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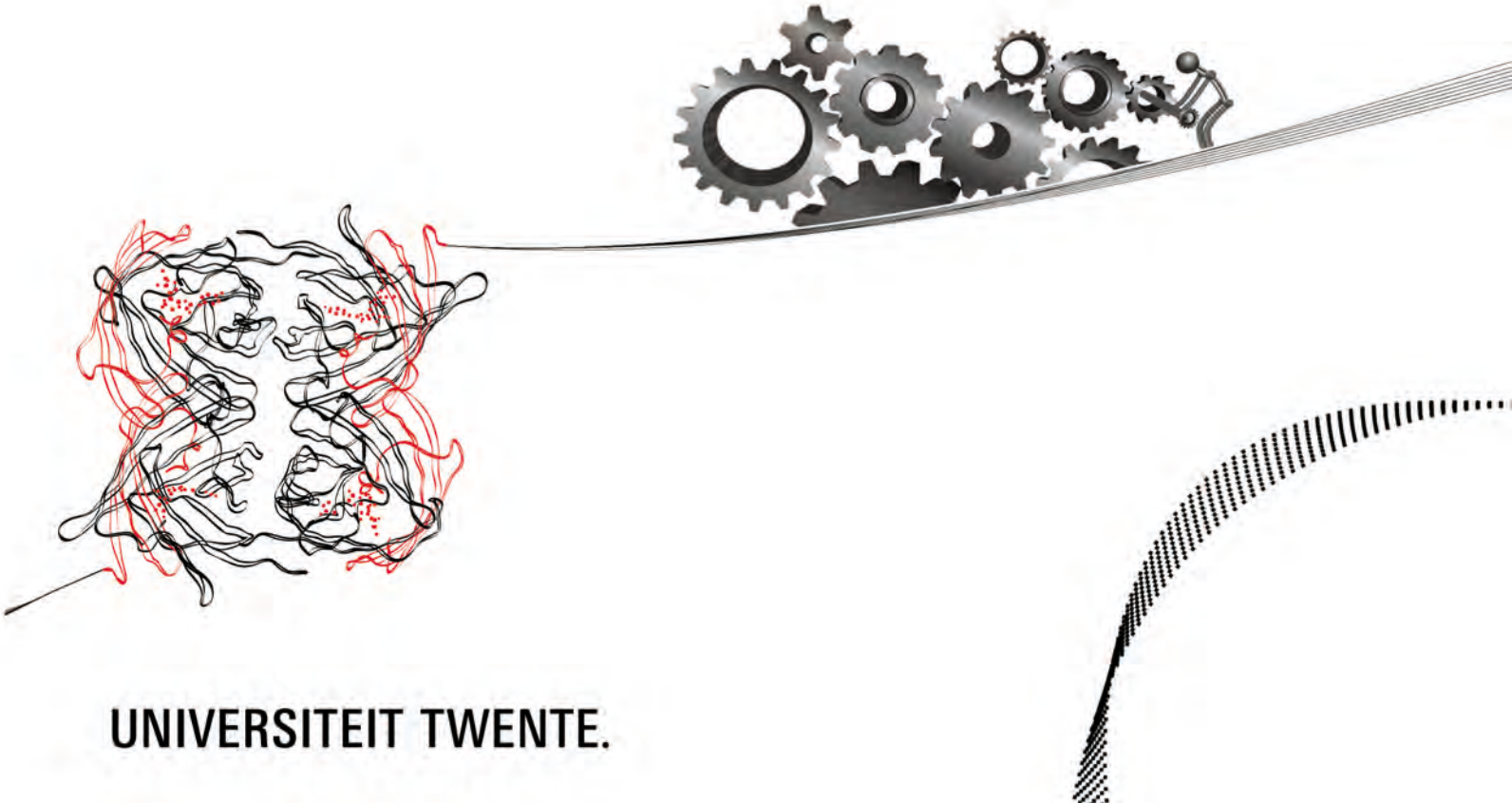
The Identification Of Key Processes To Control Infrastructural Maintenance Strategies

Increasing the maintenance performance of DBFM-contracts by identification of key performance processes, based on an evaluation of the N31 and A59

Public Version



UNIVERSITEIT TWENTE.

