Faculty of Civil Engineering
Department of Design and Construction Processes
Master Thesis

Information Management by the contractor in a
Best Value context

Using Data Warehousing techniques to present the Performance Information of
a contractor

Master Thesis

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<td>Amsterdam Information Management</td>
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<tr>
<td>BV</td>
<td>Best Value</td>
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<td>BVP</td>
<td>Best Value Procurement</td>
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<td>COR</td>
<td>Coaching and Observation Round</td>
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<td>CIM</td>
<td>Contractor Information Management</td>
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<td>DB</td>
<td>Data Base</td>
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<td>DW</td>
<td>Data Warehouse</td>
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<td>EMAT</td>
<td>Economically Most Advantageous Tender</td>
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<td>GWW</td>
<td>'Ground-, Road- and Waterworks'. GWW is the Dutch term for the building industry which includes the construction of amongst others Bridges, Dikes, Canals, groundwork’s, Dredging, Hydraulic Engineering, and Road Construction</td>
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<tr>
<td>IM</td>
<td>Information Management</td>
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<td>IF</td>
<td>Injury Frequency</td>
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<td>KPI</td>
<td>Key Performance Indicator</td>
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<td>MIP</td>
<td>Management of Information Provision</td>
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<td>Project Action Plan</td>
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<td>Performance Data</td>
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<td>PIPS</td>
<td>Performance Information Procurement System</td>
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<td>RAVA</td>
<td>Risk Assessment and Value Added plan</td>
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<td>RWS</td>
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<td>SE</td>
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PREFACE

All my life I have been interested in the large infrastructural network in both the Netherlands and other countries. In September 2009 this interest resulted in starting my education to become one of the engineers graduating from Delft University of Technology. Today I am proud to write the preface of the final document to bring this six and one-half year track at Delft University of Technology to a conclusion.

The past seven months of my life represent a period in which sheer commitment, ups and downs, and hard work have led to the results presented in this document. This document contains the graduation research which I have conducted with great pleasure at Mobilis. This thesis is part of the MSc track ‘Construction Management and Engineering’ of the Department of Design and Construction Processes at the faculty of Civil Engineering and Geosciences of Delft University of Technology.

I could not have completed this track without the help, input, and steering received from many people. In particularly I would like to thank my committee from the TU Delft for all the support and criticism received over this period. I would like to thank Sicco for his knowledge, open mind, criticism, and challenging me to go beyond the ordinary; Marian, for her expertise on researching methods, positive attitude, criticism, and helpful behaviour; and Leon, for his knowledge, criticism, and supportive behaviour.

From Mobilis I would particularly like to thank Carlita for being my company supervisor as well as being part of my committee. You have been actively involved in this research and your positive attitude, criticism, and open minded view have provided me every opportunity to develop both personally and educationally. I also would like to thank all the colleagues at Mobilis for creating a warm and positive working environment and especially the interviewees for providing relevant input to this research.

Furthermore I would like to thank my close friends, girlfriend, parents, brother and sister, and family for supporting me over this period and providing me with the ability to discuss the subject matter in order to improve the content of this document.

Tijl de Jonge
May 2, 2016
Lately more and more clients in the Dutch civil engineering contracting industry consider the use of past performances as a project award criteria during tenders. Best Value Procurement which uses this method has been adopted by Rijkswaterstaat who is the biggest client in the Dutch civil engineering construction industry. Best Value Procurement requires the contractor to prepare tender documents showing the contractors ability to reduce risks, optimize the project by exploiting all possible opportunities, and providing relevant evidence that the contractor is most likely to successfully realize the project. This evidence is named Performance Information and is based upon delivered performances of the contractor. This change in contracting however requires the contractors to reuse the data generated while realising projects.

Unfortunately collecting this evidence or Performance Information proves to be a difficult task for contractors. This mainly results from the fact that this Performance Information should be gathered from multiple places within the organization. Determining these places or documents is difficult due to the fact that the structure and the content of these documents differ from each other resulting in difficulties to collect the Performance Information. Although contractors do succeed in transforming project data into Performance Information there is still room for improvement.

The increasing pressure to structure the project data as well as to analyse this project data requires the contractors in the Dutch construction industry to no longer approach this project data as a separate aspect of the organization. It becomes increasingly important to treat project data as an asset of the organization. Approaching project data as an asset of the organization requires the contractor to integrate Information Management within the organization. Mobilis who is a contractor in the Dutch civil engineering construction industry decided to allow a research in order to determine how Performance Information is currently used at a contractor and to determine the possibilities of Information Management processes at a contractor. This research therefore looks at the relation between Information Management and Performance Information.

All over the world so called information technology departments are implementing Data Warehouses as a method to transform data into relevant information. In this research it is therefore assumed that Data Warehousing techniques could be the solution to the Information Management issue contractors are currently having to deal with. The Data Warehousing techniques suggest to approach the situation by firstly analysing and map the project data. Secondly rules to determine which project data is to be considered as Performance Data should be created after which the project data can be transformed. Thirdly the transformed Performance Data, or now to be called Performance Information, should be presented somewhere accessible. Last but not least the Performance Information can be used in the tender documents.

According to the literature organizations often tend to implement bottom-up approaches in order to understand their performances. This behaviour is also noted at Mobilis. This approach is used to trace the Performance Information which is directly available which is often highly appreciated by the contractor. Although this approach is often used it is not recommended by the literature as it often results in a time consuming process with a high risk of failure to determine which Performance information can be found within the project data. It is recommended that the contractor firstly determines which Performance Data is ought to be relevant before trying to collect it.
Approaching the project data without a clear query indeed resulted in a very time consuming process without clear results. Due to the diffuseness of the project data it was not possible to determine which Key Performances showed up regularly within the project data. Although it was possible to compare documents created in different projects no clear similar structure in the project data were discovered. According to the interviewees the project based organizational structure of contractors can be used to explain this issue. Contractors often tend to organize departments and personnel around projects resulting in small 'organizations' working separately from the other projects. A direct result is that Information Management is being applied in the projects rather than being applied over all projects. The overall result is the fact that Key Performances in each project are different.

Having to deal with separated small 'organizations' also causes project data to be inaccessible. This is however to be explained by the sensitivity of the project data since not everyone may (competition) work with the documents created in projects. Nevertheless this approach results in tender teams having to perform the same query over many different projects in order to determine whether the needed Performance Data to create Performance Information is available or not. Incomplete Performance Data results in not being able to transform the project data since the input is missing.

One of the key solutions suggested by the Data Warehousing techniques for this issue is to embed clear rules regarding which information is important and gather information on these aspects. Key Performance Indicators allow a contractor to structure and determine the most crucial performances of both the contractor and the client. KPIs should be determined on the highest level within the organization and should be embedded within all processes of the contractor. These KPIs could be used create the predetermined information queries which can be used to gather Performance Data. Performance Data represents the data on a single indicator generated while executing projects.

Using Key Performance Indicators as a means for Information Management should be approached as if they are award criteria of the client. The contractor should approach each delivered project and actively seek for all Performance Data resulting from expressing the KPIs in measurable indicators. Extracting this Performance Data from the projects and storing them somewhere retrievable and accessible is the first step towards efficiently creating Performance Information. Introducing a general 'Plan for KPI Measurement' into every project could prevent incomplete Performance Data from occurring by measuring the same KPIs in every single project. Embedding this within every project being executed allows the contractor to generate a constant flow of specific, time stamped, accurate, verifiable, non refutable, and consistent Performance Data. The KPIs should be measured according to a regular interval and kept track off.

Last but not least it may occur that the award criteria of the client requires additional Performance Information to be used as input for the tender documents. It could therefore occur that the Key Performance Indicators do not cover this request by the client. Therefore it is advised to also create a platform where all project data which possibly contains Performance Data can be found. This platform should be accessible by everyone but should not contain edible documents to prevent the 'sources' to be changed. This platform should therefore contain viewable project data only. It is recommended to analyse the document output from the quality management system in order to make a 'document selection list' showing which documents contain Performance Data. Storing these documents according to subject should allow efficient analysis of these documents.
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PART A: INTRODUCTION

This part of the research describes both the introduction as well as the methodology of this research.

Chapter 1, the first chapter of part A is used to explain the context, problem, objective, and research question of this research. Topics in this chapter are amongst others the Dutch construction industry, Best Value Procurement, competition and differentiation, Information Management, performances, and data.

Chapter 2, the second chapter of part A is used to explain the methodology used in this research. In this chapter a general approach is explained as well as the phasing used in this research. The relationship between the phases and the supportive research questions are sketched in an illustration.
1. INTRODUCTION

Up to the year of 2001 the Dutch civil engineering contracting industry has characterized itself as a conservative industry in which the price of construction often used to be the leading and dominant award criteria for large civil engineering projects. On November 9th, 2001, the national Dutch television station VARA/NPS with its program Zembla revealed shocking evidence in their broadcast ‘Sjoemelen met miljoenen’ that the biggest construction contractors in the Netherlands had been secretly increasing the prices of projects by an average of 8.8% (Braak & Berg, n.d.). On February 5th, 2002, a parliamentary inquiry towards the extend of this fraud in the Dutch construction industry was conducted as a result to this broadcast.

On December 12th, 2002, the committee presented its final report which showed that the extend of the fraud was in fact huge and proved that a fraudulent process had been taking place. In total 344 Dutch contractors where guilty of committing fraud (OM, n.d.). Several hundreds of millions euro's were lost due to these illegal price arrangements and often the prices increased by 10% to 50% (Dorée, 2004). The total extend of the fraud could never been determined and has never been revealed. One of the recommendations resulting from this inquiry was to redefine the tender procedures and let the awarding criteria 'lowest price' only be appointed to standard works.

This chapter firstly elaborates the change in tender procedures as a result to this parliamentary inquiry. The most obvious difference between the tender procedures are the awarding criteria used. Changing these procurement types and thereby introducing new awarding criteria require contractors to use a different approach while tendering. These changes lead up to the problem definition of this research.

1.1. CHANGES IN PROCUREMENT TYPES

1.1.1. PRICE COMPETING CONTRACTS

Price competing contracts as executed in 2001 are characterized by the following procedure: Design and Bid after which the selection of the vendor is based upon the lowest bid (Duren & Dorée, 2008, p. 2). Even though changes were issued in this procurement method over 80% of the projects were still based upon this method in 2008. This procurement method in which there is a heavy competition on price is mentioned as a bottleneck by over 80% of the Dutch contractors (Rijt, Hompes, & Santema, 2010, p. 42). Contractors are either forced to make unrealistic offers or cannot change execution methods. These price competing contracts therefore often results in conflicts between the client and the contractor regarding the quality (value) of a project (Ridder & Noppen, 2009, p. 12). The quality delivered at the end of a project is often not what the client expected it to be. Obtaining the expected quality is often achieved by additional costs resulting in cost overruns of the project. These procurements are often characterized by a client who hires all necessary actors in order to thoroughly specify a project including costs, quality, and appearance (Duren & Dorée, 2008, p. 2) as a set of project requirements. Generally these actors include designers, engineers, and specialists.

By hiring all these actors and preparing a highly elaborated contract the client takes away the opportunity for the contractor to propose alternative solutions. This conservative procedure results in a contractor who is only able to tell the client what they are likely to charge (offer based on price) which results in price competition (Duren & Dorée, 2008, p. 2). After all offers are submitted the client selects the contractor who
may deliver the project. The price based tender process is visualized in Figure 1 where the client is seen at the left, and the contractor on the right.

![Diagram of price based tender process]

**FIGURE 1 - GENERAL PROCESS IN PRICE BASED CONTRACTING (OWN ILL.)**

The main conflict in this procurement approach is the different interest which both the client and the contractor have. Duren and Dorée (2008, p. 2) describe this process as:

“The client tries to force the contractor (who may lack the opportunity to utilize the latest know-how and experience) to act in a particular way, while the contractor tries to make a profit despite the low margins due to the lowest price selection. This means the contractor actively seeks opportunities to charge for extra work. In other words, in this contractual arrangement there is no alignment of goals; the relationship has more to do with competition than cooperation. This leads to cost blowouts, delays and dissatisfaction for both client and contractor”

One of the recommendations by the committee and resulting from the parliamentary inquiry suggested to no longer use this procedure for all tenders. A slow progress towards new innovative contracting methods started which eventually resulted in the Economically Most Advantageous Tender (EMAT). Although changing an industry which has proved to work for years proves to be a difficult task it is sometimes necessary to change current methods in an ever changing environment (Ridder, 2011).

