second change is located near the red dot and concerns a bridge over the Schokkertocht-channel. Initially it was expected that this bridge needed no alterations and was suitable for the extension of the road. This means that the bridge was not initially part of the scope and snapshots. Throughout realization it however appeared that adaptations of the bridge were required to facilitate the four lanes.

With the examples that we gave, we illustrated how the comparing of snapshots allows us to identify differences between the expected scope at the outset and the realized scope at completion. Important to note is that in contrast to cost and time, the scope snapshots allow us to specifically address were changes in the project have taken place. However compared to time and cost, it is harder to get an overview of the total "scope result" of the project which is that total sum of scope changes.

5.3.2   Results of the change event procedure

The second procedure for which we gathered data of our case projects is the change event procedure. As originally defined in section 4.3.2, the change event procedure aims to give insight in the separate events and decisions that explain the difference between the expectations and that what has been realized. With our case

studies we tested their effectiveness in the realization phases of the three projects. This means that with our change events we try to explain the difference between the second and third snapshot.

Important indicators for changes are mutations of the budget and the contract. Since this data is rather confidential, we cannot give very detailed results of the change events that we identified in the cases. The confidential appendix D does give a more detailed view on the events.

CHANGE-EVENT EFFECTIVENESS				
Project	Contract uplift	# events	Part uplift explained by CE's	Part uplift explained by 5 largest CE's
A	53%	26	77%	59%
B	23%	27	89%	79%
C	10%	23	72%	58%

Table 28 - Effectiveness of the change-event procedure in explaining contract uplifts

One indicator for the effectiveness of the change event procedure is the degree to which the change events are able to explain the contract uplifts of projects. The second column of Table 28 shows the relative cost uplift of the contract for each of the three projects (comparable to Table 27). The third column indicates the amount of change events that we have recorded in each case. The fourth column indicates the degree to which all identified events are able to explain the contractual uplifts and is in fact an indicator of the effectiveness of our procedure. The last column shows the relative importance of the five most valuable contract mutations with respect to the entire contract uplift. The following numerical example illustrates how the percentages relate to each other:

If the contract of project A had an initial value of 100, at the end of the project a value of 153 was rewarded to the contractor due to contractual uplifts. 77% of the total uplift (53*0,77 = 41) can be explained by the 26 change events that we identified. 59% of the total uplift (53*0,59 = 31) can be explained by only considering the five most costly changes.

With the above illustration we show how the change event procedure is able to break down the total difference between what was expected of the project and what has been realized in the project in separate change events. Together these events are able to largely (70-90%) explain how the project has developed. The contribution of the largest events, which are the events with the highest impact on the project result, is considerable. Comparable figures can be constructed for other indicators such as the project budget.

5.3.3 Results of the project characteristic procedure

The last procedure for which we gathered data in our cases is the project characteristic procedure. This procedure aims to grasp the data of projects that might eventually help to explain how project results relate to the inherent characteristics and the external environment of projects. It is important to note that this aim can only be truly fulfilled after data of multiple projects has been recorded, compared and analyzed. In contrast to the snapshot procedure and the change event procedure we can therefore not fully demonstrate that the project characteristic procedure is able to fulfill its aims.

Instead we take an alternative approach to demonstrate that the recording of characteristics is useful. By means of three examples we will show how particular characteristics of projects have led to the occurrence of typical change events in these individual projects. As it is not possible to anonymize the projects in these examples, the examples are presented in the confidential appendix D.

With the examples we showed how project characteristics can be helpful in explaining the results of projects. The characteristics are especially helpful in explaining changes which had a negative effect on the result. It is promising for a broader analysis of project characteristics that these characteristics already hold value on an individual project level.

5.4 EVALUATING THE SNAPSHOT PROCEDURE

With a rough outline of the cases and their results described, this section will evaluate the working of the snapshot procedures on basis of the weaknesses and the adaptations that we could identify during our tests on the procedure. The first part of the section will be devoted to the weaknesses that affect the concepts, and thereby the functionality, of this procedure. In the second part we will describe the practical adaptations that are desired to the procedure.

Before we start we will recall the main functional aims of this procedure. The main aim of the snapshot procedure is to provide an overview of the project at times of:

1. the project definition,

2. the route decision

3. project completion

By comparing the snapshots the result of the project or a particular phase can then be determined.

A second functionality that the snapshot procedure fulfills is the registration of the project scope in order to map the technical characteristics of projects.

5.4.1 Weaknesses the snapshot procedure

The present section will report on four potential weaknesses that were identified. Per weakness we will give a description and explanation of the weakness and conclude on it affect the functioning of the snapshot procedure.

Uniformity of snapshots vs flexibility for ambiguity through project life cycle

The first observation of our case study is that the snapshot procedure neglects the different degrees of ambiguity in a project's life cycle. In a typical project, ambiguity is relatively high in the early life cycle phases and tends to decline in later phases. This means that in the beginning of a project one can only make rough predictions of the project outcome, while in the end one can indicate the realized outcome with a high degree of precision and certainty.

In our snapshots, we neglect these differences as we ask similar degrees of detail for all three snapshots. This has two consequences:

1. Our first snapshot tends to asks too much and too detailed information that is not available.

2. Our third snapshot asks us to register data on a limited amount of milestones while the registration of data on more milestones is easily possible and potentially valuable for research to the realization phase.

We will show two examples to illustrate these findings;

EXPECTED AND REALIZED OPENING			
Project	Expectation S1	Expectation S2	Realized S3
A50 Ewijk-Valburg	2011	2014	3-2013
A74 Venlo	2007	Q4-2011	4-2012
N50 Ramspol-Ens	2012	Q3-2013	11-2012

Table 29 - Different degrees of ambiguity for each snapshot (stripped version of Table 25)

Table 29 shows how for the first snapshots the expected data of opening is mentioned in years. At the moment of the second snapshot, expectations regarding the opening are expressed as a quarter of year. While the actual opening itself can be pointed to a specific month.

MORE DETAILED MILESTONES FOR S3			
Initial milestones for all three snapshots		Detailed milestones for snapshot 3	
1	Preference decision	1	Preference decision
2	Draft track decision	2	Draft track decision
3	Contractclose	3	Partial implementing order
4	Track decision	4	Contractclose
5	Start realisation	5	Track decision
6	Opening	6	Start realisation
7	Decharge	7	Track decision irrevocable
		8	Implementing order
		9	Opening
		10	Decharge

Table 30 - Initially demanded milestones vs detailed milestones for snapshot 3

Table 30 provides an overview of the milestones for which recording was initially demanded in all the three snapshots and the milestones that could be identified (and were relevant) in the realization phase of our case-studies. Two differences can be noted:

1   The partial implementing order and the definitive implementing order are relevant milestones. These are the moments at which the clients sets available budget to the project team.

2   The general term "route decision" should be split up in the two more accurate milestones "route decision completed" and "route decision irrevocable".

Although the described examples are limited to the time aspect of the snapshot, similar patterns can be discovered for cost and scope aspects as well. A combination of these findings on all three aspects makes us conclude that the desired data profile and abstraction level of a snapshot should be attuned to degree of ambiguity that is present at the time that the particular snapshot is taken.

Changing the abstraction levels of the snapshots however holds consequences for the main function of recording the project result. The snapshot with the highest abstraction level, the first snapshot, will thereby become normative for the degree of detail with which the result of the project as a whole can be mapped. A more detailed result can however be obtained for the realization phase specifically, as the abstraction level of the second and third snapshot will be higher than that of snapshot one.

Value of mapping the scope of the third snapshot

The main functional contribution of recording scope related data is that it must allow us to detect how and when the scope has changed throughout the project by comparing the differences between the snapshots.

A weakness of the snapshot procedure is therefore the limited effectiveness of the procedure in detecting these change events between the second and third snapshot. Instead of allowing for detection of scope changes, it tended to work exactly opposite. In practice, the scope description of the third snapshot turned out to be the result of combining the scope description of the second snapshot with the identified change events that have affected the project scope during the realization phase. The main reason why we cannot easily record the scope in the third snapshot is that there is no comprehensive and aggregated description of the scope published once the route decision has been published.