MASTER THESIS

Construction Management and Engineering

THE IDENTIFICATION OF KEY PROCESSES TO CONTROL INFRASTRUCTURAL MAINTENANCE STRATEGIES

Increasing the maintenance performance of DBFM-contracts by identification of key performance processes, based on an evaluation of the N31 and A59

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PREFACE

Voor u ligt de definitieve publieke[1] versie van mijn afstudeerrapport met de titel *"The identification of key processes to control infrastructure maintenance strategies"*. Dit rapport vormt de afsluiting van mijn Master Construction Management & Engineering binnen de afdeling Bouw/Infra aan de Universiteit Twente. Het onderzoek is uitgevoerd in samenwerking met BAM Infraconsult.

Deze studie gaat in op een nieuwe ontwikkeling in de infrastructuur, het gebruik van geïntegreerde contracten. Meer specifiek gaat het in op DBFM-contracten, een contractvorm waarin de aannemer verantwoordelijk is voor het ontwerp, de bouw, de financiering en het onderhoud van een project voor een lange periode. Er zijn op dit moment twee van dit soort projecten in Nederland waarvan de onderhoudsfase al enige jaren loopt, de N31-Wâldwei en de PPS-A59. De Koninklijke BAM Groep is in beide projecten mede verantwoordelijk voor het onderhoud waardoor er mogelijkheden zijn om te leren van beide projecten en daarmee de concurrentiepositie te verbeteren.

Dit rapport begint met een theoretische beschrijving van prestatiemeting, onderhoudstrategieën en onderhoudsprocessen op basis van beschikbare literatuur. Aan de hand hiervan is een model beschreven waarin uitgelegd wordt waar de studie zich specifiek op richt. Vervolgens zijn de beide projecten beschreven aan de hand van dit model en wordt er een koppeling gemaakt met welke processen belangrijk gevonden worden voor een goede uitvoering van het onderhoud. Het resultaat van deze studie is voorgelegd in een bijeenkomst met experts op het gebied van onderhoud binnen de Koninklijke BAM Groep.

Deze studie is uiteraard niet tot stand gekomen zonder de bijdrage van verschillende personen. Mijn dank gaat uit naar mijn directe begeleider vanuit de BAM, Arjen Vos. Zijn ervaring, vragen om concreet te worden, en contacten hebben mij ondersteund in de uitvoering van deze opdracht. Daarnaast gaat mijn dank uit naar mijn begeleiders vanuit de Universiteit, Geert Dewulf en Andreas Hartmann, voor hun inzet en kritische blik op deze opdracht. Tot slot de medewerkers van de afdeling beheer en instandhouding bij de A12 voor hun gezelligheid en natuurlijk de geïnterviewde personsen voor hun openheid en medewerking

Verder wil ik graag mijn ouders, familie en vrienden bedanken voor hun belangstelling en betrokkenheid. Dit heeft mij altijd gesteund en gemotiveerd. Daarnaast waren de vele koffie-uurtjes op de Universiteit waarin we onze frustraties en successen op tafel konden gooien erg fijn; het besef dat iedereen dezelfde 'beren' tegenkomt werkt geruststellend. Tot slot natuurlijk Denise, je enthousiasme en vertouwen in een goede afronding heeft mij altijd gesteund en gemotiveerd.

Met deze afstudeeropdracht is er een einde gekomen aan een leerzame periode binnen de BAM en de Universiteit. Daarnaast betekent dit het einde van een mooie studententijd. Met veel plezier kijk ik terug op deze periode, maar met net zoveel interesse kijk in naar de ontwikkelingen die de toekomst zal brengen.

Odijk, november 2011

Jeroen van der Meer

[1] In deze publieke versie is de evaluatie van de projecten niet weergegeven.

SUMMARY

The BAM is (as consortium partner) until 2020 responsible for the design, construction, finance and maintenance of the PPS-A59 and N31-Wâldwei, two integrated contracts (DBFM). The complex nature of construction projects and the cyclical process of maintenance makes that the BAM struggles with understanding of what processes need to be controlled to increase the maintenance performance. Knowledge about how the maintenance stage performs and what processes influence the performance can be help to improve the efficiency of assts. This makes maintenance a strategic issue for the Royal BAM Group.

This study examines which important processes have to be controlled to improve the maintenance performance for two infrastructural DBFM-projects, the A59 and N31. By studying literature about performance measurement, maintenance strategy and –processes a framework is developed using a holistic view, based on 'input-process-output-outcome'. With this framework important processes for supporting the maintenance performance can be identified. In order to map these processes interviews are held with the operator and the project director of both projects. By successively comparing the planned and realized process goals and maintenance costs, is the relation between the process- and outcome goals studied. For validation reasons the results are evaluated in an expert meeting.