1.1.2. **Economically Most Advantageous Tender**

In the Dutch construction industry one of the more effective changes towards interrupting the dominance of this price competing industry is a procedure called ‘Economically Most Advantageous Tender’. In the EMAT the selection of the contractor is no longer solely based upon the price. In this tender procedure the client puts a heavy burden on the elaboration of the contractor showing how the contractor is able to deal with e.g. the economic and environmental interests of the client. In the EMAT the contractor is asked to prepare tender documents in which the contractor elaborates their reaction on the award criteria of the client. Besides these tender documents the contractor also prepares a price offer. Clients of the Dutch construction industry are obliged to maintain a ‘EMAT, unless’-principle (CROW, n.d.) which states that many of the contracts put in the market are tendered using an the EMAT principles.

During the Economically Most Advantageous Tender a proper elaboration of the methods used can result in a fictive discount. This fictive discount is subtracted from the price resulting in a fictive price \((price - discount = fictive\:\text{price})\) which is assessed. This discount can vary anywhere between 0 and 100% of the total price, based upon the wishes of the client (Strand, Ramanda, Canton, & al., 2011). The purpose of the EMAT is to allow the contractor to have some influence in the earlier stages of a project as well as to generate more value for money (Rijt & Santema, 2013). Although the EMAT shows potential it is still based upon a strange principle where the client creates elaborated designs and thereby tells an expert what to do. Significant cost savings, time reduction and quality increase could be possible when the client accepts to have less influence in the early stages of the project Kashiwagi (2011).
The process used in the Economically Most Advantageous Tender is visualized and compared with price based tenders in Figure 2.

![Figure 2 - General Process in Economically Most Advantageous Tender (Own Ill.)](image)

1.1.3. **Best Value Procurement**

Many publications lately consider the use of *past performances* as an award criteria (Duren & Dorée, 2008, p. 2). One of the leading author and researcher in these procurement procedures is prof. dr. Dean Kashiwagi who promotes an approach called the *Performance Information Procurement System* or PIPS. PIPS is nowadays in the Netherlands known as the *Best Value approach* or *Best Value Procurement (BVP)*. BVP is designed to optimize this process by allowing the expert (contractor) to predict the outcomes. Kashiwagi (2011) claims to have phenomenal results in over 1,500 projects totalling nearly $4.0 billion. These results are achieved in both project performance and client satisfaction (up to 98%). The Best Value methods makes use of the knowledge of the contractor and effectively reduces the selection period of tenders from an average of 16 months towards 4 to 6 months. Besides this the average cost of tendering is reduced by 25-30%. In addition to this the quality of the project increases - "The quality goes up, and the price goes down" (Santema, 2012).

The Netherlands are the second in line considering the use of Best Value Procurement. In 2009 Rijkswaterstaat has decided to bring 16 infrastructural projects totalling nearly €600 million ($800M) to the market as BVP projects (Rijt & Witteveen, 2011). These projects are the start of a new procurement era in which ‘accountability’ is a key word along many projects. BVP is based upon eliminating the flaw where a 'blind' client tries to act as an expert and causes confusion and limits the possibility of an expert to act as an expert. BVP makes use of four phases in this process which is shown in Figure 3.

![Figure 3 - Phases in Best Value Procurement (Rijt and Santema, 2013, p.43).](image)

In Best Value Procurement the contractor is asked to prepare *tender documents* just like in the Economically Most Advantageous Tender as well as a price offer. Nevertheless, the tender documents in BVP differ from the tender documents in the EMAT. The biggest change is noted when contractors are no longer asked to completely...
elaborate plans in tender documents. Therefore only the tender documents are discussed in this research. In BVP contractors are asked to deliver dominant Performance Information (PI) regarding the risks, optimization, and the opportunities in a so called Risk Assessment en Value Added (RAVA) plan. This dominant PI should undoubtedly show the contractors ability to reduce risks, optimize the project by exploiting all possible opportunities, and providing relevant evidence that the contractor is able to construct the project within the boundaries (context) given by the client. This PI, or evidence, should be based upon delivered projects of the client. Figure 4 visualizes the Best Value process where PI is the input for tender documents.

In this process it is the intention of the client to actively seek for dominant Performance Information pointing towards the most suitable contractor. The goal is to eliminate contractors who have shown incompetence in the past and increase the overall performance of the projects (Kashiwagi, 2011, pp. 3-1/2). To make sure that the contractor is speaking the truth in-depth interviews are conducted which are often the most weighted criteria (Rijt & Santema, 2013, p. 56). If in this selection process no dominant PI is to be found amongst the contractors, the selection will be based upon the lowest bid (Rijt & Santema, 2013).

For a contractor to deliver dominant Performance Information regarding the award criteria of the client it therefore becomes increasingly important to understand their performances. Dominant PI provided in the tender documents should be based upon knowledge derived from past performances of the contractor. According to Rijt and Santema (2013, p. 70) dominant information must be:

- Non refutable;
- Verifiable;
- Accurate;
- Measurable in numbers, percentages, and time;
- Relevant to the project

Multiple non-official articles have appeared over the internet in which sceptics criticize the Best Value processes (Heijden, 2013). Sceptics state that the Best Value Procurement suppresses the possibilities for a contractor to use innovative working methods because they will be unable to show relevant Performance Information showing that the innovative working methods will work. Besides this the Best Value processes are according to sceptics similar to existing methods using a qualifications-based selection procedure. These articles for instance claim that contractors are currently not...
ready for this change since these organizations are not set to managing information on this scale. This procurement type is therefore, according to these articles, meant for organizations which are more developed with respect to Information Management (IM) (Heijden, 2013). Besides this BVP can be very confusing for contractors as unclear demands and unclear procedures are taking place.

1.2. COMPETITION REQUIRES DIFFERENTIATION

A common factor in the procurement types as mentioned in the previous paragraph is competition. The leading author in competition amongst organizations is Michael E. Porter. According to Porter (2008) competition is the beating heart of every organization and activates organizations. Kashiwagi and Massner (2002) agree that competition is an important aspect in the current construction industry and forces contractors to constantly improve themselves. Competition contributes to the overall performance by having to create innovative solutions to problems, creating a cohesive culture, and an overall proper implementation of the current working methods. Besides this the ability of an organization to put their strategies into practice and control the performance output from this process is tested (Porter, 2008).

The construction industry is characterized by many organizations willing to profit from the same projects. The changes towards more performance based procurement types such as Best Value Procurement requires the contractor understand their performances by keeping track of their data and information. By doing this the contractor is able to provide dominant Performance Information of the past years. Differentiation is mentioned by Porter (2008) as one of the generic strategies to create a competitive advantage on any market. Creating a differentiation strategy requires to determine the core values of the contractor and gather dominant Performance Information on (Porter, 2008). In Best Value core values are often referred to as Key Performance Indicators (KPI).

For a contractor to be able to have a differentiation strategy means being able to understand the performances of the organization and properly analyse and present these to the tender teams. Having a generic strategy which lays it focus on differentiation means that the contractor should actively seek in their data to present their dominance in the market. According to Duncan, Ginter, and Swayne (1998) this data cannot directly be used and requires a systematic method to collect and evaluate. The Carnegie Mellon University has conducted a series of researches towards managing data and state that the following processes are needed to be included before this data can be used while tendering (Krishnan, 2013):

- Organizing the data;
- Acquiring the data;
- Storing the data;
- Retrieving the data;
- Managing the data.

Unfortunately creating a differentiation strategy and thereby needing to manage data is not a new topic but it is something of which many organizations have lost their feeling with (Porter, 2008). If a contractor is willing to embed a differentiation strategy within the organization it becomes increasingly important to embed Information Management techniques within the organization.
1.3. **Problem Analysis**

Progressive focus of the clients in the Dutch contracting industry towards performance based contract types such as Best Value Procurement requires contractors to use different approaches than used in price based contractors or the Economically Most Advantageous Tenders. The biggest changes are noted when contractors are asked to use data and information resulting from already delivered projects in the tender documents.

Many contractors in the Dutch construction industry are currently driven by one factor, which is: *to win and build as many projects as possible*. This can be noted from the project based organizations where personnel and departments are situated around projects. Once a project is successfully realized the personnel is transferred to a new project. Being focussed on winning tenders and realizing projects has resulted in the classic phenomenon as described in paragraph 1.2. The contractors lose sight of the importance to create and uphold a differentiation strategy in order to determine which performances are delivered or should be delivered by the contractor. In Best Value Procurement these performances are the selling point of the contractor.

Dominant Performance Information as presented by the contractor should at all time be *non refutable, verifiable, and measurable in numbers*. Rules regarding the current processes used to create this dominant PI are undefined resulting in inefficient transformation of the available data. An Information Management process to help create a differentiation strategy could therefore provide relevant insights in presenting the core performances of a contractor.

Unfortunately many differentiation strategies regarding Information Management consist of complex solutions such as restructuring the organization or embedding complex software which are difficult to implement in contractors. A non-complex solution with quick wins as well as a solution which is able to be implemented in the current systems is ought to be most useful.

1.3.1. **Relevance & Limitation**

Several researches towards the core values of contractors have provided general methods to determine the Key Performance Indicators of contractor. Unfortunately no researches have provided clear rules regarding the Information Management processes needed to transform project data into dominant Performance Information. Besides this no researches have been performed towards which data is to be collected as well as to determine how a contractor can embed these IM processes within the organizational structure are yet to be researched.

Therefore the scientific relevance of this research is to determine if it is possible to embed an Information Management process to a contractor in the Dutch construction industry. The goal of this IM process is to transform project data into Performance Information. The practical relevance of this research is to increase the overall use of PI under contractors.

A major limitation of this research is linked to the organizational structure of the organization. This research is performed by using the contractors perspective. A contractor is a project-based organization in which departments and personnel are organized around a specific project. Being a project-based organization results in data being generated at projects. Therefore this research is limited by project based organizations. Data resulting from realizing projects is from now on called project data.
1.4. PROBLEM FORMULATION

Many contractors in the Dutch construction industry cope with the same problem as the request from the client is changing towards procurement types where Performance Information is required. General information regarding which Key Performances could be analysed is available. However, which project data contains relevant information on these Key Performances remains rather vague.

Performance Information as required by the tender teams and to be used in the tender documents results from transforming project data. This project data results from delivered projects of the contractor. These projects are a combination of different types of works as well as a combination of different clients. Although contractors succeed in transforming project data into dominant PI these processes are often unstructured resulting in inefficient processes taking place. The processes in order to *transform* project data and to *store* the transformed project data therefore remain rather vague. This problem is formulated as: *efficiently transforming project data into Performance Information.*

Figure 5 illustrates the problem formulation as mentioned above. In this figure the delivered projects by the contractor represent a set of diverse project types (water works, rail works, etcetera) as well as projects with different clients (ProRail, Rijkswaterstaat, etcetera). The problem as formulated is indicated by the red arrow.

1.5. RESEARCH OBJECTIVE

The main objective of this research is to identify how a contractor can efficiently transform project data in Performance Information in order to reuse in future tender processes. Supportive research objectives are formulated in the beginning of each part in the research. Reaching all objectives eventually results in reaching the main research objective. In the end of the research a proposition is made on how a contractor can manage their use of Information. The ultimate objective of this research is to determine how the gap between the delivered projects and the tender documents to be created can be filled with an efficient process.

In order to reach this research objective this research is therefore performed at a contractor in the Dutch construction industry. Mobilis who is part of the overlapping TBI contracting group offered a position to perform this research. Mobilis is a contractor in
the Dutch construction industry who aims at finding relevant solutions to situations regarding infrastructural works, water works, and industrial works. Mobilis upholds a sustainable and transparent working relation with their clients while realising projects regarding these topics.

1.6. **Research Question(s)**

In order to reach the objective as defined in the previous paragraph this research uses a main Research Question (RQ) and Supportive Research Questions (SRQs) in order to give structure to the Research. Once the SRQs have been answered it is possible to answer the RQ. By answering the SRQs it is possible to approach the research in a structured way.