A second weakness to the main functionality is the high workload that is required to map (small) adaptations of the scope. The high degree of detail that is required to map the differences of the scope makes the procedure rather inefficient. The inefficiency weakness especially shows off when the second and third snapshot are to be compared as both the amount and size of scope changes tend to get smaller when a project is in its later phases. As a result, we need to enter a lot of similar data with a very high degree of detail for both snapshots in order to be able to detect very specific and small scope changes.

On basis of the observed limitations in the effectiveness and efficiency of mapping the scope for all three snapshots, it can be argued if the recording of the scope in all three snapshots is valuable. On basis of the observations it can be considered to skip the recording of scope in the third snapshot from the procedure.

Two things are however important to note regarding this observed shortcoming and the given implication:

1   It specifically concerns the recording of scope related data. The recording of data on time and costs on all three snapshots appears to be effective and efficient with regard to the main functionality

2   It specifically concerns the scope record of third snapshot. The comparison of the scopes of the first and second snapshot, the planning phase, is valuable as the early scope changes are generally larger and thereby easier identifiable with snapshots than the later scope changes. Besides there are various comprehensive scope descriptions throughout the design phase that can be used for mapping the scope of the first and second snapshot.

Challenges in the indexation of project budgets

A third weakness that was observed in carrying out the case study was that the snapshot procedure does not allow for adequate indexing of the financial figures. When setting up the procedures, it was implicitly assumed that the gathered financial information would be suitable for indexing to one price level. This equal price level is desirable to compare, and judge on, the financial data that is gathered in the snapshots.

Two conditions however need to be met before indexing can take place:

1   Additional data needs to be gathered on cash rhythms throughout the realization phase. Only then we can index the predicted (snapshot 2) and realized (snapshot 3) costs to the same price level. A potential problem that needs to be overcome is the confidentiality of the cash rhythms since the cash rhythm reveals a lot of financial information that has no further use for the database except indexing.

2   It should be clear how and if task setting budgets are indexed throughout the planning phase. More insight is required in the indexing rates that are applied on the planning phase in practice. Throughout

the case-studies it appeared that during the realization phase of projects budgets are indexed with the IBOI-index rate and that contracts are indexed with actual market fluctuations.

In the ideal situation all financial data for one project can be indexed to one price level with one "push on the button". In such situation we are able to switch between the real and the indexed price levels in each snapshot very easily. In such a case we can also make a direct comparison between snapshots. Further research on the conditions and habits of indexing in MIRT-projects is necessary to conclude if this functionality is possible.

Changing the timing of the second snapshot.

A last observation of our case studies is that it is better to take this snapshot at the moment of the (partial) implementing order instead of the moment at which the route decision is published. Figure 17 of section 4.2.2, which shows the initial moments of the snapshot, should therefore be replaced by Figure 27.
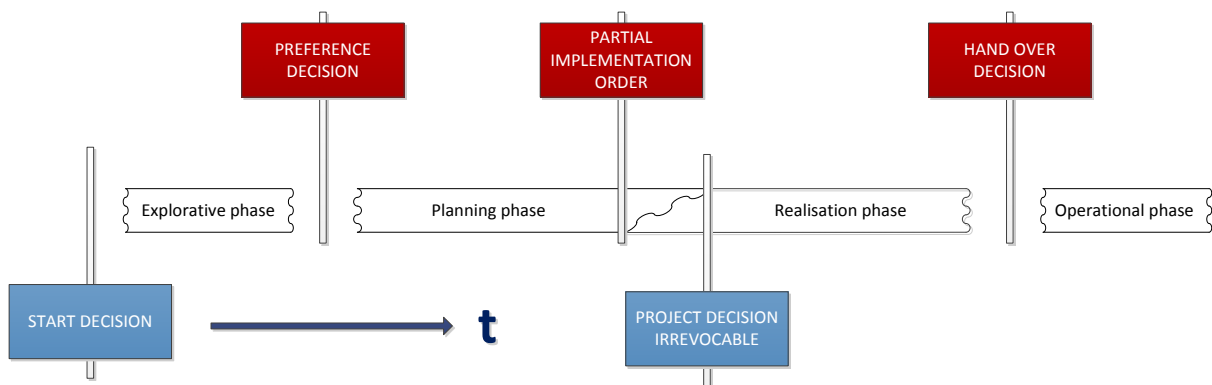

Figure 27 - Snapshot moments after database testing

The main motivation to take the snapshot at another moment is that the (partial) implementing order better demarcates the transition from the planning to the realization phase. With the partial implementing order, budget is set available by the director of Rijkswaterstaat to the project team. The advance payment, which comes with the partial implementation order, allows the project team to start the realization of the first preparatory activities and the contracting process. These first activities are based upon the project scope as is described in the draft route decision. Once the route decision is completed and irrevocable, the definitive implementation order is made.

What we can also conclude from this is that we should not model the transition from the planning to the realization phase as one moment. Instead we can best consider it a gradual process that starts with the partial implementing order and ends when the definitive implementation order has been granted.

5.4.2 Practical adaptations for the scope mapping procedure

The present section will report on the various adaptations to the procedure that are desirable for a better connection to the project practice. The desired adaptations will be grouped to the adaptations that concern the mapping of time, the mapping of costs and the mapping of scope.

Practical adaptations in the mapping of time

Two adaptations were desired for a better integration of the procedure with practice:

1 The recording of two additional milestones is required. These new milestones are the (1) partial implementing order and the (2) definitive implementing order. As described in the previous section, recording of them is relevant as they mark the start and the end of the process in which the planning phase shifts into the realization phase.

2   It appeared relevant to differentiate between the moment that the route decision has been completed and the moment at which it has become irrevocable, instead of considering it as one moment only.

Practical adaptations in the mapping of costs

Also for the mapping of cost two adaptations were desired. These adaptations were required to allow for a correct interpretation of the cost figures of the project. The following data should be added to the cost figures:

1   their price levels

2   The inclusion or exclusion of VAT.

Practical adaptations in the mapping of scope

When mapping the project scope of our cases, three adaptations appeared desirable to record the scope of projects in a more unambiguous manner:

1   stating the amount of driving directions in a considered stretch

2   adding various answering options to predefined answering fields

3   splitting up "environmental compensation" in "nature compensation" and "forest law compensation"

Stating the amount of driving directions on a stretch, when entering the road makeup, is relevant in order to correctly interpret the amount of lanes in a stretch. In the presented procedure it was implicitly assumed that all road stretches would have two driving directions. Throughout the testing of the procedure it appeared however that there are also road stretches, mostly within interchanges, that only facilitate one driving direction.

For three predefined answering fields answering options needed to be added:

1   For the layout type of stretches the option "bridge" was added. We can thereby deviate between bridges that cross the highway (under structures) and bridges that are part of the highway (under stretches)

2   For the type of intervention (both stretches and structures) the options "relocation" and "adaptation" were added. The activities that were carried out on the structures and stretches of our case study projects could not all be categorized under one of initial options. The new options allow us to do so.

3   For the structure types, the options "exit[12]" and "interchange" were added. These two new options allow us to classify the project scope at a higher abstraction level in the first snapshot.

The last change comprised the splitting up of the input option "environmental compensation" in "forest law compensation[13]" and "nature compensation". The main reason to do so is that different types of legislation apply for forest law compensation and nature compensation and that therefore their amounts are determined separately from each other in practice.

5.4.3   Conclusions on the snapshot procedure

Despite the various weaknesses and required adaptations that we detected, the use of snapshots for the recording of a project's result has turned out promising in our case study. This does not alter the fact that it is still necessary to have a closer look on how can best be dealt with the mentioned weaknesses in order to ascertain the maximum maintaining of functionality. Especially a study to the problems with the degree of detail and

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[12] Op- en afrit

[13] Boswetcompensatie

indexation is required as it appears as if these problems are the largest threat to the precision with which the result can be mapped.