Based on literature performance is defined as: 'the relation between the needed (financial) means and the required quality of a system, to attain the company objectives and targets'. The strategic aim for maintenance is to keep the condition of the infrastructure at the required level by executing maintenance or not. Performance measurement is needed for checking purposes and is defined as the process by which a company manages its (desired) performance by the quantification of the efficiency and effectiveness of actions. In literature no suitable indicators for performance measurement are available due to the complex nature of maintenance. Furthermore, no suitable project data is available that can be used to formulate indicators.

In order to gain an insight into the relevant processes for performance improvements at the BAM, the output goals are firstly analysed by means of the financial result. The process goals are furthermore analyzed by using the PAS55. This is a general accepted structure to optimally manage assets and asset systems. The utilization of the framework has resulted in the identification of four important processes to improve the maintenance stage. These are, 1) structure for the exchange of knowledge and information, 2) Research maintenance related risks and method for identifying risks, 3) Mapping the desired performance and condition in time, and 4) Criteria for prioritizing goals and plan.

Both projects are successful when taking the financial results and schedule of the first five years into perspective. A comment is that large maintenance has to be executed in the future. Currently success if achieved by dedicated employees with a lot of knowledge and experience and by having a positive relationship with the principal. The choices about the necessary maintenance are made using a financial model in which the financial results is at the centre. This makes maintenance mainly budget-oriented. Therefore, the influences of maintenance actions on the quality are not clearly known which makes it difficult to qualitatively support the necessity of maintenance actions. Furthermore, the described processes in the PAS55 are mostly executed but the steps taken (sub processes) are not clearly traceable. This makes that maintenance actions and processes are difficult to check on the effectiveness and efficiency. The results of this study give possibilities for improvements of the maintenance stage to stay competitive in the future and to better comply with the strategic agenda of the Royal BAM Group. In order to improve this, the following steps have to be taken: a) Developing a maintenance policy and related goals to measure performance and support decision making, b) standard evaluation of projects as learning effect in the organisation, c) and increasing the knowledge about the degeneration process through establishing damage-patterns.

SAMENVATTING

De BAM (als consortium partner) is tot 2022 verantwoordelijk voor de projecten PPS-A59 en N31-Wâldwei, twee geïntegreerde contracten (DFBM) met betrekking tot het ontwerp, de bouw, financiering en onderhoud. De complexiteit van bouwprojecten en de cyclische vorm van onderhoud maken dat de BAM worstelt met de vraag welke processen gecontroleerd moeten worden om de prestatie van het onderhoud te verbeteren. Kennis over hoe het onderhoud presteert en welke processen de prestatie beïnvloeden kunnen helpen de efficiëntie van objecten te verbeteren. Hierdoor wordt onderhoud voor de Koninklijke BAM Groep van strategisch belang.

Deze studie onderzoekt welke processen gecontroleerd moeten worden om de prestatie van onderhoud voor twee infrastructurele DBFM-projecten, de A59 en N31, te verbeteren. Aan de hand van literatuuronderzoek over prestatiemeting, onderhoudsstrategieën, en -processen is een framewerk ontwikkeld met een holistisch perspectief, gebaseerd op 'input-proces-output-outcome'. Hiermee kunnen de belangrijke processen ter ondersteuning van de onderhoudsprestatie geïdentificeerd worden. Om deze processen in kaart te brengen, zijn interviews uitgevoerd met de onderhoudsmanager en de projectdirecteur van beide projecten. Door achtereenvolgens de geplande en gerealiseerde procesdoelen en onderhoudskosten te vergelijken, is de relatie tussen proces- en outputdoelen bestudeerd. Ter validatie zijn de uitkomsten geëvalueerd in een expert bijeenkomst.

Aan de hand van literatuur is prestatie gedefinieerd als: 'de relatie tussen de benodigde (financiële) middelen en de te leveren kwaliteit van een systeem, om de bedrijfsdoelen te bereiken'. Het strategische doel voor onderhoud is om de conditie van de infrastructuur op het afgesproken niveau te houden door het wel of niet uitvoeren van onderhoud. Prestatiemeting is nodig ter controle en is gedefinieerd als het proces waarin het bedrijf de (gewenste) prestatie controleert door het kwantificeren van de effectiviteit en efficiëntie van acties. Vanuit de literatuur zijn geen geschikte indicatoren beschikbaar om de prestatie te meten vanwege de complexiteit van onderhoud. Bovendien is er geen geschikte data aanwezig vanuit de projecten zelf die kunnen leiden tot het opstellen van indicatoren.