1.6.1. **Research Question**

Combining the previous paragraphs provide the following Research Question (RQ):

*RQ: How could a contractor efficiently transform project data into Performance Information to be used in future processes?*

1.6.2. **Supportive Research Questions**

The main research question is separated into SRQs which function as a guide for the research during the different stages. The following SRQs are formulated:

- **SRQ1:** What processes could help a contractor to transform Project Data into Performance Information?
- **SRQ2:** How is Project Data currently used and embedded within the structure of Mobilis?
- **SRQ3:** How could the theoretical framework and the empirical findings be integrated in order to make Performance Data available and accessible and thereby help the tender teams of Mobilis produce Performance Information needed in the tender documents?
2. METHODOLOGY

This chapter discusses the research methodology used in this research. At first an explanation for the choice of methodology is given after which a more detailed is provided. At the end of this chapter a visualization of the research methodology and the link between the methodology and the Research Questions are given.

Before starting this chapter two things have to be made clear. At first the viewpoint of this research is that of the contractor. Although several process of the client are discussed the focus of the research is on the process which takes place at the in order to react on the request of the client. Secondly, this research takes place in the scientific field called Process Management. A closer look will be given to the methods available to transform Project Data into Performance Information. The process needed for this transformation are discussed in relation to the organizational structure.

2.1. METHODOLOGY

The methodology of this research is inductive in nature. The core of this research is based upon qualitative data and empirical observations. Likewise most researches this research contains amongst others the collection of data and formulating a possible solution for the problem definition. This type of research is often based upon document analysis, interviews, observations, and case studies is called a qualitative research. Besides this it is chosen to use a method which not only lays its focus on the theoretical aspects but also has much interaction with the practical issues.

This research aims at presenting solutions to be used by contractors in the end. Conducting a research in which a solution is produced by using the input over and over again in order to make the solution more optimal is described by Dubois and Gadde (2002, p. 556) as systematic combining which is described as "a nonlinear path-dependent process of combining efforts with the ultimate objective of matching theory and reality". Verschuren, Doorewaard, and Mellion (2010, p. 24) call this technique an iterative process which they define as:

"The design approach we support is an iterative process. The notion of iteration stems from mathematics, in which iteration means that the result of a calculation is taken as the input for a second set of calculations. This process is to be continued until the final calculation no longer leads to recognizable changes in the calculation results. In that case the calculations converge. In everyday language we would say that the design has been fully crystallized out. In terms of the design, iteration means that the designer must constantly switch from the one part of the design to the other. Each time, he or she reconsiders the consequences that the provisional decision concerning the one part will have on each of the other parts of the design to be. That is, both the parts that are still to follow, and the parts that have already been designed must be adapted if necessary. This process stops as soon as an adjustment does not have recognizable consequences for any of the other parts of the design." Verschuren et al. (2010, p. 25)

The goal of this research is to find a solution which is possible to implement at the contractor without being too complex. This iterative process is combined with the engaged scholarship (diamond) research model of ( Ven, 2007) which takes into account the Theory building, the Reality, the Solution, and the Model. Products are often developed together with the relevant stakeholders or end users which provides an end
product with a high probability to be possible to implement. Interviews with the key people of Mobilis are therefore included in the research.

2.2. Phasing
This research can be divided into five parts which interact throughout the entire research. The first part is designated to introduction, the problem formulation, and the research questions. The second part describes the literature study. This phase compares several theories and methods on topics such as Information Management, Data Warehousing, Performance Information, and Key Performance Indicators. This phases is used to create a Theoretical Framework which is used in the parts following this part. The goal of Literature study is to create the Theoretical Framework for this research.

The third part is used to determine the current practices of Mobilis regarding Information Management. Interviews and case studies are used as research methods. Several interviews and case studies are conducted in order to determine the current practices taking place at Mobilis. The interviews are structured according to the Information Management theories. The goal of the Empirical study is to determine the ways how Information is currently managed at Mobilis.

The fourth part is used to integrate both the findings in the literature study and the empirical study. Possible issues are addressed and solutions are proposed. The goal of the integration phase is determine points of attention in the Theoretical Framework.

The last part serves as the phase in which the Research Question is answered. The discussion points out the points of attention, the conclusions are used to answer the RQ and the SRQ's, the recommendations point out possibilities for further research and points for Mobilis to take a closer look at, finally the reflection gives my personal view on the research. The goal of the Conclusion phase is to derive recommendations and conclusions from all previous chapters as well as answering the Research Question.

Figure 6 visualizes the parts as 'phases' in the research.

![Figure 6 - Phases and Interfaces of the Research (Own Ill.)](image-url)
PART B: LITERATURE STUDY

This part of the research describes the literature study which is used to form the Theoretical Framework. This part is divided over three chapters with a common goal to answer the first supportive research question (SRQ 1) as formulated in paragraph 1.6:

**SRQ1:** What processes could help a contractor to transform Project Data into Performance Information?

Chapter 3, the first chapter of part B is used to explain the need for Information Management as well as methods to approach IM issues at a contractor. Topics in this chapter are Performance Data, Information Management, Data Warehousing, and the AIM model.

Chapter 4, the second chapter of part B is used to elaborate the proposed Information Management technique (Data Warehousing) in the context of Best Value Procurement and the contractor. Topics in this chapter are amongst others Data Warehousing, and Key Performance Indicators.

Chapter 5, the third and last chapter of part B is used to combine the conclusions from chapter 3 and 4 and thereby answering the first Supportive Research Question. Chapter 5 is also used to create the Theoretical Framework which is used to approach the Research Question.
3. INFORMATION MANAGEMENT

3.1. INTRODUCTION

The introduction of Best Value Procurement in the Dutch GWW industry has resulted in a recognizable need for contractors to manage their information. This chapter discusses the need for Information Management at the contractors and the relation of IM to the Research Question. At first the importance to see IM as an asset within the organization is discussed after which Data Warehousing (DW) is introduced as a method to structure Performance Information of the contractor. Secondly the Amsterdam Information Management model (AIM) is introduced as a method to help positioning DW techniques within the contractor. The chapter is used as input for the Theoretical Framework.

3.2. INFORMATION MANAGEMENT AS AN ASSET

3.2.1. PERFORMANCES OF THE CONTRACTOR

Since the late 20th century organizations are increasingly understanding that data is a crucial part of making strategic decisions (Kelly, 1994). Unfortunately data collection has reached a point in which its scale is no longer manageable by the everyday user. In today's market this increasing pile of data is referred to as ‘Big Data’ to which the following definition is given to the word ‘data’:

Data: “Data represents the lowest raw format of information or knowledge” – (Krishnan, 2013).

As mentioned in chapter 1 a contractor is a project-based organization in which departments and personnel are organized around a specific project where data is generated. Appendix A shows this matrix structure. Combining this definition with the project-based organization forms the following definition for project data:

Project Data: “All lowest raw formats of information or knowledge generated while realising projects”

The decision of the client to change the current tender procedures towards Best Value Procurement has resulted in contractors becoming increasingly dependent on this project data. Project data is retrieved from various points within the organization and is often scattered throughout various types of documents, departments, units, people, and much more (Ahmad & Nunoo, 1999). This project data includes information on the performances of the contractor and should therefore be included in this research.

3.2.2. INFORMATION MANAGEMENT

Since the introduction of computers and especially since the late 70’s Data Bases (DB) have been used by most organizations. A DB is a storage system where the most essential project data is stored (Vaisman & Zimányi, 2014). DBs are used for day-to-day processes rather than for data analysis, evaluation, and decision making (Vaisman & Zimányi, 2014). For a contractor to understand their performances it is believed that this can only be achieved when the project data is properly valued and analysed Huang, Lee, and Wang (1999). Unfortunately DBs are not for today’s expectations of Information Management leading to new IM techniques to have emerged.

According to Huang et al. (1999) and (Ballard et al., 1998) Information Technology (IT) departments in all industries are implementing so called Data Warehouses (DW) as a means to transform data into readable Performance Information.
A DW arranges data into categories providing consistent chunks of PI which can be valued and analysed (Kimball, Ross, Thornthwaite, Mundy, & Becker, 2008). According to Vaisman and Zimányi (2014) a DW is the infrastructure of combining processes related to analysing data. A DW can help by (Ponniah, 2001):
- Provide an integrated overview of the organization;
- Making Performance Information available;
- Speed up processes;
- Present a flexible and interactive source of Performance Information;
- Increase the overall performances of an organization.

According to Ponniah (2001) the Data Warehouse includes the five required steps to create a differentiation strategy as indicated by Krishnan (2013) in paragraph 1.2. In order to apply DW techniques as a means for Information Management Kimball et al. (2008, p. 1.2), Ponniah (2001, p. 16), and Ballard et al. (1998) agree on the following fundamentals to be included:
- Source Data (identifying project data);
- Transformation (cleaning and structuring project data);
- Presentation (accessibility of Performance Information);
- Reporting (analysing).

Berardi (2011) visualizes a comparable Information Management process according to ‘filters’. This process is characterized by data being collected at the sources at first, is processed into information secondly, and thirdly is analysed. Determining a proper set of rules to this IM process applied to a contractor could help by presenting their Key Performance Indicators. The IM process of Berardi (2011) is shown in Figure 7.

![Figure 7 - Information Management Process (Berardi, 2011)](image)

3.3. **Approaching Information Management**

3.3.1. **The AIM Model**

Positioning the Data Warehousing techniques within a contractor is assumed to be possible by using the Amsterdam Information Management model (AIM) which allows a researcher to map the relationships between business processes and Information Management processes (Akker, 2006, p. 1). In Dutch this model is called the ‘negenvlaksmodel’ or ‘Nine Square framework’. The model is developed at the University of Amsterdam after it has been further enhanced by Rik Maes (Maes, 1999). The AIM
model is used to support strategic discussions and is mainly developed for IT Managers and architects (Akker, 2006, p. 2).

The AIM model is derived from the Strategic Alignment model from Henderson and Venkatraman which takes into account the interrelation between the business element and the IT element of an organization in a 2x2 matrix. The AIM model however extends this 2x2 matrix by adding the information element as well as looking at these three elements from a strategic, tactical, and operations perspective (Akker, 2006, p. 4). In this model Rik Maes balances the rational top-down approach with the practical bottom-up approach.

In the AIM model strategy is defined as the goal of an organization within the boundaries of the market, tactic is defined as the methods used and decisions made to reach the goal of the organization, and operation is defined as the operational field in which the methods and decisions made to reach the goal of the organization are brought into practical use (Akker, 2006, p. 4). The AIM model is used to help positioning Information Management issues on an organizational level (Akker, 2006, p. 8). It is therefore not used as a method to provide a solution, but used to get insight in the current practices regarding IM. The following figure shows the Management of Information Provision model which is a practical, filled in form of the AIM model in which the squares and links are specified to get a better feeling of the AIM model.

![Figure 8 - MIP Model Derived from AIM Model (Akker, 2006, p.11)](image)

**NOTE:** A point of discussion should be added to the MIP model discussed by Akker (2006, p. 11) as arrows are added to indicate a process flow. Operational limitations can for instance have an impact on the tactical decisions made but are according to this model not included in the discussion. When considering to use the MIP model it is advised to take a close look at each connection and analyse the flows taking place. Nevertheless the defined and specified squares and connections provide a relevant overview of the processes taking place.

### 3.3.2. Using the AIM Model

The AIM model puts focus on positioning Information Management related issues in one or more squares of the model. In theory each of the nine squares should therefore be
discusses as well as the relations between those squares (Akker, 2006, p. 6). In order to gain relevant insight from the AIM model is needed to approach the model in three steps, namely (Akker, 2006, p. 5):

1. The content of the squares;
   a. Which activities are carried out, who is responsible, what are the results (departmental approach);

2. The relationship of the squares;
   a. Discussion of the IT governance and provides overview of the current methods used;

3. The relation between Business <-> Information <-> Technology;
   a. What is the relation between Business <-> Information and what is the relation between Information <-> Technology.

3.4. CONCLUSIONS

Since Data Warehousing techniques are implemented in all industries it is assumed that these techniques can be used to address the problem as formulated in this research. It is assumed that DW techniques can provide a framework (or rules) for collecting project data, processing project data into Performance Information, and analysing PI in order to use in Best Value tenders. The DW can therefore be summarized as the place where project data of the contractor can be transformed into readable Performance Information. When correctly implemented a DW should provide PI which is:

- Clean;
- Structured;
- Accessible;
- Understandable;
- Usable.

Structuring the search for the most suitable ways to implement the Data Warehousing techniques can be approached by using the AIM model of Rik Maes. The AIM model helps by positioning Information Management issues on an organizational level. Positioning IM issues on an organizational level helps to determine the origin of the input of the 'filters' and thereby facilitates in determining how the filters can be created. Figure 9 visualizes the DW in the context of this research. This figure differs from Figure 5 by combining all delivered projects together and showing the context how projects are successfully delivered. It should not be mistaken that the ‘delivered projects’ square represents only 1 project. It represents multiple projects from multiple clients.