The case studies also showed that the recording of the project's technical characteristics, which is the second aim, is possible with the snapshot procedure. None of the shortcomings directly affects this functionality of the procedure. However it needs to be kept in mind that adapting the degree of detail with which the scope is mapped in the procedure has a direct consequence for this second functionality.

5.5 EVALUATION OF THE CHANGE EVENT PROCEDURE

After evaluating the snapshot procedure, we now shift our focus to the functioning of the change event procedure. Like with the snapshot procedure, also for this procedure we will investigate whether the procedure succeeds in fulfilling its initial aim. The main functional goal of the change event procedure, as set before the case study, is to: complete the "movie" of a project that shows how and why a project has developed from its prognosis at the start to the realized result at completion.

In the upcoming sections we will describe our findings on verifying the functionality of our procedure. In the first section we will describe two shortcomings that we have detected that threat the functionality of the procedure in its essence. The second section describes two practical adaptations.

5.5.1 Weaknesses in the change event procedure

In gathering the data for the change event procedure, two weaknesses in the change event procedure appeared. In using the procedure applying the procedure it appeared unclear:

1 Whether a change event affected the "project" or the "contract" sphere of the project.

2 With which degree of detail change events should be recorded.

Splitting up project and contract consequences

Although some provisions were made in the initial change event procure, it proved to be difficult to indicate to whom or what the change event had consequences. This made it hard to correctly understand how the project developed and how the result has been affected. A more explicit distinction between "the project sphere", which concerns what the client and project team have agreed upon, and "the contract sphere", that concerns the agreements between the project team and the contractor, is therefore desired in the change event procedure. By doing so, the records will better allow to demonstrate how the project and contract relate to each other.

Consequently we will have to indicate which sphere the change event primarily affected. Then, if applicable, it can be indicated whether the changes in one sphere did also have consequences on the other sphere. It will then be very clear which data should be gathered and how the two spheres are mutually related. An example that illustrates this principle comes from the project A50 Ewijk-Valburg:

During the project it appeared that a certain department of Rijkswaterstaat was planning to locate several NSL-barriers[14] along the route between Ewijk and Valburg. For efficiency reasons, the client (the director of Rijkswaterstaat) decided to transfer the realization of these barriers from the NSL-department to the project team. He thereby set available additional budget to the project team to finance the realization of these barriers. In first instance the consequence of this change event is in the project sphere. In second instance, the project team

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[14] NSL-barriers are barriers that aim to improve the air quality in surrounding neighborhoods. NSL barriers are placed by the national NSL-program of Rijksw aterstaat.

assigns the realization of these barriers to the contractor. Thereby they adapt the contract that they initially had by adding the barriers to the scope and agreeing on a higher rewarding.

By explicitly indicating what is affected by the change event (the project, the contract or both), a first improvement to the procedure is made. However to achieve maximum advantage of this we need to make an additional adjustments to our procedure by indicating who initiated the change event. This is important in order to understand how various actors have influenced the project result. When all change events that are initiated by one actor are grouped, we get a representation of the role that this actor has had in the entire movie of the project.

Worth noting is that the division between the project sphere and the contract sphere, is only relevant for the realization phase. The contract sphere does not exist in the planning phase of the project.

Degree of detail

A second weakness that appeared, is that it is unclear when a change-event has had "enough" impact on the project result that makes it worth recording. In fact this is comparable to considering how detailed the explanation for the project result must be. To get data uniformly recorded for all projects it is however desirable to define some criteria that help indicating if a change event is relevant to record.

Interesting to note in this dilemma of determining the required degree of detail is that the workload increases when the degree of detail is increased. Two reasons underlie this phenomenon:

1. Identifying change events with a smaller impact tends to be more difficult than events with a high impact as the smaller ones tend to be less well documented and memorized by project team members.

2. The relative explanative value of a smaller event is lower, so if a small event has been identified it only explains a small part of the final result. In that sense it is interesting to note that the five events with the largest impact, Table 28 on page 71, are able to explain more than half of the contract uplift.

Given this dilemma, it can be discussed how relevant and efficient it is to record all the changes. If recording five to ten changes largely explains how the result has come about, we have already taken a big step in fulfilling our intended functionality. On the contrary, with all information on all changes available more detailed research to the coming about of project results can be done.

5.5.2 Practical adaptations of the change event procedure

While testing the change events, two practical adaptations appeared desirable.

- Also in the change event procedure it appeared desirable to indicate the price level and the inclusion of VAT for all cost figures. This allows us to correctly interpret the cost consequences of each change event.

- In the initial procedure, we demanded to give two descriptions of an event: (1) a general description and (2) a description that states how the scope is affected. In practice it appeared that the two descriptions are not sufficiently distinctive and largely overlap. That is why we combined them under the general description.

5.5.3 Conclusion on the change event procedure

Evaluating the change event procedure gives us important input for further developing of the procedure in practice. Of the two weaknesses that we identified especially the degree of detail appears to give an important

dilemma in developing the database. Recording data that is too detailed increases the workload too heavily while recording the high impact events only decreases the value of the database.

5.6 VERIFYING THE PROJECT CHARACTERISTIC PROCEDURE

The remaining procedure to be verified is the project characteristic procedure. The main aim of this procedure is to record data on the characteristics of projects that might potentially be of influence on the project result. Once data on sufficient projects is gathered, it allows us to investigate how project results and project characteristics are related. Unlike the previous two procedures, where we had to verify the working of the concept to map the project result, the verification of the project characteristic procedure only comprised the detection of practical shortcomings for which adaptations are desirable.

5.6.1 Practical adaptations to the project characteristic procedure

Analogue to chapter four, we will subsequently present our findings on the organizational and external characteristics. Potential problems with the technical characteristics have already discussed as part of the snapshot procedure, as the main technical characteristics are mapped with the identification of the project scope.

Adaptations for the recording of organizational characteristics

When the interaction with the market was concerned. Two small problems showed off for which improvements are desirable:

1. The exact firms that make up the contracted consortium tend to be unstable through times.
2. Listing the contract and procurement type only gives a limited view upon the market interaction.

The main reason for the first problem is that contracted firms are often a daughter company of a larger holding. Reorganizations and take overs of these companies are not uncommon in the sector. To keep this understandable in future it might be relevant to indicate both the specific daughter company as well as the larger holding.

The second problem is addressed as all three cases used a D&C contract and procurement has taken place via a dialogue or non-public procedure. The image that might be gained is that the projects did not deviate in contractual sense. While studying the cases it became clear that each project has chosen a specific strategy to create specific incentives for the market in line with the ambitions of the project. An extension of the procedure with the applied bonus or rewarding structure might therefore be added.

When the internal organization and team are concerned. Two practical adaptations appeared desirable for this step.

1. Renaming of the data input "organization and team" appeared desirable as the term does not cover its intended purpose. Instead we will replace it by "human resources".
2. Adding additional information on the members of the project management team appeared desirable. Next to their name, it is worth to know their role, the period in which they were involved in the project, the department or organization that they work for and contact information.

Adaptations for the recording of external characteristics

After the organizational characteristics, we shift our focus to the external characteristics of the project. Like in chapter four, we will treat the physical environment separate from the stakeholder environment. Three adaptations are proposed for the physical environment:

1. The initial format to enter the location was by name the place of the track start and track end. This appeared rather impractical. Instead listing the province in which the project is located is proposed, to get a quick overview of which projects have been completed in one region once the database is filled.

2. The inclusion of the kind of environment in which the project is realized. Including this classification is valuable to indicate whether the project or specific parts of the projects are realized in a rural or urban environment. A five point scale that ranges from "very urban" to "very rural" seems to give sufficiently distinctive answers, whereby the "most urban" parts of the project are leading in determining the score.

3. Mentioning where a certain type of heritage is present in the project scope appeared to be difficult and ineffective. To be more valuable and explaining, each relevant piece of heritage should be defined and specific properties should be attached the theses defined pieces of heritage. Only then we can state why a certain piece of nature or monument is of influence for the project.