Om toch inzicht te krijgen in de relevante processen voor prestatieverbetering bij de BAM, zijn in dit onderzoek allereerst de outputdoelen geanalyseerd door middel van het financiële resultaat. Daarnaast zijn de procesdoelen geanalyseerd door gebruik te maken van de PAS55. Dit laatste is een algemeen geaccepteerde structuur voor het optimaal beheren van objecten en systemen. De toepassing van het framewerk heeft uiteindelijk geleid tot de identificatie van 4 belangrijke processen ter verbetering van het onderhoudsproces. Dit zijn, 1) het gestructureerd uitwisselen van kennis en informatie, 2) het onderzoeken en identificeren van onderhoud gerelateerde risico's volgens een vaste methode, 3) het vastleggen van de gewenste prestatie en conditie in de tijd, en 4) het vaststellen van criteria voor het prioriteren van doelen en plannen.

Beide projecten zijn succesvol gezien het feit dat de eerste vijf jaar binnen budget en planning blijven. Een kanttekening is dat het groot onderhoud nog uitgevoerd moet worden. Dit succes wordt bereikt door toegewijde werknemers met veel kennis en ervaring, en door een goede relatie met de opdrachtgever. De keuzes betreffende het uit te voeren onderhoud worden bepaald aan de hand van een financieel model waarbij het financiële resultaat centraal staat. Als gevolg is het onderhoud voornamelijk budget georiënteerd waardoor de invloeden van onderhoudsacties op de kwaliteit niet helder in beeld zijn en het lastig is om de noodzaak van onderhoudsacties kwalitatief te onderbouwen. Daarnaast worden de beschreven processen uit de PAS55 veelal uitgevoerd maar de genomen stappen (subprocessen) zijn niet helder traceerbaar. Dit maakt dat de onderhoudsacties en processen moeilijk te controleren zijn op effectiviteit en efficiëntie. De resultaten van deze studie geven mogelijkheden voor verbetering van de onderhoudsfase om in de toekomst concurrerend te blijven en een betere aansluiting te krijgen met de strategische agenda van de Koninklijke BAM Groep. Hiervoor moeten de volgende stappen ondernomen worden: a) het opstellen van een onderhoudsbeleid met gerelateerde doelen ter ondersteuning van prestatiemeting, b) het standaard evalueren van projecten als leereffect in de organisatie en c) het vergroten van kennis over het degeneratieproces.

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LIST OF ABBREVIATIONS

BAM	Bataafsche Aanneming Mij
BCWW	BouwCombinatie Wâldwei (Build Combination Wâldwei)
EPCM	Engineering, Procurement, Construction Management
CBM	Condition Based Maintenance
CM	Corrective Maintenance
DBFM	Design – Build – Finance - Maintain
DG	Director-general
FBM	Failure Based Maintenance
KPI	Key Performance Indicator
MTC	Measured Term Contract
PAS55	Public Available Specification
PPS	Publiek Private Samenwerking (Public Private Partnership)
PvDB	Poort van Den Bosch
RAW	Rationalisering Automatisering Water en wegenbouw
RWS	Rijkswaterstaat
SG	Secretary - general
SLA	Service Level Agreement
SMART	Specifiek, Meetbaar, Acceptabel, Realistisch, Tijdsgebonden
SPC	Special Purpose Company
TBM	Time Based Maintenance
RCM	Reliability Centered Maintenance
ZOAB	Zeer Open Asfalt Beton

1 INTRODUCTION

The goal of this introduction is to give a rough sketch of the how this study is established. Therefore, the current change in the construction market and the consequences for the construction companies are shortly described. Thereafter, their immediate cause and the structure of this thesis are given.

1.1 CURRENT CHANGE IN THE CONSTRUCTION MARKET

In this paragraph the change of the infrastructure market is discussed.

THE NEW MARKET APPROACH OF RIJKSWATERSTAAT

In the last few years, a change has taken place in the infrastructure market. Rijkswaterstaat (RWS) started a transformation process from being an infrastructure oriented management organization towards a public oriented network manager. RWS is the main contracting authority in the Netherlands for infrastructural projects. They are responsible for the Dutch national network of roads and waterways. Their activity program consists of maintenance, repair, renovation and new construction to keep road infrastructure in optimal condition. They work under the authority of the Minister and the State Secretary of Transport and Public Works. Due to the parliamentary inquiry in 2002/2003 the government became aware that the relationship with the market had to be changed. For RWS this meant that their policy had to change towards a more frequently and early use of the market.