FIGURE 9 – DATA WAREHOUSING ASSUMED TO BE A POSSIBLE SOLUTION (OWN ILL.)
4. Transforming Project Data

4.1. Introduction

In 1995 the Data Warehousing Institute was founded with their main goal to distribute as much knowledge on Data Warehousing as possible. In 1996 in response to this institute Ralph Kimball, who is considered to be among the top players in DW technology, presented the book ‘The Data Warehousing Toolkit’ which is still used today. A Data Warehouse contains a series of technologies and processes to transform data into readable information. The goal of the DW is to improve decision making as well as providing a platform in which all Performance Information is stored according to pre-set subjects (El-Sappagh, Hendawi, & El Bastawissy, 2011).

The goal of this chapter is to determine how Data Warehousing processes can help by transforming project data of a contractor into readable Performance Information. This is assumed to be achieved by determining the fundamentals of a DW and implementation methods. In the end conclusions are conducted which are used in chapter 5 to form the theoretical framework.

4.2. Fundamentals

Creating a Data Warehouse is often considered to be one of the first steps towards Information Management and making Performance Information available within an organization. Creating a DW includes the use of several fundamentals which are, if not properly designed, bottlenecks in the system. Kimball et al. (2008, p. 1.2) use the careful studying and positioning of chess pieces on a board as a metaphor for the construction of a DW. As mentioned in chapter 3 and according to Kimball et al. (2008, p. 1.2), Ponniah (2001, p. 16), and Ballard et al. (1998) the four fundamentals are:

- Source Data;
  - Identification of the documents, departments, units, people, and much more providing input for the presentation of Performance Information.
- Transformation;
  - The transformation area consists of (Ponniah, 2001, p. 151):
    - Extracting the selected documents, etcetera from the source;
    - Transforming the selected documents, etcetera into Performance Information;
    - Loading the PI in an accessible Data Base to present the PI.
- Presentation;
  - The way PI is presented depends on the wishes of the contractor and the architecture which is chosen Ponniah (2001, pp. 33, 156). The most obvious difference in architectures is the use information subjects.
- Reporting;
  - Relevant Performance Information is selected to use in tender documents in BVP or writing EMAT documents. This PI can also be used for strategic or tactical decision making.

The choices made with respect to the presentation of the Performance Information determine the rules of the transformation area. By determining clear rules for this transformation process it is possible to prevent unnecessary or double steps to be executed (Kimball & Caserta, 2004, p. 63; Kimball et al., 2008). Each of the fundamentals is briefly discussed in the following paragraphs.
4.2.1. SOURCE DATA

According to Ballard et al. (1998, p. 83) and Ponniah (2001, p. 125) project data is one of the two inputs forming the source data which is used in the Transformation process. Project data consists of production data, internal data, and archived data. The second input consists of external data which is used to add benchmarks and standards to the data Koolwijk (2013). E.g. external data could be a national mean or scaling used to express Performance Information. This mean or scaling could be of importance while reporting the PI in tenders. The input of source data is visualized in Figure 10.

FIGURE 10 - PROJECT DATA AS INPUT OF SOURCE DATA (OWN ILL.)

According to Ponniah (2001, p. 116) an analysis of the processes within a contractor could provide relevant insights in the source data available. According to (Krishnan, 2013, p. 36) this source data is unfortunately not structured and is infinite. Ponniah (2001, p. 283) advises to consider the following points carefully:
- Diversity and disparity of Source Data;
- Source Data over multiple platforms;
- Different database technologies;
- Historical data is not preserved;
- Dubious quality of data;
- Structures may vary;
- Inconsistent data;
- Cryptic and ambiguous data representation.

Krishnan (2013) mentions several places where data on the performances of a contractor can be found. The following list is a list of possible places where performances can be found: Memos, contracts, analysts reports, competitive research, financial statements, emails, supplier data, vendor data, excel, spreadsheets, videos, images, audio, word documents, websites, corporate documents, social media, governments, institutions, etcetera.

4.2.2. TRANSFORMATION AREA

The transformation area is the beating heart of the Data Warehousing processes (El-Sappagh et al., 2011; Kimball & Caserta, 2004). According to Vassiliadis, Simitsis, and Skiadopoulos (2002) these processes take up between 35% and 80% of the total time and effort put in implementing Data Warehousing techniques. Typically transforming project data into Performance Information consists of extracting all relevant data containing information on the performances of the contractor, transforming the data into Performance Information according to pre-set rules, and loading the PI in the selected place to present the PI.

According to Kimball et al. (2008, p. 9.10) every method used in the transformation area should have a verification and validation process whether the selected methods meet up with the requirements. According to Vaisman and Zimányi (2014, p. 285) designing the transformation requirements may take a long time to develop and can be very complex. Reducing the processes to an absolute minimum can
help managing the system as well as making it easier to implement. The process is designed to (Kimball & Caserta, 2004, p. xxi):
- Remove mistakes and correct missing data;
- Provide documented measures of confidence;
- Capture the flow of data for safekeeping;
- Combines data from multiple sources;
- Structures data for strategic decision making.

The Transformation area as described above can be summarized as a process containing three steps and is visualized in Figure 11.

**FIGURE 11 - FUNDAMENTALS OF THE TRANSFORMATION AREA (OWN ILL.)**

**EXTRACTION**

After identifying all possible source data it is needed to extract only the data which matches the requirements set to the Performance Information needed. For the sake of this research all data matching these requirements and suitable to function as input for PI is hereby called **Performance Data (PD)**. The following definition is given to PD:

*Performance Data (PD): “All data matching the input requirements of Performance Information”*

Selecting and extracting only the Performance Data ought to be relevant is called *partial extraction* and reduces the complexity of the overall extraction (Ballard et al., 1998, p. 73). Ponniah (2001, p. 151) and Kimball and Caserta (2004, pp. 55-111) define several steps which can help in the extraction process:
- Select filter type and source;
- Extract files by copying or other techniques;
- Create a temporary storage system or file;
- Apply previous steps on multiple sources;
- Validate the data;
- Reformat input if needed;
- Generate common files;
- Resolve inconsistencies.

Keeping track of these steps is of uttermost interest to the traceability of the Performance Information and thereby the ability to verify the PI.

**TRANSFORMATION AND CLEANING**

Performance Information which is to be used by tender teams differs from Performance Data by being *non refutable, verifiable, and measurable*. This means that the quality of the PI presented to the tender teams should at all time be (Ponniah, 2001, pp. 318, 319):
- Accurate;
- Consistent;
- Complete;
- Timeless;
- Relevant;
- Clear;
- Identifiable.
Although this list might sound obvious it is often quite difficult to reach this level of quality (Ponniah, 2001, p. 316). Achieving high quality Performance Information can be achieved by applying the following corrections (Kimball & Caserta, 2004, p. 18; Ponniah, 2001, pp. 151,327):

- Normalize inconsistent Performance Data;
- Restructure Performance Data towards Information Subjects;
- Provide Performance Data quality measurements;
- Standardize Performance Data formats;
- Validate the Performance Data;
- Convert source types;
- Remove duplicates.

Never should transformed Performance Data find its way back into the source data to prevent loss of quality due to multiple transformations being performed on the same PD.

**LOADING**

Loading is the last step in the transformation area and defines the process of physically structuring the Performance Information into predetermined information subjects making the PI available for use (Kimball & Caserta, 2004, p. 19). Before the Performance Information can be loaded and presented the PI should be accurate meaning that the data should be correct, unambiguous, consistent and complete (Kimball & Caserta, 2004, p. 150). Ponniah (2001, p. 151) and Kimball and Caserta (2004) define several steps which can help in this process:

- Sort Performance Information and load according to Information Subjects;
- Generate explaining information to be loaded along with the PI;
- Determine a refreshing interval;

The third step as listed above is introduced to make sure the Performance Information presented is always up-to-date. The refreshing interval may vary with the organizational requirements (Kimball & Caserta, 2004, p. 106; Vaisman & Zimányi, 2014, p. 77). A contractor is as mentioned before a project based organization in which Performance Data is generated while realising projects. Therefore it is advised to set the minimal refreshing period to 'delivery of project'. Determining the correct interval will allow the contractor to make an analysis of the past, relate information to the present, and predict the future (Ponniah, 2001, p. 27).

**PRESENTATION**

Determining the best ways to present Performance Information to the tender teams can be a difficult task. The most important aspects regarding the presentation of PI are the architecture and approach used to present PI. The following paragraphs discuss the most frequently used architectural types and the use and importance of Information Subjects. The different approaches are discussed in paragraph 4.3. - Approaches. According to Ponniah (2001, p. 5) the presentation of PI must be integrated, integer, accessible, credible, and timely at all time.

**ARCHITECTURE**

Both Ponniah (2001, pp. 32, 156-160) and Ballard et al. (1998, p. 15) underpin the importance of the architecture to present Performance Information. The architecture is the method used to store and present Performance Information. The design choices can have a huge impact on the success; therefore a distinction is made between several architectures which are briefly discussed. Ballard et al. (1998, p. 15) and Ponniah (2001) distinguish a total of five main designs to present the PI.
The designs are mainly distinguished by the way information subjects are organized. According to Sean Kelly (Ponniah, 2001, p. 24) and Vaisman and Zimányi (2014, p. 4) the Performance Information should at all time be available, accessible, and separable in order to be useful. The following table provides an overview of the five main designs used to present Performance Information.

<table>
<thead>
<tr>
<th>Method</th>
<th>Presentation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global / Centralized</td>
<td><img src="image" alt="Diagram" /></td>
<td>Ponniah (2001, p. 15) and Ballard et al. (1998, p. 32): An organizational wide view of data with a high degree of data access. The lowest format is stored and allows queries. No information subjects are included.</td>
</tr>
<tr>
<td>Independent</td>
<td><img src="image" alt="Diagram" /></td>
<td>Ponniah (2001, p. 17) and Ballard et al. (1998, p. 32): Independent information subjects are distinguished and controlled/developed by workgroup, department or line of business to meet their needs. Information Subjects do not interact with each other.</td>
</tr>
<tr>
<td>Interconnected / Federated</td>
<td><img src="image" alt="Diagram" /></td>
<td>Ponniah (2001, p. 18) and Ballard et al. (1998, p. 33): A distributed implementation of Information Subjects which are integrated or connected to provide a wide view of information. Overall metadata is introduced to apply structure.</td>
</tr>
<tr>
<td>Hub-and-Spoke</td>
<td><img src="image" alt="Diagram" /></td>
<td>Ponniah (2001, p. 33): Information subjects are generated for a variety of purposes according to the individual requirements of departments.</td>
</tr>
<tr>
<td>Data-Martbus</td>
<td><img src="image" alt="Diagram" /></td>
<td>Ponniah (2001, p. 34): Atomic data is organized as a dimensional data model. Individual information subjects are designed in sequence to provide an organizational view of the information.</td>
</tr>
</tbody>
</table>

**TABLE 1 - POSSIBILITIES FOR ARCHITECTURE OF DATABASE FOR PI PRESENTATION**

**INFORMATION SUBJECTS**

Information Subjects are used to present Performance Information regarding a single process (Ballard et al., 1998, p. 86). Information subjects are a way to make Performance Information structured, understandable, and usable. Determining which Information Subjects to use should include both the requirements of the organization and the requirements of the client (Koolwijk, 2013, p. 14).
The presentation of the Performance Information strongly depends on the correct identification of the Information Subjects and determines the success of the process. As mentioned in chapter 1 Key Performance Indicators represent the core values of the contractor. Balancing the KPI’s which are frequently asked for by the client and the KPI’s ought to be most important for the contractor could be the key to success.

**KEY PERFORMANCE INDICATORS**

Key Performance Indicators are sets of quantifiable measures which could help by providing dominant information (Rijt & Santema, 2013, p. 70). It must be clear that these KPIs are sets of indicators grouped together (Figure 12).

E.g. In the Dutch GWW industry ‘environmental management’ is a very important ‘information subject’ or KPI. Environmental management can e.g. be expressed by the amount of ‘noise hindrance’, ‘vibrations’, ‘pollution’, etcetera to the surroundings. Carefully selecting and determining which indicators express the selected KPI helps to understand the KPI as well as structuring it. All these indicators together form a KPI or ‘information subject’.