Two difficulties showed up in identifying the stakeholder environment:

1. Throughout the cases, it appears that the teams use slightly different stakeholder methods

2. The classification of power, attitude and interest that project teams attribute to a stakeholder varies through time.

The different methods make that for example not all projects report on the attitude of the stakeholder towards the project or give a description why a certain stakeholder is relevant to consider in the project. As an outsider it is however not always self-evident why a certain stakeholder has been included. Giving such a description in the database therefore does not always make sense. Filling in this procedure is therefore only possible if a standardized stakeholder method is applied on all project or if project team members help to provide all demanded data of the procedure.

The moment at which the stakeholders are mapped has a large influence on the properties that are assigned to them and how their relation to the project must be valued. A typical example in that sense comes from the project N50 Ramspol-Ens and concerns the relation between the project team and the water board that owns the nearby storm surge barrier of Ramspol:

In first instance, at the start of the project the relation between the project team and the water board was good, various agreements had been made and the water board was a cooperative and trustful actor. Due to various changes in personnel, support for the agreements however declined and a previously held discussion was held anew. So in second instance, the cooperativeness and trustworthiness was lower. After new agreements had been made the positive attitude of both was restored.

What can be concluded from this is that the timing of the stakeholder procedure is important to get a representative image of the entire project life cycle. It might therefore be considered to map the stakeholder environment at several moments to get an "average" judgment.

5.6.2 Conclusion on project characteristics procedure

While studying the cases, it appeared that our initial procedure was rather concise for various aspects. A more elaborate registration of the market interaction and the commissioning structure is possible and appears to be valuable for getting a more nuanced view on the organizational context of the project. Likewise, for the external characteristics, a more comprehensive recording of heritage and stakeholders will contribute to a better understanding of their influence and relevance for the project result.

5.7 CONCLUSIONS

In the previous paragraphs we have reported and concluded on the functioning of the three individual procedures. In this section we will concludes upon the results of the case study as a whole. Together, our findings from the cases allow us to answer the sub-questions 4c and 5a.

4c What additional challenges arise after testing the database design in practice?

In verifying the working of the data gathering procedures it appeared that there are two weaknesses to the procedure which put a challenge to a proper functioning of the database. The first one is the degree to which financial figures can be indexed to one price level. Without a proper indexation mechanism two problems arise: (1) it is difficult to conclude upon the financial result of a project and (2) it is difficult to compare the costs of projects in an absolute way. The second one is the degree of detail with which data is recorded. On the one side a high degree of desirable as this best allows to categorize and analyze the data that is recorded. On the other side a low degree of detail is desired in order to keep the workload of gathering the data as low as possible.

It is recommended to investigate how can be dealt with indexation by consulting financial experts from practice and secondly it is recommended to discuss the desired degree of detail with potential users of the database.

5a What is a feasible technical design for the database?

By carrying out the case study, we have demonstrated and shown that the three data gathering procedures are a promising manner to record: (1) projects, (2) their results (3) the events that have led to these results and (4) various characteristics that might explain project results in general. We therefore conclude that the data gathering procedures are a feasible technical design for a database.

Two remarks regarding the validity of this conclusion have to be made. The first remark is that the data gathering procedure has proven to function for MIRT-related road projects carried out by Rijkswaterstaat. For appropriate functioning of this design in another context additional research is required. The second remark to be made is that the change event procedure has specifically been tested on the realization phase of projects, which means that our conclusions are only valid for the realization phase of projects. To increase the value of data gathering procedures, we recommend verifying the working of the change event procedure in the planning phase in the same fashion as we tested it for the realization phase.

6 DISCUSSION

The previous chapters have mainly been devoted to determining what data is to be gathered and to setting up a procedure that allows to gather this data. Although the procedure appears promising in a technical sense, it is not yet evident if it will become successful and fulfil its intended purposes. Therefore, we will discuss how the database can be implemented in practice and examine how this relates to the output that can be generated and the purposes that can be served. In doing so, we will find an answer to our last sub-question, 5b: How should the organizational process around the database be set up?
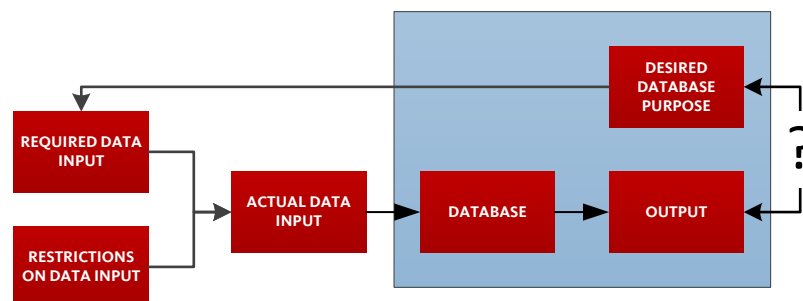
Figure 28 - Relevance of discussion for research aim

This chapter comprises four sections. In the first section we will focus upon a potential owner of the database and how this is related to the potential value of the database. In the second section we propose how the eventual data gathering and processing can best be organized based on the findings of our research. The third section will mention the limitations of our findings and the chapter will end by discussing the relevancy of the findings.

6.1 DATABASE OWNERSHIP

Despite the generic value that the recording of the project related data will have for the entire sector, specific aims are more persuasive for a potential database owner to set available the required resources for use and implementation of the database. The practical value of the developed data gathering procedure and the exact data that has to be gathered will eventually depend upon the party who will own the database. A further development of the procedure and the database is therefore only sensible if it is clear how the ownership and responsibility of further developing the database is organized.

While carrying out the research, three potential database owners have been identified: (1) the individual executive organizations (Rijkswaterstaat and ProRail), (2) independent knowledge platforms that aim to improve the sector (Neerlands Diep) and (3) scientific institutions (TU Delft). The allocation of the ownership to each of these groups has certain potential strengths and weaknesses, Table 31.

	Strengths	Weaknesses
ProRail & Rijkswaterstaat	Data availability Few problems with confidentiality Direct implementation of findings	Potential lack of urgency Potential subjectivity or strategic framing of findings
Neerlands Diep	Independency of the organization Good reputation Contributes to primary objectives	Requires organizational adaptations
TU Delft	Objective interpretation of findings Stimulus for continuity and development of the database Direct incentive for research findings	Limited data access Confidentiality

Table 31 - Strengths and weaknesses of possible database owners

The main reason to opt for ProRail and Rijkswaterstaat as potential database owners is that these organizations are able to generate most of the desired data themselves. Issues with confidentiality will be limited as the data will mainly be processed internally. A last advantage is that the database can be geared in such a way that it is directly helpful to solve specific problems from practice. On the contrary a potential lack of urgency for adequate development, maintaining and use of the database might be present. Throughout our interviews the impression was gained that both ProRail and Rijkswaterstaat have a major focus on the execution of projects. Supportive activities, such as research, are considered to be of minor importance and a task that belongs to other institutions. A second weakness concerns the potential for a subjective interpretation of the findings. In a certain way the database is a means with which the organization can judge upon its own performance and shortcomings. The database will lose a part of its value if its outcome is brushed up and strategically framed.

The strength of Neerlands Diep as a potential database owner mainly comes from the independent character that it has in the public project management practice. Via its independent role it tries to combine the best of theory and practice. This creates support and trust from both the executive organizations and the scientific field. A second strength is that the intended objectives of the database coincide with the primary objectives of Neerlands Diep. Important for an adequate implementation of the database outcome in practice is the good reputation that Neerlands Diep has when project related knowledge is concerned. It therefore takes limited efforts to convince decision makers in the higher ranks of the executive organizations to implement findings and to gain required resources. Important to note is however that Neerlands Diep is currently attuned as a network and learning organization. If Neerlands Diep is to own the database a research branch should be added to, or facilitated within, their organization.