This transformation has implications on the infrastructure market because more and more integrated contracts enter the market. The result is that private parties (e.g. contractors) become responsible for the design, construction, operation, maintenance, and sometimes also financing a project for 20 to 30 years. This change needs new ways of working for both RWS and the construction companies.

According to the business plan of RWS, is "*The market, unless…"* the basic principle for the new market approach (Rijkswaterstaat, 2004). RWS will act as a professional principal. This means that work that can be (or better be) done by the market, will be left to the market. They will concentrate on the front of the design- and build-process. The market gets the opportunity to call forth all their skills and creativity. Besides this, RWS will focus towards price and quality. A suitable option for this new approach is the use of innovative procurement because it gives abundance on the market for new knowledge and experiences.

CONSEQUENCES FOR THE CONSTRUCTION MARKET

One of the methods to achieve this goal is using a DBFM-contract (Design, Build, Finance and Maintain). The constructor will become responsible for all the mentioned phases for a long period of time. All the included risks are allocated by the principle of 'the party that can control the risk best will bear the risk'. Besides the risk allocation, the contractor will also be responsible for the proof of meeting the performance levels stated in the contract. As a result, the workload for RWS will decrease during the executing of the contract because they have fewer responsibilities. But on the other hand, RWS will need to change their specification of requirements (e.g. into performance levels) which needs a different way of thinking and takes a lot of effort.

A DBFM-contract is a performance based contract which means that the contractors have to come up with (new) solutions because technical specifications (e.g. specific materials) are less prescribed. Besides this different way of specification, the contractors are also responsible for 20 to 30 years of maintenance. This implicates that there is an incentive to think about the maintenance stage. A strategy for allocating and spending the budget during this stage is necessary. Consequently, contractors need knowledge about the behaviour of the materials they use, about the costs of maintenance, about the effects of the design on the maintenance and about providing

service. In order to obtain all this information, inspections are needed before and during the operational phase, and some sort of performance measurement system is required. Also the implications on investment costs and maintenance costs need to be clear. All these changes can be summarized as the need for Asset Management knowledge.

Asset Management is a process that is recognized by many fields, for example financial services, information technology and electronic services. Many definitions exist for Asset Management but they all have the same common view. According to Tywoniak, Rosqvist, Mardiasmo, and Kivits (2008) Asset Management can been seen as the process in which assets are 'put through' in order to create a product or provide a service at optimal level. The maintenance phase should be included for optimizing the whole construction process. The overarching goal is to increase the efficiency of assets, which comprises enhancing asset productivity, maximizing asset value through the life-cycle, and minimizing the total cost of ownership. For construction companies this means that they need to (Tywoniak, et al., 2008):

- Understand business costs and performance drivers;
- Determine investments to optimize performance and operational costs;
- Manage the delivery of network performance and investments programs;
- Monitor asset conditions;
- Devise appropriate maintenance policies.

The complex nature of construction projects makes this a difficult task. The projects are dynamic and take a long time to develop and construct. Especially the development of a strategy for the maintenance stage is a difficult task. This stage is the longest stage of an integrated project, with many factors that can influence the project. Therefore the developed maintenance strategy should be flexible to be able to react on changes. This study will contribute to the identification of important aspects that need to be controlled to influence the maintenance strategy during the maintenance stage. Understanding of these key aspects is the first step towards optimizing the maintenance performance. BAM Infraconsult has commissioned this study (Appendix A).

1.2 MOTIVE FOR RESEARCH

Construction companies have little experience with DBFM-contracts, as only a few projects are executed today. The Wâldwei–N31 is the first DBFM-contract in the Netherlands put out to tender by RWS. This project consists of the construction of an additional lane in both directions including 15 years of maintenance. The construction phase of the project has been completed in October 2007 which means that the maintenance phase has commenced. The BAM is one of the consortia members in this project. Another DBFM-project in which the BAM is a consortium member is the PPS-A59. This project is the very first DBFM-contract in the Netherlands. This project is not put out to tender by RWS but by the province, which is an unusual situation. The project consists of the construction of a new highway (A59) including 15 years of maintenance.

During an initial consultation with BAM Infraconsult the two DBFM-projects were discussed. An evaluation of both projects was made directly after the construction phase by the involved parties. Many lessons were learned and recommendations about the maintenance phase have been made. One recommendation is the need to invest in the development of maintenance management to keep the lead over the competition (Infraprovider, 2007). This recommendation is supported by the following recommendation: in order to learn from the experiences it is necessary to cluster the information of the projects, hence there is a need to invest in knowledge management (Rijkswaterstaat, 2008).