![Figure 12 - Example of indicators grouped together forming a KPI (Own ill.)](image)

According to Chan and Chan (2004, p. 210) a complete set of KPIs consists of *objective* measures and *subjective* measures. Besides this Lin, Shen, Sun, and Kelly (2011) divide KPIs in the construction industry over three categories, namely:

- Process indicators, used to evaluate organizational and operational processes;
- Predicting indicators, used to predict outcomes off values;
- Outcome indicators, used to evaluate outcome performance (both tangible and intangible).

Developing KPIs for an organization should according to Chan and Chan (2004, p. 209) consist of at least:

- Focus on and indicate critical parts of outputs and outcomes;
- A limited selection should be made to maintain a manageable use;
- Systematic use of KPIs is needed to manage the KPIs;
- Simple data collection is a must;
- KPIs should be implemented in every project to prevent project specific variable impacts;
- Measures and indicators must be accepted, understood, and owned in the complete organization to be effective;
- Graphic display must be simple;
- KPIs evolve over time and may be redefined.

Key Performance Indicators should represent both the client and the contractor itself.
CATEGORIZATION: KEY PERFORMANCE INDICATORS ALL OVER THE WORLD

Determining which limited selection of KPIs should be maintained depends on the wishes of the contractor. This paragraph discusses KPIs used all over the world as well as the most common used KPIs in the Dutch construction industry. These lists could help a contractor determine the way Performance Information can be presented. Proper identification and monitoring of KPIs to determine relations and trends (Kimball et al., 2008, p. 3.7; Ponniah, 2001, p. 5) could provide:

- Performance level on a certain topic;
- Verify whether goals are achieved;
- Check whether clients are satisfied;
- Check the level of processes;
- Determine whether improvements are needed.

Atkinson (1999, p. 337) who is a dominant author and researcher in project management and information systems describes three success factors being leading for almost every project in the past 50 years. He calls these success factors the ‘iron triangle’ which are costs, time, and quality. Atkinson (1999, p. 338) already mentioned the restricted use of the iron triangle in 1999 as they do not represent the full performances of the contractor. He proposed to expand the iron triangle with new indicators and with the introduction of EMAT and BVP this need is emphasized. The following table provides an overview of KPIs in the construction industry all over the world:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Time</td>
<td>- Construction Time</td>
<td>- Construction costs</td>
</tr>
<tr>
<td>- Costs</td>
<td>- Speed of Construction</td>
<td>- Construction time</td>
</tr>
<tr>
<td>- Quality</td>
<td>- Time Variation</td>
<td>- Defects</td>
</tr>
<tr>
<td></td>
<td>- Unit Cost</td>
<td>- Client satisfaction</td>
</tr>
<tr>
<td></td>
<td>- Percentage net variation</td>
<td>- Profitability</td>
</tr>
<tr>
<td></td>
<td>- NPV</td>
<td>- Productivity</td>
</tr>
<tr>
<td></td>
<td>- Accident Rate</td>
<td>- Safety</td>
</tr>
<tr>
<td></td>
<td>- Environmental Impact Assessment (EIA) scores</td>
<td>- Predictability</td>
</tr>
<tr>
<td></td>
<td>- Quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Functionality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- End-user's satisfaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Design team satisfaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Construction team satisfaction</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Timely performance</td>
<td>- Time Management and Progress</td>
<td>- Time</td>
</tr>
<tr>
<td>- Quality Control</td>
<td>- Contract Management</td>
<td>- Costs</td>
</tr>
<tr>
<td>- Effectiveness of management</td>
<td>- Quality Management</td>
<td>- Quality</td>
</tr>
<tr>
<td>- Compliance with Labour standards</td>
<td>- Environmental Management</td>
<td>- Client Satisfaction</td>
</tr>
<tr>
<td>- Compliance with safety standards</td>
<td>- Traffic Management</td>
<td>- Change Orders</td>
</tr>
<tr>
<td></td>
<td>- Relationship management</td>
<td>- Business Performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Health and Safety</td>
</tr>
</tbody>
</table>

TABLE 2 - KPI CATEGORIZATION IN THE CONSTRUCTION INDUSTRY ALL OVER THE WORLD
Koolwijk (2013) has put together a list of KPIs and proposes a way to measure these KPI’s in his research ‘Pre-qualification of Contractors Based on Past Performance’. This list of KPIs is especially put together for the Dutch construction industry and is a combination of the KPIs in table 2. Koolwijk, Geraedts, and Chao-Duivis (2002) identify the following KPIs as being important in the Dutch construction industry:

- Time;
- Quality;
- Costs;
- Collaboration;
- Safety and Health;
- Environment;
- Communication;
- Client Satisfaction;
- Adaptability;
- Integrity;
- Management Capabilities;
- Effectiveness;
- Accessibility;
- Efficiency.

Implementing a limited selection of KPIs should be balanced and based upon are frequently asked for by the client and the KPIs ought to be most important for the contractor. Creating a manageable set of 6 to 10 of these KPIs is assumed to be most suitable for a Dutch contractor considering the use of KPIs.

4.2.4. REPORTING

The ultimate goal of applying Data Warehousing techniques is to present Performance Information in such a way that efficient use of the PI is possible by the tender department. According to Ballard et al. (1998, p. 10) querying and reporting is a method to search for a specific answer within the available Performance Information. According to Sullivan et al. (2006) this reporting process is defined as and visualized in Figure 13:

- Translate the clients awarding criteria into a query;
- Identify suitable Performance Information to be used while reporting;
- Simplify the Performance Information to the basics;
- Minimize and simplify communication in tender documents.

The process as described by Sullivan et al. (2006) suggests minimal and simplified communication in report delivery. According to Rijt and Santema (2013) the tender documents in Best Value Procurement must be specific, measureable, ambitious, realistic, and time bounded (S.M.A.R.T.) at all times.

4.3. APPROACHES

The most common approaches used to determine the most suitable architecture to present Performance Information are called the top-down approach by Ralph Kimball and the bottom-up approach by Bill Inmon. Because of the advantages and disadvantages of both approaches it is necessary to know the strategy of the organization before choosing an approach.

The top-down approach starts by defining and structuring the Key Performance Indicators to form the foundation of Performance Information to be presented (Ballard et al., 1998, pp. 19-20; Ponniah, 2001, pp. 30-31). Finding a balanced set of KPIs is often achieved by time-consuming methods such as interviews, meetings, group sessions, and
questionnaires (Ballard et al., 1998, p. 53; Ponniah, 2001, p. 110). This approach uses a limited amount of KPIs to be embedded within the systems. According to these KPIs information is gathered and structured. High implementation speed and quick wins are a result of this approach. Nevertheless inconsistencies in the Performance Information may occur as it is unsure whether all Performance Data is available.

The bottom-up approach starts by paying attention to the source data in order to determine which Performance Data is available. According to this PD Information Subjects are created after which Performance Information is structured according to these information subjects. This approach often represents the Performance Information which is directly available within the contractor and is limited by not investigating other relevant options (Ballard et al., 1998, p. 52). A wide variety of PI allows the contractor to provide PI regarding many awarding criteria's of the client. Knowing which PD is available is often highly appreciated. The following tables show both the advantageous and disadvantageous of these approaches:

**ADVANTAGEOUS**

<table>
<thead>
<tr>
<th>Top-down approach</th>
<th>Bottom-up approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast and easy implementation</td>
<td>Organizational wide PI</td>
</tr>
<tr>
<td>Manageable pieces</td>
<td>High detailed output</td>
</tr>
<tr>
<td>Low risk of failure</td>
<td>All available PD is know</td>
</tr>
<tr>
<td>Important KPIs come first</td>
<td>Large scope</td>
</tr>
<tr>
<td>Learning process available</td>
<td>Wide variety of PI</td>
</tr>
<tr>
<td>Less complex design needed</td>
<td>All PD structured</td>
</tr>
<tr>
<td>Out-of-the-box thinking possible</td>
<td>No limitation due to narrow minded people</td>
</tr>
</tbody>
</table>

**TABLE 3 - ADVANTAGEOUS OF THE BOTTOM-UP APPROACH AND TOP-DOWN APPROACH**

**DISADVANTAGEOUS**

<table>
<thead>
<tr>
<th>Top-down approach</th>
<th>Bottom-up approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPIs might be narrow viewed</td>
<td>Diffuse Performance Data</td>
</tr>
<tr>
<td>Many people involved to determine KPIs</td>
<td>Possible inconsistent and conflicting data</td>
</tr>
<tr>
<td>Some data cannot be made available</td>
<td>Possibility of unmanageable interfaces</td>
</tr>
<tr>
<td>Narrow minded people limit outcome</td>
<td>Integration of Information Subjects needed</td>
</tr>
<tr>
<td>Smaller scope</td>
<td>Delay of implementation</td>
</tr>
<tr>
<td>Expectations must be managed</td>
<td>Difficult implementation</td>
</tr>
<tr>
<td>Rework may be needed</td>
<td>High risk of failure</td>
</tr>
<tr>
<td>High risk of incorrect KPIs</td>
<td>Time-consuming process</td>
</tr>
</tbody>
</table>

**TABLE 4 - DISADVANTAGEOUS OF THE BOTTOM-UP APPROACH AND TOP-DOWN APPROACH**

4.4. **Conclusions**

This paragraph combines of the previous paragraphs in order to extract conclusions from the Literature. This paragraph is used as input in chapter 5 – theoretical framework. Data Warehousing techniques are a means to make Performance Information available, accessible, and separable within an organization by structuring only the data matching the requirements of PI and the data suitable to function as input for PI. This data is referred to as Performance Data in this research. Performance Information which is to be used by the tender department differs from Performance Data by being non refutable, verifiable, and measurable.

As mentioned in chapter 1 many contractors in the Dutch GWW industry are currently driven by one factor, which is: 'to win and build as many projects as possible'. This results in contractors wishing to know which Performance Information is directly
available and tend to use bottom-up approaches in order to understand their performances. This approach allows the contractor apply for many tenders put to the market but is mentioned to be a time-consuming process with a high risk of failure.

A contractor is a project based organization which must react to the awarding criteria of the client. Therefore it is assumed that an architecture including information subjects is most suitable for a contractor. Key Performance Indicators represent the core values of the contractor which is why KPIs are used to fill in these information subjects. Embedding KPIs within the organization in order to present the Performance Information requires the contractor to structure and gather Performance Data related to these KPIs.

Key Performance Indicators are used to focus on critical parts of the organization and are used to make Performance Information manageable. Upholding a manageable amount (6 to 10) of KPIs is a key to success when deciding to use KPIs as Information Subjects. The KPIs most often mentioned by the researchers are:
- Time;
- Costs;
- Quality;
- Safety;
- (Client) Satisfaction;
- Environmental Management.

When using the Performance Information in tender documents it is advisable to present the PI according to the definitions of ‘S.M.A.R.T.’ and ‘Dominant’ which include:

<table>
<thead>
<tr>
<th>S.M.A.R.T.</th>
<th>Dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific</td>
<td>Non refutable;</td>
</tr>
<tr>
<td>Measureable</td>
<td>Verifiable;</td>
</tr>
<tr>
<td>Ambitious</td>
<td>Accurate;</td>
</tr>
<tr>
<td>Realistic</td>
<td>Relevant to the project;</td>
</tr>
<tr>
<td>Time bounded</td>
<td>Measurable in numbers, percentages, and time.</td>
</tr>
</tbody>
</table>

TABLE 5 - S.M.A.R.T. AND DOMINANT PRESENTATION OF PERFORMANCE INFORMATION

Last but not least the Data Warehouse distinguishes four fundamental steps to be included in the process, namely: Source data, transformation, presentation, and reporting. Figure 14 visualizes the fundamentals of a DW which can be used as input as input for the theoretical framework in chapter 5.

FIGURE 14 - FUNDAMENTALS OF DATA WAREHOUSING (OWN ILL.)
5. THEORETICAL FRAMEWORK

5.1. INTRODUCTION

The previous chapters discussed the literature study towards Data Warehousing techniques. This chapter is assigned to answering the first Supportive Research Question after which this answer is used to create a theoretical framework which is used to approach the following parts of this research. SRQ1 is defined as:

SRQ1: What processes could help a contractor to transform Project Data into Performance Information?

Firstly a general answer on how to transform project data into Performance Information is given. Secondly, a proposition is given how this can be applied as possible bridge to present the contractor. This proposition acts as the theoretical framework used to approach the Research Question.