The last potential database owner is a scientific institute as the TU Delft. The major strength of a scientific institute as database owner is that it aims at developing relevant and new knowledge. Thereby, it has an incentive to continuously gather data and develop the database in order to serve new research desires and further knowledge

development. Another advantage of having a scientific institute as a database owner is that is has an outside and objective view upon the project practices. A large weakness of a scientific institute as database owner is that they are largely depended upon the executive organizations for their data supply. This appears trivial but its effect should not be underestimated as "*Despite a strong interest in the topic, data-access has made it difficult for academics to shed their light on the prevalence and causes of cost results in the transportation sector*" (Siemiatycki, 2009).

After considering all three potential owners it can be concluded that there is not a clear-cut best option for the ownership of the database. The database will hold most value with optimal collaboration between the three parties. As can be seen in Table 31, in such case the weaknesses of specific parties can be partially reversed by the strengths of the others. It is therefore recommended to all potential owners to investigate if, with whom and in which fashion they want to collaborate in facilitating a database of Dutch infrastructure projects. Only when that has been decided and if it is clear who (together) will carry the ownership and development of the database, further decisions regarding the exact content and aims can be made.

6.2   HOW SHOUD DATA BE GATHERED IN PRACTICE?

Regardless of who owns the database, effort is required in collecting and analyzing the data. This section will present our ideas on data gathering. In order to do so we will use our experiences from the case study and the interviews.

The first advice is to gather the data of one project in two separate steps. The first step will be used to collect data on the planning phase while the second step comprises the realization phase and the project as a whole. Two reasons substantiate this advice. In the first place it appeared that projects last too long to only evaluate them when they are completed. Secondly it appeared that both project phases have a different character, as the planning phase concerns the project sphere only, while in the realization phase both the project- and the contract sphere are concerned.

The second advice is to create a team of researchers that is concerned with data collection. The main reason to have more people involved in the collecting and analyzing of data is to enhance the continuation of the database. Continuation of the database is essential for the growth of its potential value. When only a few individuals are involved in the data gathering, there is a risk that the collecting of data stops when one of the individuals stops. A secondary reason to have more people involved is that it makes it harder to misuse the data for individual stakes.

The third advice is to actively involve the data gathering team in the evaluation of projects or project phases. They could for example prepare and host evaluative sessions of the project team or play a role in the gate review process that is currently in place in Rijkswaterstaat. It should be explicitly strived to come to a win-win situation by which the individual project team members profit from evaluating and reflecting on their work while the research team is able to gather the input that is required for the database.

The fourth advice is to investigate how the workload of data gathering can be reduced by a better integration of our proposed data gathering procedure with current data structures as the VTW-tool, SAP, and the current Project Database. In our current research we were limited in the amount time that we had to investigate this, but automation is certainly desirable as this reduces the required workload, and therefore resources, for a successful database.

6.3 LIMITATIONS OF THE RESEARCH

Despite the effort and care that we have put to this research, there are several factors that limit our research. In total we have identified five that we will describe subsequently in the rest of this section.

Limited amount of external validity due to delineation

Throughout this research, the term Dutch infrastructure projects gets more and more delineated due to either methodological or organizational choices. At the start we considered a database for every road, rail, waterway, tunnel and bridge related project larger than 20 million Euro's in the Netherlands. Our case studies however specifically focused on the realization phase of three recently completed road projects of Rijkswaterstaat that were part of the MIRT-program. The gradual delineation that occurred in the research bounds the external validity and the intended general character of our conclusions (Verschuren and Doorewaard, 2010).

To improve the general validity of our conclusions additional research is required. We propose to carry out this research in the reverse order as in which we delineated the concept Dutch infrastructure projects. We thereby advise to use the strategy as suggested by our interview candidate 6, challenge 9, section 3.6: "*Try to consider a database as a lively document; start with a compact version and see how it needs to develop*". So first it must be validated if the procedure works for all road related MIRT project of Rijkswaterstaat. Especially the functioning of the procedure in the planning phase and for project with a DBFM(O) contract is worth investigating. Once that is done, the data gathering procedure should be adapted to, and tested for, the MIRT-related rail and water project of ProRail and Rijkswaterstaat respectively. In the last place the adaptation and verification of the procedure for non-MIRT-projects should take place. Hereby the feasibility of the concept that underlies the procedure is also tested for projects with different clients (and different decision making procedures) and other types of projects than realization projects only (such as replacement or maintenance projects).

Major focus on the content of the database

In setting up the research we mainly focused on the feasibility of collecting the future content of a database. To a lesser extent we considered the feasibility of the organizational set-up and implementation while we did not consider IT-requirements and feasibility. However to conclude upon the feasibility of a database as a whole all three aspects should be considered. In that sense, the data gathering procedure that we developed and tested should be considered as a first explorative research step that is to be succeeded by additional (feasibility) studies on organizational and IT-aspects and finally the realization of a database.

Our choice to limit this study to the database content was in the first place driven by the restricted amount of research time for a graduation thesis. Also considering the other two aspects would comprise an effort that is too large. In the second place the database content has been picked as the most important topic as this best matches with the content of the master Construction Management & Engineering. Although the interdisciplinary nature of this study would also plea for the inclusion of IT and organizational aspects in the study.

Procedure limited to project team perspective

Due to the interview candidates that we selected, the desired data and the relevant factors to record are based upon the thoughts of project team members from Rijkswaterstaat and ProRail. These thoughts are not particularly right or wrong, but the database purpose and the corresponding data input that we describe are limited to the perspective of our interview candidates.

Adding the views of other people active in the Dutch infrastructure sector, for example those of contractors, policy staff or project team members of municipal organizations, is worth considering in future research. Their inclusion might either validate our findings regarding the desired data or reveal additional knowledge desires. If such future

research is taking place, the research methodology should be reconsidered. Instead of using interviews as in this explorative research, a sector wide survey is also an option. The survey can then be based upon the findings of our research.

Potential bias and subjectivity of case study data

A potential bias might be present in the data and information that we received from our contact persons within the project teams. For each of our three cases, we had one contact person who supplied us with relevant documents and background information. This same person also was the designated person to verify our findings. The results of our case study are rather dependent on the data access, memory, willingness and honesty of our contact persons. Especially data access is worrying as our contact persons have not been involved throughout the entire project duration. For all of the cases it was difficult to retrieve early project data.

Potential bias of researcher in evaluation of database design

A second bias in the case studies is a bias of us as researcher. There are two reasons why we might have potentially judged the functioning of the data gathering procedure too positive:

1   We have to judge upon our own work. With evaluation our procedure we conclude upon the applicability of a procedure that we developed ourselves and which we want to function in practice. The parameters with which we judge the function are however limitedly objective.

2   We conclude upon the explanative value and completeness of the recorded data while we have more background knowledge on how to interpret the data. Due to this background knowledge the data might be explanative for us as we know how causes and consequences are related. Outsiders, that do not have this background knowledge, might consider the same data not explanative at all. In that sense additional verification of the procedures by objective auditors is desirable.

6.4 REFLECTION

Despite the various limitations of the research, our research holds value in various manners. In this section we will subsequently indicate the relevance and importance of this research in the view of academics, Neerlands Diep and AT Osborne.

6.4.1 Scientific value of the findings

With this thesis we have made a contribution to a further development of the field of project management. The data-gathering procedure that we set up is a first step to a systemic recording of projects, their results and the events that have caused these results, for infrastructure projects in the Netherlands. Thereby our research contributes to the scientific need as identified by Siemiatycki (2009) to find prove for the causes of project results in infrastructure projects. More specifically it is our concept of snapshots, change-events and project characteristics that appears promising for investigating the coherence between what Verweij and Gerrits (2013) call the local conditions and generic patterns. This will give us an ex-post understanding of what has led to certain project outcomes and helps us ex-ante in determining how future projects should be managed and set up given their specific circumstances.

The relevance of the data that we gather in our procedure follows from the study that we did to the principles of complexity and contingency theory in a project management setting. Next to the literature study, we based the data to be gathered on the input that senior project practitioners of ProRail and Rijkswaterstaat gave throughout

the interviews. A combination of both the theoretical and practical input ensures the relevancy of the data for the explanative aim that we try to fulfill.