A new evaluation makes it possible to include the experiences (based on the first maintenance years) of the maintenance phase. This phase (maintenance and operate) is an important phase for optimization because almost 80% of the Total Cost of Ownership are made here (Jonge & Timmer, 2009). Knowledge about how the maintenance phase performs and what processes influence the performance can make this phase more successful and can be helpful to increase the efficiency of assets as stated by Tywoniak (2008). This knowledge can be used to develop maintenance strategies for other integrated projects, such as the recent DBFM project A12 (project solely executed by BAM).

1.3 STRUCTURE OF THESIS

At the start of this study a literature study is carried out in order to obtain proper understanding of the subject matter. Besides the literature study several consultations with BAM Infraconsult have resulted in the problem definition. This report discusses the problem and gives an answer to the research question (see chapter 2). The following research model (Figure 1) represents the schematic overview of the most important steps that are taken in this study. Related chapters are given in the clarification of the model and are described below.

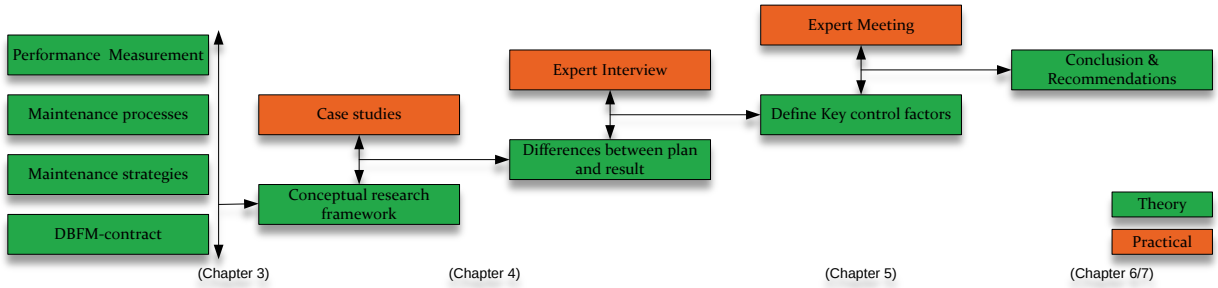


FIGURE 1: RESEARCH MODEL, METHODOLOGY OF VERSCHUREN AND DOOREWAARD (2007)

Chapter 1 *Introduction* – discusses the establishment of this research by introducing the current situation in the construction market and gives the motive and structure for this study.

Chapter 2 *Research Design* – discusses the conceptual and technical framework of the study. These two topics will provide insight into what the study is about. The problem context, the objectives, the research questions and boundaries are given. The choices for using case study research, the execution and selection of the cases are also discussed.

Chapter 3 *Theoretical Framework* - gives an overview of the theory and background information for this study. The knowledge gathered in the literature helps to find relations between the different topics and gives the theoretical foundations that are used for understanding the maintenance stage and the cases. First of all the literature about performance measurement is discussed. The second section of this chapter discusses the different maintenance strategies and their effect on the maintenance cost. Thereafter an overview of what processes can be found in the maintenance stage is given. This will altogether result in the design of the research framework that is discussed in the last section.

Chapter 4 *Integrated project of the Royal BAM Group* - discusses the case studies. The case N31 – Wâldwei and the PPS-A59 are both studied. This chapter gives an overview of the projects based on conversational interviews with the operators and the project plans. Thereafter, a more descriptive perspective is used by more structured interviews with both the operators and project directors. This information makes it possible to check what aspects described in the framework are present in the cases. The goal of this chapter is to evaluate the projects based on the aspects described in the framework.

Chapter 5 *Important processes and Improvements* – discusses the aspects of the maintenance stage that need to be controlled based on the results of the case studies. Where chapter 4 discusses the presence of processes, this chapter discusses what processes are important in the maintenance stage. The aspects that are already under control in the projects as well as the aspects that need to be controlled are given. The result of the analysis is discussed with experts to find the most important/relevant processes of the maintenance stage.

Chapter 6 *Discussion* – gives the discussion of this study and the discussion of the results.

Chapter 7 *Conclusions and recommendations* – provides the conclusion of this study and some recommendations for the BAM as well as for future research are given.

Chapter 8 *Limitations* – discusses the limitations of this study.

The **Appendices** give information about BAM Infraconsult, DBFM-contracts, the case studies, the interview protocol, the expert meeting protocol and the PAS55 questions.