5.2. PART 1 – ANSWERING SRQ1

Transforming project data of the contractor into Performance Information is assumed to be possible by applying Data Warehousing techniques to the current organizational processes. Data Warehouse distinguishes four fundamental steps to be included in the process, namely: Source data, transformation, presentation, and reporting.

Contractors in the Dutch GWW industry are characterized as project based organizations. This results in source data being identified as "all lowest raw formats of information or knowledge generated while realising projects" and should be considered to be project data. The main goal of the transformation area is to determine which data within this project data includes information on the performances of the contractor. This selected data should be considered Performance Data. The selected and available PD can than be transformed Performance Information. At all time being able to present this PI in order to make it available, accessible, and separable for efficient use is the main goal of the presentation area.

The way Performance Information is presented depends on the choices made towards the architecture of the presentation area. PI can either be structured and gathered according to predetermined requirements. These requirements are called information subjects or Key Performance Indicators. Another option is to group together overlapping and available Performance Data. A contractor is a project based organization which at almost all times reacts to the awarding criteria of the client. Therefore it is assumed that an architecture including information subjects is most suitable for a contractor. Key Performance Indicators represent the core values of the contractor which is why KPIs can be used to fill in these information subjects. Upholding a manageable amount (6 to 10) of KPI's is a key to success when deciding to use information subjects.

In order to implement Data Warehousing techniques it is advised to consult the Amsterdam Information Model (AIM) which allows the contractor to map the relationships between business processes and information processes within the organization. The AIM model is used to help positioning Information Management related issues on an organizational level. It is therefore not used as a method for providing a solution, but used to get insight in the current practices regarding IM.
5.3. **Part 2 – Building the Theoretical Framework**

In chapter 1 the main problem is indicated as the gap between the *delivered projects* and the tender documents needed to be created while tendering. The first research objective is therefore summarized as 'determining how this gap can be filled'. This objective is visualized in Figure 15.

Data Warehousing as elaborated on in chapter 3 and 4 offers a more accurate and more efficient solution to fill this gap by approaching this situation in four steps. Contractors are currently forced to undergo unclear and inefficient steps while trying to put together tender documents. The core of a DW lies within the fact that it helps in providing rules for transformation and storage in order to prevent the same Performance Data to be transformed multiple times.

When comparing the four essentials of Data Warehousing with the process of a contractor it can be noted that the *source data* equals the *delivered projects* since both are identified as the place where Performance Data is hidden. Another interesting aspect to see is that the *reporting of selected Performance Information* equals the *tender documents* since both focus on generating a report based upon the PI. Figure 16 shows these overlapping steps.

Since both process start and end with the same steps it is therefore assumed that only two additional steps are required in order to embed DW techniques within a contractors organizational structure. Figure 16 could provide a relevant solution towards filling the gap as indicated in Figure 15 by providing a clear set of rules. Besides this the transformed information is stored by using a clear way to prevent the same transformation from taking place over and over.
As mentioned in the literature contractors are often marked as organizations who are not likely to change current working methods. Applying these two additional steps does not radically change the current processes but assists the already existing processes by providing clear rules. Embedding these two additional steps to the current Best Value process taking place at a contractor is visualized in Figure 17. This figure acts as the theoretical framework used to determine where focus needs to be put while performing the empirical research and describes the most important aspects to take into account.

The AIM model by Maes (1999) is used to help positioning the relationship between the delivered projects and the tender documents to be created. Placing the steps of the theoretical framework (Figure 17) within this model could provide relevant insights regarding the implementation and possible issues to occur. In this model the ‘business process operation’ are both the delivered projects and the tender documents needed to be produced. The ‘information requirement management’ is the place where rules or requirements to the information are defined and thereby the transformation area, especially the extraction rules. The ‘functional support’ is now to be seen as the presentation of PI. This placement of the theoretical framework within the context of the AIM model is renamed to the ‘Contractors Information Management (CIM)’ Model which is visualized in Figure 18 and is used to structure the interviews.
PART C: EMPIRICAL STUDY

This part of the research consists of the empirical observations which have been noted while performing interviews and case studies at Mobilis. This part solely discusses the observations of the interviews in relation to the Contractors Information Management model and the findings during the case studies. The main goal of this part is to provide an answer to SRQ2 which in paragraph 1.6 is formulated as:

SRQ2: How is Project Data currently used and embedded within the structure of Mobilis?

Chapter 6, the first chapter of part C, is allocated to forming a general overview the current practices towards Information Management at Mobilis. This chapter is based upon interviews with key people of Mobilis. The goal of this chapter is to determine how Mobilis is currently generating project data and how Information Management plays a role in this. The interviews are structured by using the CIM model.

Chapter 7, the second chapter of part C, is allocated to case studies. This chapter is based upon an exploratory and descriptive study towards the project data of Mobilis. In this chapter medium-large infrastructural projects are used as cases in order to determine which project data is available and how this can be used to create Performance Information.

Chapter 8, the third and last chapter of part C, is used to combine the conclusions from chapter 6 and 7 in order to answer SRQ2. The conclusions from chapter 6 and 7 as well as the answer to SRQ2 act as input for part D - Integration phase in which issues discovered in this part are answered by given possible solutions.
6. INFORMATION MANAGEMENT AT MOBILIS

6.1. INTRODUCTION

6.2. KEY PEOPLE – INTERVIEWEES

6.2.1. Process from tender to delivery

6.2.2. Expansion of the Theoretical Framework
6.2.3. Selecting the interviewees

6.3. SUMMARY OF THE INTERVIEWS

6.3.1. Mapping key people in the CIM model

6.3.2. Information policy
6.3.3. Mobilizer and Chapoo

6.3.4. INFORMATION REQUIREMENTS

6.4. CONCLUSIONS
7. Project Data of Mobilis

7.1. Introduction

7.2. Objective and Selection Criteria of the Case Study

7.2.1. Objective & Methodology

7.2.2. Case Selection by Means of Convergence

7.3. Source Identification

7.3.1. General Process Structure in Mobilizer

7.3.2. Process Output

7.4. Results of Process Output

7.4.1. Accessibility (Storage)

7.4.2. Structure

7.4.3. Output Example: Numeric Performance Data

7.5. Conclusion
8. **ANSWERING SRQ2**

The previous chapters (6 and 7) discussed how Information Management is currently embedded within the structure of Mobilis as well as the source data available resulting from the quality management system ‘Mobilizer’. This chapter is assigned to answering the second Supportive Research Question as mentioned in the introduction of Part C. SRQ2 is defined as:

**SRQ2:** How is project data currently used and embedded within the structure of Mobilis?

Mobilis upholds a project based structure which explains the bottom-up approach used to determine performances. This bottom-up explains why no clear rules and requirements are found in order transform project data into Performance Information. As a result to these missing rules regarding the transformation of Performance Data the situation occurs where tender documents are directly based upon the project data. Since project data is not directly accessible for all employees inefficient processes take place to get access to all relevant project data resulting in a high probability that useful Performance Data is not included in the transformation of PD. Besides this, the information represented in the Kennisbank is not traceable meaning it cannot directly be reused.

It seems that a clear and recognizable need for Information Management seems to be needed before it is implemented. A recognizable need for IM is directly to be seen at the Key Performance Indicator 'safety'. The client introduced the ‘Veiligheids-prestatieladder’ which requires the contractor to embed safety within all layers of the organization. This recognizable need for IM is seen by the board of directors after which a managerial decision is made to implement a system to measure 'safety'. This recognizable need for Information has led to the creation of the Coaching and Observation Round (COR) which is created by using a top-down approach. The experts of Mobilis where approached to determine and split up the KPI 'safety' using the approach as indicated in Figure 12.

CO2 registration is another example of a recognizable requirement from the client which is implemented in the project Maximabrug. In order to create specific, verifiable, and measurable Performance Information on other relevant Information Subjects it is therefore needed to adopt a top-down approach as used to create the Coaching and Observation Round. By doing so Mobilis will be able to efficiently collect and use PD for future use.

Analysing the project data of Mobilis proved to be a time consuming process with a high risk of failure and being too complex for one person. Nevertheless the case studies proved that the current project data of Mobilis contains incomplete and inconsistent Performance Data which is also difficult to check on quality. Having incomplete and inconsistent PD results in missing input of the transformation area and thereby making the process very inefficient as clear trends cannot be discovered.

Approaching the project data of Mobilis without a predetermined query results in being unable to determine which Performance Data is hidden within this project data. It however shows that once a query is generated it is possible to create Performance Information. Unfortunately the current methods used to create PI are not traceable resulting in the wheel being reinvented once the same PI is needed again.
PART D: INTEGRATION PHASE

This part consists of the analytical part of the research in which the findings in Part C are integrated with the literature study in Part B. The goal of this part is to determine how Mobilis could apply the theoretical framework. In the end of this part the third Supportive Research Question is answered which in paragraph 1.6 is formulated as:

SRQ3: How could the theoretical framework and the empirical findings be integrated in order to make Performance Data available and accessible and thereby help the tender teams of Mobilis produce Performance Information needed in the tender documents?

Chapter 9, the first chapter of part D, is firstly allocated to the necessity of top level commitment by the contractor with respect to Information Management. Secondly the Coaching and Observation Round which Mobilis uses and successfully creates Performance Data on the Key Performance Indicator ‘Safety’ is analysed. These analysis are combined to form a general approach for alternative KPIs. Last but not least this chapter is allocated to pointing out the quick wins for Mobilis as well as the conclusions from this chapter.

Chapter 10, the second chapter of part D, is allocated to answering the third Supportive Research Question of this research. By answering this question all SRQs are answered. Answering all SRQs results in being able to answer the main Research Question.
9. GENERATING AND PRESENTING PERFORMANCE DATA

9.1. INTRODUCTION

9.2. ANALYSING THE COACHING AND OBSERVATION ROUND (COR)

9.3. IMPLEMENTING ADDITIONAL KEY PERFORMANCE INDICATORS

9.4. THE IMPORTANCE OF TOP LEVEL COMMITMENT

9.5. QUICK WINS
9.5.1. REDUCING THE AMOUNT OF QUERIES NEEDED

9.5.2. DOMAINS OF DEPARTMENTS; AN ADDITION

9.6. CONCLUSIONS
10. **ANSWERING SRQ3**

The previous chapter discussed the possibility to create accessible Performance Information as well as how numeric Performance Data can be generated while realising projects. This chapter is assigned to answering the third Supportive Research Question as mentioned in the introduction of part D. SRQ3 is expressed in two parts and the following answer suits for both SRQ3.1 and SRQ3.2.

SRQ3: How could the theoretical framework and the empirical findings be integrated in order to make Performance Data available and accessible and thereby help the tender teams of Mobilis produce Performance Information needed in the tender documents?

Due to the diffuseness and the large amounts of the project data no general transformation rules can be defined since too many different document types exist. Simply gathering all possible Performance Data is unfortunately not possible since the future award criteria used by the client are unknown. Besides this it is near impossible to express the projects of Mobilis according to the documentation used while realising projects due to the fact that the amounts of documents created while realising projects are unmanageable in the time span of this research. It is therefore assumed that without clear goals or transformation rules to transform project data is it not possible to manually transform the project data into possible Performance Information to be presented. Nevertheless several processes are possible to make the transformation process more efficient.

Currently Mobilis uses a reactive behaviour to gather Performance Information. In this process the tender teams of Mobilis transform project data from many projects into PI. Unfortunately these transformation methods are not tracked or stored somewhere centralized. This results in the tender teams having to perform the same transformation over and over. Besides this the quality of the PI is not known upfront as it is unclear whether the project data used contains the Performance Data needed.

In the issue and process described above two main issues are identified. The first is the *incomplete and inconsistent Performance Data*. The first issue can be solved by securing top-level commitment of the organization regarding Information Management. Key Performance Indicators can be expressed into *performance indicators* and *measurable indicators* once top-level commitment is embedded within Mobilis. Once KPIs are embedded within Mobilis it is possible to gather all related PD while executing projects and thereby preventing having to transform project data after delivery.

Mobilis could create a general 'Plan for KPI Measurement' which can form part of the input in the Project Action Plan. The PAP is the first document to be created when going to execute a project. Embedding this *plan for KPI measurement* in the PAP could result in a consistent flow of Performance Data being generated while executing projects. Combining this PD with comparable PD of other projects directly results in being able to present Performance Information.