With the three case studies that we conducted, we verified the potential value of using our procedure in practice. The results of this verification step are promising in the sense that the data that we want to gather can for a large share be found directly in project administrations. Also the change events seem to be able to largely explain the project results. Due to various steps of delineation, the domain to which we developed and verified the procedure is however rather narrow when compared to our initial domain of all Dutch infrastructure projects of a certain size. Therefore a degree of caution is needed in attaching general value to the procedure and the outcome of the verification process as the external validity might be limited (Verschuren and Doorewaard, 2010). The three specific MIRT related road projects of Rijkswaterstaat that we have been part of our case-study should therefore be considered as only a first (but important) step to come to a database on all Dutch infrastructure projects. To get there, this step should be succeeded by a further development and verification of the data gathering procedure for other modalities, types and clients of infrastructure projects.

6.4.2 Relevance of the findings for Neerlands Diep

The knowledge platform Neerlands Diep has a specific interest in up-to-date knowledge on public construction and infrastructure projects so that they can distribute this knowledge among the project management teams and public clients. For both project teams and clients the development of the database is relevant as the insights and patterns that we hope to find will provide useful reference and guiding for the decisions that they have to make throughout future projects. In the first place this concerns decision making of public clients in the early project phases in which the characteristics of the project are determined. In the second place it is about the decisions that are made by project teams in achieving their project goals.

Before the database and the source of reference will however be developed the data still needs to be gathered. This research provides the various public organizations that commence and realize infrastructure projects a practical, yet grounded, method with which they can make a first start with recording of the data. The method will be of specific interest for Rijkswaterstaat as the most detailed elaboration of the method is tested on their MIRT related road projects. When they set up an internal gathering, evaluation and implementation process, the method might be of direct use for them.

6.4.3 Relevance of the findings for AT Osborne

As an independent consulting firm AT Osborne provides expertise in the fields of Housing & real estate and Infrastructure, spatial development & environment to a diverse range of (mainly) public clients such as ProRail and Rijkswaterstaat. To successfully deliver its customers managerial and advisory service, AT Osborne puts effort in developing and sharing process and project management related knowledge. In-depth insights into the relation between project characteristics and project results suit that domain. The specific value of a database on infrastructure projects will lay in the evidence based reference and guidance that the database will provide to support the decision-making of these projects and to achieve better results.

Coming to such an explanative database is however difficult for an organization as AT Osborne on its own. Compared to the public executive organizations, AT Osborne's possibilities of data access are limited. Parts of the data gathering procedure and its underlying concept will therefore need to be fleeced if AT Osborne wants to set up a database. Albeit a part of the explanatory value is likely to be lost in a fleeced form, the recording, comparing and analyzing of any data that is available on multiple projects can be advocated as it will still holds value to support advice and management. Additional verification of the procedure will be needed to investigate

which data is publicly available and which data is not in order to determine how the procedure needs to be attuned.

6.5 CONCLUSIONS

This section gives the answer to the last remaining sub-question of this research:

5b How should the organizational process around the database be set up?

In setting up a database of Dutch infrastructure projects, two organizational issues are relevant. In the first place this concerns the potential database owner. Determining an owner appears to be a crucial step in getting to implementation of the database. After analyzing the three main types of potential database owners, there appears to be no ideal owner as each potential owner has its own strengths and weaknesses. To eliminate the individual weaknesses, collaboration between scientific instances, Neerlands Diep and executive organizations is desirable.

The second organizational issue concerns how the actual data gathering will take place in practice. Four advices have been given: (1) gather data from the planning phase separate from data on the realization phase of a project, (2) actively involve the people who gather the data in the evaluation of projects or project phases, (3) create a team of people that together supply all input for the database and (4) investigate how the data gathering workload can be limited by better integration with current databases and ICT-systems.

7 CONCLUSIONS & RECOMMENDATIONS

With all major research steps taken, this chapter will finish off this thesis by concluding on our findings and by formulation the recommendations that we have for use in practice and for additional research.

7.1 CONCLUSIONS

Our conclusions are presented by answering our research questions. Subsequently we will answer our five sub-questions so that we have sufficient basis to answer our main research question:

What are the possibilities and limitations for a database on project results and why?

The first sub-question that we conclude upon is:

1. What factors are relevant in recording an infrastructure project's results?

The following four factors are relevant to record: (1) management approach, (2) inherent project characteristics, (3) external environment and (4) the project result itself.

The applied management approach is relevant since the approach be rightly attuned to the presence of contingency factors in a project in order to increase the likelihood of successful project results. An ex-post evaluation of the management approach and the properties of projects might help us explain why a particular result has been realized.

These properties comprise the inherent characteristics of the project itself and the environment with which the project is to interact. This distinction is necessary as a project manager and decision makers are (partially) able to steer and define the characteristics of the project at its start, but they do have no, or at most indirect control, over the external environment.

Although mentioning the project result is rather trivial, we need to mention it since various success criteria can be used to conclude upon the result of a project. Result can therefore mean various things.

2. What are unfulfilled knowledge needs and applications that the database can serve?

Interviews with project practitioners have shown that two knowledge needs exist that a database of infrastructure projects can serve. In the first place this is a database that unlocks best-practices and general project management knowledge. Secondly it is a database that is used for recording of objective project data that can be analyzed once data for multiple projects is entered. On basis of the interviews, there appears to be an equal amount of support for each of the two possible applications. Both applications are however such different in their nature, that it is not possible to serve them both in one database. In choosing which database to further develop, we decided to focus on the development of a database on objective project data. We choose this type since (1) it best suited our intend research purpose and (2) it will deliver the highest scientific and practical contribution as there are already knowledge retrieval mechanisms and initiatives known that aim to spread best-practices whereas objective recording and knowledge creation tends to be limited in practice.

3. What data must be recorded to serve the most valuable purpose and knowledge need?

In the interviews that we have done, project practitioners indicated 23 aspects of projects that are worth recording for investigation of projects and their results. After analyzing the 23 individual aspects, they were grouped in the six categories: planning, costs, contract, project characteristics (incl. scope and complexity), risks and project results. In setting up a database it needs to be ascertained that aspects of each of these categories is included in the design.

4. What factors hamper the recording of this data and what effects do these limitations have on a database?

A first indication of factors that potentially hamper the recording of data was gained throughout the interviews. The main factors that threaten a successful database have either a data-related or organizational nature. The three data-related limitations are: a lack of uniformity of the data, subjective data and a lack of relevancy of collected data. The three identified factors with an organizational nature are: the required workload to gather the data, confidentiality of (especially financial) data and an unsuccessful implementation of the database.

To investigate the effects that these limitations have on the database, we developed a data gathering procedure and tested this on three projects. The procedure that we developed demands the recording of data on all six categories of desired data. In developing this procedure, we tried to design it in such a way that the impacts of the potential threats were limited. In order to do so, we further delineated our research before we developed a data gathering procedure. In the first place this comprised defining the project result along the criteria of project management success (time cost and scope). Since this data is likely to be yet available we thereby limit the required workload in gathering the data. The second delineation we made was from infrastructure projects in general to MIRT-projects specifically. In doing so, we increase the relevancy and uniformity of the data that is to be collected.

Once the procedure was completed, we tested whether the workload, uniformity, subjectivity or confidentiality limit the database. Due to our limited research time we could not test the impact that the factors lack of relevancy and unsuccessful implementation would have on the database. Additional research activities are therefore required to investigate how it can be prevented that the database lacks relevancy and will be implemented unsuccessfully. After testing, it appeared that uniformity, subjectivity and confidentiality do not necessarily limit the functioning of the database. The workload can become a problem if the demanded degree of detail in mapping the project

scope and change events becomes too high. It can be discussed which degree of detail is relevant for adequate functioning of the procedure but this will largely be dependent upon the eventual owner of the database. An second factor that might potentially hamper the recording of the desired data is a lacking indexation mechanism. Further research will have to make clear how sever this factor can limit the functioning of the database.