2 RESEARCH DESIGN

The following chapter discusses the conceptual framework and the technical framework. The current situation in the construction market is translated into a problem formulation, objectives and research questions. The strategies and methods used for this study are explained in the technical framework. The goal of this chapter is to make clear what is included in this study, which perspective is used and what methods and strategies are used to find a solution of the described problem.

2.1 CONCEPTUAL RESEARCH FRAMEWORK

The focus of the conceptual framework is the presentation of the research concepts and to clarify the research questions and objectives. Hence, this section determines what, why and how much is studied. It consists of the problem context, the problem statement, the objectives, the research boundaries, research questions and the research model.

The conceptual research framework is designed based on the concept of business problem-solving (van Aken, Berends, & van der Bij, 2007). This means that a problem can be defined as a certain situation in the real world with which one or more stakeholders are dissatisfied. That is, the problem statement is a choice made by the researcher together with the stakeholders, in this case the BAM. In order to count as a problem, stakeholders should believe that the situation can be solved within a reasonable amount of time, spending a reasonable amount of resources. To put it differently, the problem could be solved within half a year of work by the researcher.

PROBLEM CONTEXT

Infrastructural projects are more often being put out to tender as integrated contracts instead of RAW-contracts[2]. During the tender, construction companies come up with a high variety in costs. This is a rather strange situation because the profit margins are narrow in the construction industry. It alludes to a situation where construction companies do not have a clear idea about the expected costs and the way the costs can be controlled. They are forced to make a rough estimation about the life cycle costs based on no past experience.

In the Dutch building industry little information is available to make a cost-estimate for those integrated contracts. The difficulty is to make an estimate about the cost for the upcoming 20 years of construction and maintenance. Many firms make assumptions based on their RAW-contract experience, in which every technical aspect is prescribed. Next to this, the contract is designed for a specific construction phase. Due to this situation there was no incentive to be innovative or gather knowledge about the life cycle of projects. By contrast, the current change towards integrated contracts makes it necessary to obtain this information. As a result construction companies could increase profit if they improve their performance by developing new technologies, understanding of the processes that influence the project, or by improving their accuracy of cost estimates.

Performance can be defined as to meet one's commitment. The required performance in a project is established in a performance contract that usually is a part of integrated contracts. A performance based contract is a contract in which the principal describes the required situation, is rather reserved with prescribing activities, gives the contractor freedom in the design and execution of activities, and creates a link between the (delivered) performance and payments in a predetermined period (Schoenmaker, 2011). This changes the commitments of the contractors, and the way in which they can improve their project activities. In contrast to other industries, just a

[2] The standard RAW-provisions are a comprehensive set of legal, administrative and technical provisions . These provisions automatically apply to all RAW-specifications. They are the result of consultation between clients and contractors. The provisions are used by clients to write a RAW-contract. (CROW)

few studies have been conducted to improve the performance of construction projects. The studies all agree on the usefulness of performance measurement, but they differ in the way they approach performance measurement. The performance can be approached in relation to the product as a facility or in relation to the creation of the product. The latter one has been the prime performance measurement of construction projects (Kagioglou, Cooper, & Aouad, 2001). This means that the focus is on time and cost. A more balanced view can be achieved by using other techniques such as Total Quality Management (TQM) that shifts the focus from 'lagging' indicators towards 'leading' indicators. Some studies propose Key Performance Indicators (KPIs) to benchmark projects (Bakens, Vries, & Courtney, 2005) which leads to the possibility of finding the best in class.

The influence of the construction stages on performance in a project is recently studied by Haponava (2009). She has indicated process-based KPIs for the pre-project stage, design stage and construction stage. However, the maintenance stage is not specifically considered because of the traditional separation of the construction stages. The use of integrated contracts creates an incentive to identify the main aspects within the maintenance stage for performance measurement.

Figure 2 indicates the project stages and the opportunity to influence the costs. It illustrates that the influence on the outcome of the project is much easier in the beginning of the project. This makes the processes in the early project stages critical for the performance of the maintenance phase. However, the length of the maintenance stage and the high costs for changes make it critical to have a sound maintenance strategy. The maintenance stage of an integrated project is the stage where payments are received if the required performance is delivered. However, unforeseen circumstances can call for a change in the developed strategy because it is almost impossible to predict the future.