The second issue is the *inaccessible project data* resulting in many queries to be performed before Performance Data is to be found. This issue is directly related to the efficiency of the transformation process as allot of effort is needed to gain access to all project data. Determining which documents within the project data could contain PD is therefore suggested. The 'document selection list' as shown in *Appendix C - Case Studies*.
could provide a start for Mobilis and be extracted from the project data and stored somewhere accessible for all tender teams.

Creating a database to present Performance Information as well as documents containing Performance Data could significantly help by creating tender documents in future Best Value tenders. The current KennisBank of Mobilis is created to store PD. Unfortunately it is currently not used or filled. Therefore it is assumed that filling this system with both the PD and PI could be a relevant step to help tender teams produce PI needed in the tender documents.

The first solution directly generates Performance Data in each project. Combining this PD creates Performance Information which should be stored somewhere accessible for the tender teams. It is suggested to use the KennisBank to store the PI since it is a system which is already available. Nevertheless the KennisBank should become more user friendly if it is to be used to present PI.

The second solution aims at reducing the amount of queries needed to extract Performance Data from the projects. The KennisBank could include a separate platform where the documents containing Performance Information but are not part of the Key Performance Indicators are stored for possible future use.
PART E: CONCLUSIONS

This part is allocated to answering the Research Question as defined in chapter 1 and deducting recommendations. All parts of this research are combined in this part to be able to answer the RQ. The RQ of this research is defined as:

RQ: **How could a contractor efficiently transform project data into Performance Information to be used in future processes?**

Chapter 11, the first chapter of part E, is allocated to firstly discussing the limitations of this research which could influence the answer to the main Research Question. Secondly the practical and scientific relevance of this research are discussed in order to discuss how this research contributes to both the practical and scientific aspects. This discussion is important as it explains context of the answer provided to the RQ and SRQ’s.

Chapter 12, the second chapter of part E, is allocated to answering the Supportive Research Questions which lead to be able to answer the main Research Question of this research. Each part of the research is discussed by answering SRQ1 to SRQ3 and last but not least providing an answer to the RQ.

Chapter 13, the third chapter of part E, is allocated to mentioning several possibilities for further research and mentioning the recommendations for Mobilis from this research. In this part a total of 5 recommendations for further research and a total of 8 recommendations for Mobilis are discussed.

Chapter 14, the last chapter of part E, is allocated to my personal view on this research and thereby contains the reflection of this report. It discusses time related issues, ups and downs, my personal view, and many more.
11. DISCUSSION

The results of this research might not be completely consistent and limited due to the fact that research is based upon interviews and the available data from 2 projects. This approach resulted in a complex and time consuming process. Besides this the data used as input for the empirical studies is difficult to check on quality. Nevertheless, relevant findings which lead to several conclusions are found. This chapter discusses the limitations off this research as well as both the practical and the scientific relevance of the research.

11.1. LIMITATIONS

In this research the context of the AIM model is used as a method to help structure the research. The context of the AIM model is combined with the Data Warehousing theories in order to create the Contractors Information Management model. Although Rik Maes is a well known and respected player and author in the IM business other relevant IM models could have been used to create this ‘CIM’ model. This is unfortunately not included in this research and therefore limited to the three models used in this research.

As noted and mentioned many times in this research this research has been performed at a contractor. Contractors are characterized by a project based organizational structure. This research is therefore limited to organizations which uphold a comparable organizational structure where personnel and departments are situated around projects. Fundamental changes could occur when applying these theories to contractors or other industries who uphold a different organizational structure.

A limitation of this research is the fact that a practical solution to the Information Management related issues is searched for within the boundaries of Mobilis. This can be explained by the fact that complex or extravagant solutions to the current issues have a high probability to not being implemented at all. Therefore the current recommendations of this research are focussed upon improving or changing systems which are all ready implemented or adapting the organizational structure which is currently being used. Nevertheless this approach proofs that it is possible to apply Data Warehousing techniques to a contractor. This research could therefore also be executed at other contractors.

Another limitation of this research is also the data used from only two projects. The immense quantity of project data resulted in the inability to perform transformation as firstly thought off. Due to this immense quantity the research’s scope is narrowed down to mainly determining which project data could contain Performance Data as well as how to efficiently extract PD in future projects. The complexity and large amounts of project data resulted in only 2 projects being checked for the available Performance Data. This process turned out to be a time consuming process with a high risk of failure.

Due to the difficulties regarding the availability and accessibility of project data this research is limited by projects which used the systems provided by Mobilis. This limitation eliminated a common used alternative which is the fact that Dutch contractors often work together and use systems of other organizations or create a system which is most suitable for this combination. The results of which is the current ‘document selection list’ in which probable Performance Data can be extracted can only be used to projects using Mobilizer. This unilateral perspective eliminates alternative systems and sources which could be relevant to the research question.
Another limitation is the number of interviewees used in order to get insights in the Information Management related issues by using the CIM model. Although the results of the interviews pointed towards the same answers, questions can be raised whether the interviewees within the department are influenced by each other and have formed a common thought on these subjects.

Unfortunately the Coaching and Observation Round was noted as a relevant subject only in the end of the research. The COR quantifies ‘safety’ over projects. Unfortunately the importance of this system was only acknowledged in a late state due to the iterative process used in this research. The process used by the COR is of great importance as it shows how it is possible to quantify performances while realising projects. It is believed that better results could have been gotten when the structure used by the COR was acknowledged in an earlier stage of the research.

This structure used by the COR showed many characteristics of the theoretical framework and could have been used as an example to create more comparable systems. Unfortunately this insight was only achieved near the end of the research and is therefore elaborated on as one of the possible solutions to the current Information Management issues. Researching and elaborating on the COR is therefore a recommendation for Mobilis.

11.2. **Practical Relevance**

The practical relevance of this research is adequate as all possible solutions are found within the context of existing systems of a contractor. In this research a closer look has been given to the process taking place from tender to realisation and thereby finding the gaps needed to be filled in to generate numeric Performance Data in projects. This insight provides contractors with the possibility to supplement the existing project data with much needed numeric PD. Acquiring this PD efficiently is currently difficult to do in projects. This is also relevant in scientific view as no specific research has been conducted to this process.

Although the approach used in this research turned out not to deliver the information needed for the first goal of this research relevant insights regarding the Information Management of contractors is obtained. Typical project based structures of a contractor which are mainly focused on winning tenders and realising projects are not suitable for the new Best Value requests of the clients. Unfortunately this research is limited to only one contractor in the Dutch GWW industry and therefore the results of this research might not be applicable to all Dutch contractors.

The outcome of this research directly contributes to the points of attention for contractors when trying to implement Information Management with respects to Best Value Procurement in the organization. Quick wins can be achieved by applying an IM Department which extracts Performance Data upfront according to predetermined Key Performance Indicators. Steering towards KPIs allows experts to be created on certain topics as well as embedding a learning cycle within the contractor. These KPIs could also be used to structure the extraction of PD in already realised projects.

11.3. **Scientific Relevance**

The first goal of this research was to contribute to the discussion regarding performance measurement at Dutch contractors by providing a general model to directly extract numeric Performance Information from the project data. Although this first goal proved
to be too complex to solve due to the large amounts of inaccessible and unavailable project data, relevant insights are obtained. It can be stated that without a clear query it is not possible to efficiently perform manual extractions of Performance Data from project data. The results of this research therefore contribute mainly by showing how numeric Performance Data can be generated and extracted while executing projects. Guidelines for contractors are given by analysing the process from tender to delivery and addressing the points where additional processes can be added. No specific literature on this process is found.

Many researches take into account only the view of the client. This research contributes to science by exploring the processes of a contractor and determining how project data of the contractor could be improved and used in Best Value Procurement. No specific research towards the project data of a contractor has been performed. It has been discovered that a contractor often tends to work with project data rather than Performance Data which causes complex situations to occur in which the wheel keeps being reinvented. Therefore the scientific relevance to the operational side of Best Value Procurement is significant.

No specific research has been performed to apply Data Warehousing techniques in the Dutch construction industry to solve the current issues related to Information Management. A model indicating the data transformation needed to create efficient tender processes during Best Value Procurement has been created. This research therefore covers part of the gap related to Information Management by pointing out the points of interest at a contractor.
12. **CONCLUSIONS**

This chapter contains the conclusions of the iterative research as presented in the previous parts and chapters. In this research part B to D are introduced in order to give answer to the Supportive Research Questions which act as a guide to answer the main Research Question. The conclusions of this research come in the form of answering the RQ and providing a framework for contractors. The RQ is formulated as:

*RQ:* How could a contractor efficiently transform Project Data into Performance Information to be used in future processes?

Before answering the RQ the answers of the SRQs are presented below.

12.1. **Supportive Research Questions: The answers**

12.1.1. **Part B: Literature Study**

This paragraph is allocated to providing the answer to Supportive Research Question 1 which is defined in chapter 1 as:

*SRQ1:* What processes could help a contractor to transform Project Data into Performance Information?

Transforming project data of the contractor into Performance Information is assumed to be possible by applying Data Warehousing techniques to the current organizational processes. Data Warehouse distinguishes four fundamental steps to be included in the process, namely: Source data, transformation, presentation, and reporting.

Contractors in the Dutch GWW industry are characterized as project based organizations. This results in source data being identified as "all lowest raw formats of information or knowledge generated while realising projects" and should be considered to be project data. The main goal of the transformation area is to determine which data within this project data includes information on the performances of the contractor. This selected data should be considered Performance Data. The selected and available PD can than be transformed Performance Information. At all time being able to present this PI in order to make it available, accessible, and separable for efficient use is the main goal of the presentation area.

The way Performance Information is presented depends on the choices made towards the architecture of the presentation area. PI can either be structured and gathered according to predetermined requirements. These requirements are called information subjects or Key Performance Indicators. Another option is to group together overlapping and available Performance Data. A contractor is a project based organization which at almost all times reacts to the awarding criteria of the client. Therefore it is assumed that an architecture including information subjects is most suitable for a contractor. Key Performance Indicators represent the core values of the contractor which is why KPIs can be used to fill in these information subjects. Upholding a manageable amount (6 to 10) of KPI's is a key to success when deciding to use information subjects.

In order to implement Data Warehousing techniques it is advised to consult the Amsterdam Information Model (AIM) which allows the contractor to map the relationships between business processes and information processes within the organization. The AIM model is used to help positioning Information Management
related issues on an organizational level. It is therefore not used as a method for providing a solution, but used to get insight in the current practices regarding IM.

12.1.2. PART C: EMPIRICAL STUDY
This paragraph is allocated to providing the answer to Supportive Research Question 2 which is defined in chapter 1 as:

**SRQ2:** How is the use of Performance Data currently embedded within the structure of Mobilis?

Mobilis upholds a project based structure which explains the bottom-up approach used to determine performances. This bottom-up explains why no clear rules and requirements are found in order transform project data into Performance Information. As a result to these missing rules regarding the transformation of Performance Data the situation occurs where tender documents are directly based upon the project data. Since project data is not directly accessible for all employees inefficient processes take place to get access to all relevant project data resulting in a high probability that useful Performance Data is not included in the transformation of PD. Besides this, the information represented in the Kennisbank is not traceable meaning it cannot directly be reused.

It seems that a clear and recognizable need for Information Management seems to be needed before it is implemented. A recognizable need for IM is directly to be seen at the Key Performance Indicator 'safety'. The client introduced the 'Veiligheids-prestatieladder' which requires the contractor to embed safety within all layers of the organization. This recognizable need for IM is seen by the board of directors after which a managerial decision is made to implement a system to measure 'safety'. This recognizable need for Information has led to the creation of the Coaching and Observation Round (COR) which is created by using a top-down approach. The experts of Mobilis where approached to determine and split up the KPI 'safety' using the approach as indicated in Figure 12.

CO2 registration is another example of a recognizable requirement from the client which is implemented in the project Maximabrug. In order to create specific, verifiable, and measurable Performance Information on other relevant Information Subjects it is therefore needed to adopt a top-down approach as used to create the Coaching and Observation Round. By doing so Mobilis will be able to efficiently collect and use PD for future use.

Analysing the project data of Mobilis proved to be a time consuming process with a high risk of failure and being too complex for one person. Nevertheless the case studies proved that the current project data of Mobilis contains incomplete and inconsistent Performance Data which is also difficult to check on quality. Having incomplete and inconsistent PD results in missing input of the transformation area and thereby making the process very inefficient as clear trends cannot be discovered.