> 5. *In what configuration is a database on Dutch infrastructure projects feasible and meaningful?*

The abovementioned data gathering procedure, which demands the recording of snapshots, change events and project characteristics, has appeared to be a promising method to come to a database of Dutch infrastructure projects. The procedure is therefore considered a technically feasible design although we acknowledge that this conclusion is bound by the fact that we only tested it on a select sample of road related MIRT-projects of Rijkswaterstaat and that we have only verified the mapping of change events in the realization phase of our cases. Further testing and a gradual expansion of the procure will therefore be required before the database can concern data on the Dutch infrastructure projects in general. Additional activities are also required to determine how the database should be organized in an organizational sense. Especially finding an owner for the database is considered essential to safeguard that the database becomes meaningful and will be implemented in practice.

With our five sub-questions answers, we can now return to our main question:

> *What are the possibilities and limitations for a database on project results and why?*

Our research shows that the developed data gathering procedure provides us a possibility to record (1) projects, (2) their results, (3) the events that have led to these project results and (4) various characteristics that might explain project results in general. A few remarks regarding the validity and threatening limitations need to be made. Due to the chosen methodology, the procedure has proven to work for three MIRT-related road infrastructure projects of Rijkswaterstaat, but it should be investigate to which these findings can be generalized to other types of projects. In testing the data gathering procedure it appeared that a high work load for a high degree of detail and the lacking of a proper indexing mechanism potentially limit the database in a technical sense. From an organizational viewpoint two potential limitations still threaten a database. These are the limited relevancy of the data that is to be gathered for the eventual owner of the database and unsuccessful implementation of the database in practice.

7.2   RECOMMENDATIONS

On basis of the research that we have done, the following recommendations are proposed:

> 1. *Strive to come to a database on Dutch infrastructure projects and their results by further developing the data gathering procedure.*

Throughout the interview our candidates confirmed that there is a need for a database that will help to explain the realization of the project results. As our case study has demonstrated our data gathering procedure is a feasible method to record relevant data but it should still be further developed to get this database functioning properly.

> 2. *It is recommended to ProRail and Rijkswaterstaat to investigate ways in which best practices can be better unbolted.*

Throughout our interviews, eight out of the sixteen candidates have indicated that a better unlocking of best practices of colleagues would be helpful for their work. Current standards and companions, that should currently unlock the best practices, are often considered to be rather bureaucratic and inept. Instead a more intuitive platform is desired.

3. *Implement the database for a small group of projects first and then gradually expend it for other projects.*

A small start will only require a limited investment and will keep initial workload acceptable. In an iterative process it allows to thoroughly test, validate and prepare the procedure for a wider application. A possible start-group can be all road projects of Rijkswaterstaat.

4. *Find a database owner, or a coalition of owners, before further developing of the database*

Throughout the interviews it appeared that there are still differing visions on who should own and maintain the database. Finding an owner is however important as this will, specific desires, needs and limitations for the database. Once an owner is found it can be exactly determined which data is to be gathered and which strategy will be used for a successful implementations.

5. *Investigate how the database can be integrated with existing databases and ICT-systems*

Some of the interviewed project practitioners fear additional workload and double work. A good integration of the data gathering procedure with current databases and ICT-system will prevent double work.

6. *Leave the responsibility for filling in the database a specific team of researchers*

This recommendation is three folded. In the first place it limits additional work for project team members. In the second place it safeguards the entry of data of relevant projects in the database. In the third place it increases the uniformity and objectivity of the data as only a selective group of people is concerned with filling in the database.

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APPENDICES

APPENDIX A – OVERVIEW OF INTERVIEWED CANDIDATES

#	ORGANIZATION	FUNCTION	EXPERIENCE (yrs)
1	Municipality of Amsterdam	Projectmanager	25
2	Rijkswaterstaat	Projectmanager	15-20
3	ProRail	Projectmanager	20-25
4	ProRail	Projectmanager	20-25
5	Rijkswaterstaat	Projectmanager	?
6	Rijkswaterstaat	Projectmanager	15-20
7	Rijkswaterstaat	Portfoliomanager	?
8	Rijkswaterstaat	Portfoliomanager	± 20
9	Rijkswaterstaat	Manager projectbeheersing	± 15
10	ProRail	Projectmanager	20
11	ProRail	Projectmanager	± 15
12	ProRail	Projectmanager	22
13	ProRail	Projectmanager	20-25
14	Rijkswaterstaat	Manager projectbeheersing	15
15	ProRail	Manager infraprojecten	± 20
16	Rijkswaterstaat	Projectmanager	25-30

APPENDIX B – INTERVIEW PROTOCOL

Introductie

Het doel van het onderzoek is om te onderzoeken op welke wijze en in welke vorm een databank geschikt is voor het vastleggen en leren van reeds uitgevoerde infrastructuur projecten. Uiteindelijk dient zo'n databank om de resultaten van infrastructuur projecten te verbeteren en te komen te betere inzichten in de totstandkoming van succesvolle projectuitkomsten.

Het doel van dit interview specifiek is om te verkennen welke vormen van dataregistratie er momenteel plaatsvinden en aan welke voorwaarden een databank zou moeten voldoen om tegemoet te komen aan de behoeften van de mensen in het veld.

Spelregels/voorwaarden

De duur van het interview is ongeveer een uur en zal semigestructureerde aanpak hebben. Gegeven antwoorden zullen anoniem en vertrouwelijk behandeld worden, in zoverre dat zij in publicaties niet te herleiden zijn tot de persoon. Ter controle hierop zal ik een uitwerking van dit interview toezenden alvorens de antwoorden te gebruiken voor onderzoeksdoeleinden. Van de interviews zal ik, mits u daarmee instemt, een geluidsopnamen maken zodat ik me tijdens het interview optimaal kan focussen op het vraaggesprek en op een later moment het interview kan uitwerken. Indien gewenst kan de geluidsopname in overleg en na uitwerking vernietigd worden.

Vragen

A. Achtergrond en persoon – 5 min

A1   Kunt u kort aangeven bij wat voor een werkgevers u zoal gewerkt heeft en welke werkzaamheden u daar verricht heeft?

A2   Kunt u kort aangeven welke rol u bij uw huidige werkgever binnen infrastructuurprojecten vervuld?

Welke opleiding(en) heeft u genoten?

Hoeveel jaar werkervaring heeft u?

Bij wat voor een soort projecten bent u gedurende uw loopbaan zoal betrokken geweest?

B. Algemene visie op dataregistratie en kennisontwikkeling – 5 min

B1   Wat zijn uw eerste gedachten bij een databank voor Nederlandse infrastructuurprojecten?

Waar komen deze gedachten vandaan? Waar zijn ze op gestoeld?

C. Huidige registratie en toepassingen daarvan – 10 min

C1   Welke informatie en data van projecten registreert u momenteel van projecten?

Bij niets: Doorvragen naar trimester/kwartaal reportages en/of projecten database?

Evt doorlussen naar wat aannemers registreren.

C2   Welke informatie en data wordt er door de uw organisatie over de verschillende projecten momenteel geregistreerd?

C3   Hoe waardevol vind u deze geregistreerde gegevens?

C4   Maakt u persoonlijk, dus voor uw projecten, gebruik van deze vastgelegde data?

Indien ja: met welke doelen?
Indien nee: waarom niet?

C5   Waarvoor wordt deze vastgelegde data in algemene zin, dus binnen het bedrijf of de dienst waarvoor u werk, gebruikt?

C6   Op welke wijze probeert u lering te trekken uit eerdere activiteiten? (en te voorkomen dat "het wiel" iedere keer opnieuw uitgevonden wordt?)