Approaching the project data of Mobilis without a predetermined query results in being unable to determine which Performance Data is hidden within this project data. It however shows that once a query is generated it is possible to create Performance Information. Unfortunately the current methods used to create PI are not traceable resulting in the wheel being reinvented once the same PI is needed again.
12.1.3. PART D: INTEGRATION

This paragraph is allocated to providing the answer to Supportive Research Question 3 which is defined in chapter 1 as:

SRQ3: *How could the theoretical framework and the empirical findings be integrated in order to make Performance Data available and accessible and thereby help the tender teams of Mobilis produce Performance Information needed in the tender documents?*

Due to the diffuseness and the large amounts of the project data no general transformation rules can be defined since too many different document types exist. Simply gathering all possible Performance Data is unfortunately not possible since the future award criteria used by the client are unknown. Besides this it is near impossible to express the projects of Mobilis according to the documentation used while realising projects due to the fact that the amounts of documents created while realising projects are unmanageable in the time span of this research. It is therefore assumed that without clear goals or transformation rules to transform project data is it not possible to manually transform the project data into possible Performance Information to be presented. Nevertheless several processes are possible to make the transformation process more efficient.

Currently Mobilis uses a reactive behaviour to gather Performance Information. In this process the tender teams of Mobilis transform project data from many projects into PI. Unfortunately these transformation methods are not tracked or stored somewhere centralized. This results in the tender teams having to perform the same transformation over and over. Besides this the quality of the PI is not known upfront as it is unclear whether the project data used contains the Performance Data needed.

In the issue and process described above two main issues are identified. The first is *the incomplete and inconsistent Performance Data*. The first issue can be solved by securing top-level commitment of the organization regarding Information Management. Key Performance Indicators can be expressed into *performance indicators* and measurable *indicators* once top-level commitment is embedded within Mobilis. Once KPIs are embedded within Mobilis it is possible to gather all related PD while executing projects and thereby preventing having to transform project data after delivery.

Mobilis could create a general ‘Plan for KPI Measurement’ which can form part of the input in the Project Action Plan. The PAP is the first document to be created when going to execute a project. Embedding this *plan for KPI measurement* in the PAP could result in a consistent flow of Performance Data being generated while executing projects. Combining this PD with comparable PD of other projects directly results in being able to present Performance Information.

The second issue is the *inaccessible project data* resulting in many queries to be performed before Performance Data is to be found. This issue is directly related to the efficiency of the transformation process as allot of effort is needed to gain access to all project data. Determining which documents within the project data could contain PD is therefore suggested. The ‘document selection list’ as shown in Appendix C - Case Studies could provide a start for Mobilis and be extracted from the project data and stored somewhere accessible for all tender teams.
Creating a database to present Performance Information as well as documents containing Performance Data could significantly help by creating tender documents in future Best Value tenders. The current KennisBank of Mobilis is created to store PD. Unfortunately it is currently not used or filled. Therefore it is assumed that filling this system with both the PD and PI could be a relevant step to help tender teams produce PI needed in the tender documents.

The first solution directly generates Performance Data in each project. Combining this PD creates Performance Information which should be stored somewhere accessible for the tender teams. It is suggested to use the KennisBank to store the PI since it is a system which is already available. Nevertheless the KennisBank should become more user friendly if it is to be used to present PI.

The second solution aims at reducing the amount of queries needed to extract Performance Data from the projects. The KennisBank could include a separate platform where the documents containing Performance Information but are not part of the Key Performance Indicators are stored for possible future use.

12.2. Research Question: The Answer

This paragraph is allocated to providing the answer to the main Research Question of this research which is defined in chapter 1 as:

**RQ:** How could a contractor efficiently transform project data into Performance Information to be used in future processes?

A contractor currently directly transforms project data into Performance Information by using the award criteria of the client. The contractor translates the award criteria into queries which are then used to extract Performance Data from the project data. The information gathered at each separate project is than combined and directly reported in the tender documents. In this process the transformation of project data into Performance Information is not systematically stored or structured resulting in the inability to directly trace where the PD is coming from. This results in the same PD being transformed all over again once the Performance Information is needed again which results in an inefficient transformation process. This process is summarized in Figure 19 where the contractor is unaware of how to transform the PI.

**FIGURE 19 - PROBLEM DEFINITION OF RESEARCH (OWN ILL.)**
A contractor often tends to implement bottom-up approaches in order to understand their performances. This approach determines the Performance Information which is directly available which is often highly appreciated by the contractor. Although this approach is often used by contractors it is not recommended by both the literature and the theoretical framework. Due to the diffuseness and the large amounts of the project data this approach unfortunately results in not being able to determine PI on or to determine general transformation rules. Too many different document types exist with complete different structures. It is therefore assumed that without a clear goal or query to transform project data it is not possible to efficiently perform a manually transformation of the project data into Performance Information upfront. Therefore it is suggested that the contractor does no longer directly transform project data into PI without systematically tracking the steps in between. Tracking the steps in between allows the contractor to present PI on predetermined subjects at all time.

Key Performance Indicators allow a contractor to structure and determine the most crucial performances of both the contractor and the client. KPIs should be determined on the highest level within the organization and should be embedded within all processes of the contractor and is a means for Information Management. Therefore, before a contractor can start creating or applying a process to efficiently transform project data into Performance Information they should be absolutely willing to embed Information Management within the organizational structure. Top level commitment of the contractor resulting in a top-down approach is required in order to develop the correct KPIs representing both the contractor and the client. These KPIs could be used create the predetermined information queries to be used to gather Performance Data. PD represents the data on a single indicator generated while executing projects. Combining this PD from all projects results in PI which should be stored in an accessible place at all times.

Using Key Performance Indicators as a means for Information Management should be approach as if they are award criteria of the client. The contractor should approach each delivered project and actively seek for all Performance Data resulting from expressing the KPIs in measurable indicators. Extracting this PD from the projects and storing them somewhere retrievable and accessible is the first step towards efficiently creating Performance Information. Once the PD on all projects is extracted it can be combined to form PI and be presented somewhere accessible to be efficiently used in future processes.

It could however occur that projects lack information regarding a specific indicator. For example, 'environmental management' could be seen as a Key Performance Indicator and 'CO2' as a measurable indicator. If CO2 is not properly measured in all projects this results in incomplete Performance Data in the delivered projects. Incomplete PD results in not being able to transform the PD into Performance Information since the input is missing. Therefore it is advised to take into account the measurement of KPIs while executing projects. Introducing a general 'Plan for KPI Measurement' into every project could prevent incomplete PD from occurring by measuring KPIs in every single project.

Embedding such a general 'Plan for KPI Measurement' within every project being executed allows the contractor to generate a constant flow of specific, time stamped, accurate, verifiable, non refutable, and consistent Performance Data. Measuring these Key Performance Indicators while realising projects however puts an additional burden on the execution teams of the contractor. The KPIs should be measured according to a
regular interval in order to prevent incomplete PD from occurring all over again. Embedding a department which is responsible for extracting this PD from projects being realised is therefore suggested. A so called Information Management department could provide a solution. This process is visualized in Figure 20 in the theoretical framework.

![Figure 20 - Efficient Transformation Process of Project Data into Performance Information (Own Ill.)](image)

Last but not least it may occur that the award criteria of the client requires additional Performance Information to be used as input for the tender documents. It could therefore occur that the Key Performance Indicators do not cover this request by the client. Therefore it is advised to also create a platform where all project data possibly containing Performance Data can be found. This platform should be accessible by everyone but should not contain edible documents to prevent the 'sources' to be changed. This platform should therefore contain viewable project data only. It is recommended to analyse the document output from the quality management system and make a 'document selection list' which shows all possible project data which could contain PD. Storing these documents according to subject should allow efficient analysis of these documents.
13. RECOMMENDATIONS

This chapter contains the recommendations resulting from this research. At first further research possibilities are discussed which are intended for any person willing to expand this research and use this research as a foundation for their research. Secondly recommendations for Mobilis are extracted from this research in order to point out the most relevant and direct quick wins for the organization.

13.1. FURTHER RESEARCH

Putting together this research and conducting the research resulted in many useful insights which could help a contractor transform Performance Data into Performance Information. Nevertheless due to time related issues as well as insights to emerge only at the end of the research further research is still possible. The following list is a list of possible further researches:

- This research is limited to the Performance Data generated while executing projects meaning that only projects which are successfully tendered can be included in this short list. Nevertheless, for tender purposes it can also be helpful to analyse projects which are non-successfully tendered to determine where improvements can be made;
- A contractor often works together with multiple other contractors which use their own system. This research only approached the project data resulting from the quality management system of one contractor. A research can be conducted towards creating a general system which could be adopted by all contractors as a guide to create comparable project data which can easily be integrated. A part of this could be to create a general document selection list for multiple contractors;
- This study is limited to the explicit knowledge available as a result of the quality management system. This means that the tacit knowledge available within an organization is left aside. These experiences, deeds, and methods of thinking could contain relevant Performance Information which is much needed in the context of Best Value. It is therefore recommended to conduct further research towards transforming tacit knowledge of a contractor towards explicit knowledge.
- Further research can be conducted towards the use of Performance Information in relation to the prequalification process of projects. Currently contractors are taking a shot at a wide variety of projects resulting in many tenders not being won. Perhaps this PI could influence the prequalification process of a contractor and allow a better win/loss ratio while tendering.
- Many studies have been conducted towards Key Performance Indicators in the construction industry. As it turned out a focus should not be put on the KPIs but on the performance indicators and the measurable indicators. A focus in this research can be towards expressing the needs of a contractor and a client into relevant indicators instead of KPIs.

13.2. RECOMMENDATIONS FOR MOBILIS
14. REFLECTION

In this part of the research I reflect on the processes which have taken place over the past months. One of the biggest problems which have occurred and have been a great learning school for me is the fact that I believe everything is important and everything is interesting. This resulted in a broad scope which at some point could not be controlled anymore. The supervisors had fortunately noticed this and pointed out several aspects which could be put under the loop in order to get back on track.

I learned to focus more clearly on one aspect in order to fully understand the meaning of this part of the research. It also learned me that it is impossible to research everything related to the subject matter and that sometimes only small parts can be solved. Zooming in is the key to understanding something and hovering above the subject matter in order to see the bigger picture does not yield the promising results wanted in the end. The following thing Sicco told me made me think more clearly about this fact: "The scope is as infinite inside the scope as it is outside the scope".

When starting this research first of September of 2015 I have had created a planning to uphold during this research. This planning was created according to theories of Oost and Markenhof (2002, p. 17) who state that an average research consumes around 30% of the time to prepare (theory), 30% to collect data (practice), 20% to analyse it (integration), and 20% to process it (conclusions). All self-set deadlines where achieved on time, unfortunately two unpleasant circumstances have occurred which negatively influenced the time schedule. Nevertheless, this theoretical planning turned out to be quite resembling for the actual planning which I used to conduct this research and has helped me to keep on track over the complete period.

I do believe that an additional 1 to 3 months of further research could have improved the results by being possible to test alternative systems related to the Coaching and Observation Round. In depth interviews with the experts on several Key Performance Indicators could have led to interesting insights in possible alternative solutions. I believe that these interviews yield promising results and could really be implemented. Unfortunately due to time related issues and not being part of the scope of this research this part was not possible to conduct.

The complexity of the project data and the time it took to understand this project data did not positively contribute to the overall process of the research. Nevertheless this complexity has shown very interesting similarities with the things which the literature mentioned. These insights eventually resulted in being able to answer the main Research Question. At first sight it looked like I had wasted 3 weeks of research but eventually it turned out to provide relevant insights.

I believe that the fifth recommendation for further research is the most important recommendation. Many scientific researches have been performed in order to understand KPIs. When it comes to transforming the Performance Data of a contractor it is more important to understand the way a KPI is split up into performance indicators and measurable indicators than to understand the KPI itself. Therefore I strongly believe that more research should be performed towards these aspects.

Last but not least it proved to be an extremely big task to write down everything properly which I have underestimated significantly. I believe I have had excellent help from my supervisors regarding this subject but I believe improvements are still possible.


APPENDIX A – ORGANIZATIONAL CHART OF MOBILIS
APPENDIX B - INTERVIEWS
APPENDIX C – CASE STUDIES
APPENDIX D – IMPLEMENTATION EXAMPLE OF COR
APPENDIX E – NUMERIC RESULTS OF COR