> *Indien referenties ex-ante: Hoe kom je hieraan, wat weet je dan van een referentieproject en in welke aspecten van een referentieproject ben je geïnteresseerd?*
>
> *Indien evaluaties ex-post: Wat bespreek je van je project en hoe maak je concreet wat je zelf mee wilt nemen en mee wilt geven aan team/OG voor een volgend project?*
>
> *Indien niets: vragen naar activiteiten voor een project en evaluatie na een project.*

D. Vorm en doel nieuwe databank – 10 min

D1   Stel u zou mogen bepalen wat er in een databank bijgehouden moet worden, wat zou u dan registreren?

Wat zijn uw redenen om specifiek deze gegevens vast te leggen?

D2   Wat zou er vooral niet in uw databank moeten worden opgenomen?

Om welke reden vindt u dat?

D3   Waarvoor zou u uw databank zoal willen gebruiken?

D4   Wat is voor u een belangrijk voorwaarde om gebruik te maken van een databank?

D5   Wie zouden er volgens u toegang moeten hebben tot een dergelijke databank en voor welke doelen mag men deze data gebruiken?

> *Erop sturen dat zowel gedachten over toegang OG, projectteam en wetenschappers de revue passeren.*

E. Proces en kennisopbouw – 10 min

E1   Wie zou volgens u de databank op moeten zetten?
> *En waarom?*

E2   Wie zouden de databank moeten vullen met projectdata?

> *En waarom?*

E3   In hoeverre ziet u het als u taak om bij te dragen aan de opbouw van kennis over projectmanagement binnen uw organisatie?

> *Indien onderdeel van taak: Op welke wijze geeft u hier invulling aan?*
> *Indien onderdeel van taak: Wat zou u ertoe aanzetten om het daadwerkelijk te doen?*

E4   Zijn er volgens u nog andere en meer effectieve manieren dan een databank om projecten succesvoller te maken?

E5   Wat denkt u dat een intensievere samenwerking tussen kennisinstelling, zoals de TU Delft, en publiek uitvoeringsorganisaties, als Rijkswaterstaat, gemeentelijke diensten en ProRail, kan betekenen om tot meer inzichten in projecten en hun verloop te komen?

E6   Wat is dan nodig om synergie uit deze samenwerking te halen?

F. Afsluiting – 5 min

F1   Heeft u nog een afsluitende vraag, suggestie of tip in het kader van dit onderzoek? Met andere woorden wat ben ik vergeten te vragen?

F2   Dit interview wordt momenteel afgenomen onder diverse projectmanagers en portfoliomanagers van ProRail en Rijkswaterstaat. Welke personen zijn volgens u ook interessant om over dit onderwerp te bevragen?

Outro

Een woord van dank voor de medewerking en nogmaals de procedure uitleggen: nadat ik het interview heb uitgewerkt zal ik het ter goedkeuring toezenden alvorens ik het zal gebruiken voor onderzoek. Indien geïnteresseerd kan de geïnterviewde zijn/haar interesse kenbaar maken voor het toezenden van het uiteindelijke onderzoeksverslag.

APPENDIX C – INTRODUCTION TO MIRT-PROJECTS

MIRT, is the Dutch abbreviation of Multiyear-program for Infrastructure, Spatial development and Transport. With MIRT, the Dutch government tries to improve the coherence and fine tuning of investments in spatial problems (Ministerie van Infrastructuur en Millieu, 2011b). The program is a collaboration of the ministries of Infrastructure and Environment, Economic Affairs and Interior and Kingdom Relations and tries to maximize the social value by addressing spatial issue from various perspectives. To increase social value and improve the spatial domain, it schedules and defines projects and their required financial investments. As such, MIRT can be considered as the spatial investment program of the Dutch government, which amongst others includes all construction projects in the national highway and railroad network.

MIRT as a program is made up of five different elements; administrative consultation, area agendas, MIRT Research, MIRT project book and MIRT's rules of the game. The first three elements, are meant to formulate spatial ambitions and might lead to the initiation of projects via the MIRT procedure. To start the MIRT procedure, explicit political decision making is required. The way in which the MIRT procedure has to take place is laid down in MIRT's rules of the game. The start of the procedure automatically leads to the initiation of a project and from then on the project will, up to its completion or break off, be included in the MIRT project book. The MIRT project book is a yearly publication in which the progress and expectations of all projects in the MIRT procedure are described. As such, the project book is an annex of the state government budget.

Once a project is in the MIRT procedure, it will run through three different phases. As shown in Figure 29, the continuation of a project from one phase to another is explicitly organized by four decision making moment; the start decision, the preferred decision, the project decision and the hand over decision. The aim of these decision making moments is to justify the work that is done in the previous phase and make clear how the project will develop in the next phase. For each decision making moment a certain information profile needs to be composed before the minister or secretary of state can take a decision and continue to a next phase.
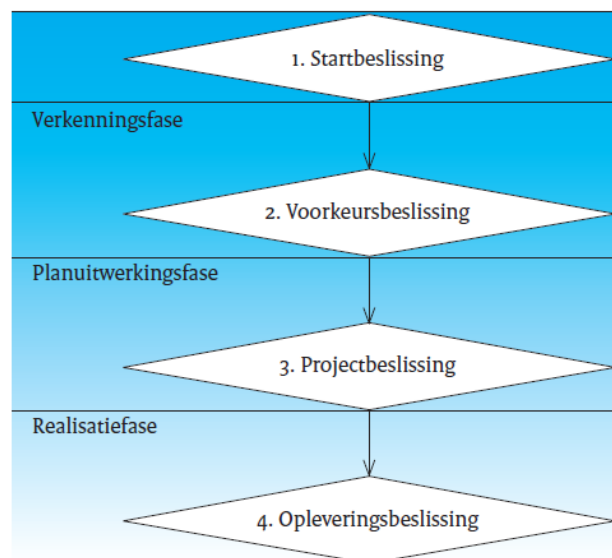

Figure 29 - Arrangement of the MIRT procedure(Ministerie van Infrastructuur en Millieu, 2011b)

The start decision, is the formal initiation of the project. On basis of the formulated ambitions, the project team will start to design and investigate possible solutions in the explorative phase. Often various solutions and alternatives

will be developed which after analysis and comparison will lead to a preferred alternative. The decided alternative and a motivation for that choice is then communicated to the parliament. The preference decision is the first moment in the project life cycle in which the scope, a task setting budget and a planning are explicitly mentioned.

In the second phase, the planning phase, the design will be further developed towards a definitive scope and design. For both, the national rail and road projects, a main activity in this phase is the hosting of participation with stakeholders and the environment according to conditions that ensue from the route law[15]. The basis for interaction is the draft route decision which has to be delivered by the project team. After the participation period and the processing and implementation of the reaction, the final route decision will be made. This route decision which is required for the route law (which is only applicable for the construction or extension of national roads, rail and waterways) coincides with the project decision required for the MIRT procedure (which is applicable for all projects in the spatial domain). The essence of the project decision is that a final impression of the planning, scope and budget is presented before the market will be approached in the realization phase. In practice however there is a tendency that market parties are contracted before the definitive route decision has been taken in order to speed up the project.

In the realization phase, a contracting party is searched and execution starts. Important to note is that the procurement procedure is likely to lead to changes in the budget and planning, on basis of the contracted financial sum and planning. Throughout the realization phase it becomes clear if the project can be realized according to the expectations that are laid down in the contract. In many projects (small) changes to contract need to be made as the circumstances and conditions as described in the contract appear to deviate in practice.

After completion a last decision has to be made, the hand over decision. The decision is mainly based upon the final financial statement and a final report, that justifies and elaborates on the realization process, the realized scope and the project course through time. It is worth noting that the hand over decision only discussed the project output, as it is not yet possible to draw conclusions on the outcome and impact of the project. Like the other decision also the last decision is reported to the parliament. For more detailed information on the MIRT procedure, we refer to the Ministerie van Infrastructuur en Millieu (2011b). The Route law (Maij-Weggen and Alders, 1993), can be approached via de website of the Dutch government.

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[15] **Tracewet**

APPENDIX D – CONFIDENTIAL CASE STUDY RESULTS

This is the public version of the report