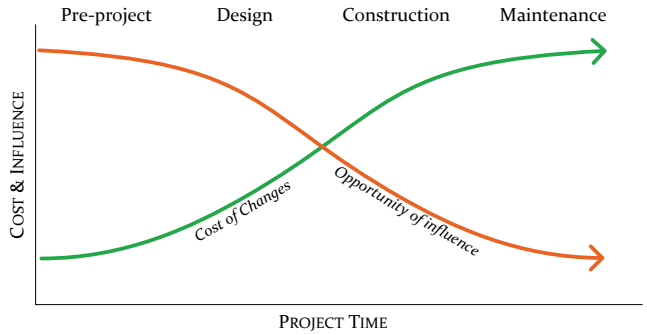


FIGURE 2: INFLUENCE ON PROJECT COST OVER VARIOUS STAGES (WINCH, 2002)

PROBLEM STATEMENT

It is difficult to design a maintenance strategy that predicts or handles all influences for the upcoming years (>15 years) of maintenance. The ever changing environment makes it necessary to design a flexible maintenance strategy. Moreover, the more frequently use of integrated contracts makes this situation a strategic issue for construction companies. Therefore, the aspects that need to be controlled to steer the maintenance stage for integrated projects are proposed as the central problem of this study project. The focus is on infrastructural projects.

> **Problem Statement**
> *"The design of a maintenance strategy for an integrated contract is difficult because of the future influences on the project and the inexperience of which aspects need to be controlled to influence the maintenance stage in such a way that the performance of the project will improve."*

OBJECTIVES

As stated above, there is a need for insight into the effects of maintenance strategies on the performance and the way the strategies can be influenced to improve the value of an infrastructure

system. By summarizing these factors, insight in the relation between the maintenance strategy and the maintenance situation of the system can be given. This will improve the efficiency and effectiveness of work packages and work processes.

The current situation at the BAM (and the whole construction industry) is that the aspects that influence the maintenance performance and their degree of influence are not known for integrated contracts. The first objective is to list aspects that can control the maintenance performance during the maintenance stage according to literature. Based on this knowledge measures to influence these aspects and how to control maintenance performance can be attained. For the BAM the costs for maintenance are an important aspect of projects. Therefore the objectives of this study are to identify the aspects that influence the maintenance costs of integrated contracts and which measures can be taken to optimize the maintenance strategy. This can eventually lead to the identification of process-based Key Performance Indicators (KPIs) for the BAM that need to be controlled to optimize the performance-cost relation of the maintenance stage.

> **Objective**
> *"Study the processes that the BAM needs to control in the maintenance stage to influence the maintenance strategy for an integrated infrastructure system, and to improve the performance of the maintenance stage."*

The relevance of this study can be described scientifically and practically. The practical relevance of this study is the learning effects of future improvement programs for the BAM. It will contribute to the development of maintenance management which is one of the recommendations made by Infraspeed (2007). Improved knowledge about how to optimize the maintenance strategy gives the BAM an advantage in keeping the lead over the competition. Knowing what aspects are important to control (when unforeseen situations occur) will increase the appearance towards the client as well as the end users. It also fits in with the recent developments in the construction market.

Creating a link between literature and the practical situation gives the scientific relevance of this study. It gives a practical contribution to literature by indicating process based KPIs of the maintenance stage. The results can also lead to improved understanding of how the integrated contracts affect the maintenance stage.

RESEARCH QUESTIONS

The research questions to accomplish the objective are divided into one main research question supported by sub-questions.

> **Research Question**
> *What processes does the BAM need to control in the maintenance stage of an integrated infrastructural system to improve the performance of the maintenance stage?*

In order to find answers to this research question the current practice at the BAM will be studied to find important learning experiences and aspects that need to be controlled. Before the cases can be studied it is necessary to understand what maintenance and performance measurement means. Therefore the following sub-questions are stated below with an explanation of the purpose of each question.

1. *What is performance and how can it be measured?*
   This sub-question will give a definition of performance that is used in this study. It will give an overview of the indicators or Key Performance Indicators (KPIs) that are currently given in literature to define the performance of a system. Furthermore the possibility of how these can be used to decide on the execution of maintenance is studied. The knowledge gathered in literature will be translated into knowledge that can be used for the BAM.
2. *Which maintenance strategies can be found in literature and what are the effects on the performance of an infrastructure system?*
   This sub-question will discuss the different maintenance strategies that can be used for maintaining a highway system and the effects on the quality and costs of the maintenance.

3. *Which processes that influence the performance of an infrastructure system can be controlled*?
   In the literature different aspects can be found to influence the performance of maintenance. Listing these factors and relate them to an infrastructure system will provide a framework that can be used to find important aspects that can be controlled.
4. *What measures can be taken to improve the performance of the maintenance stage at the BAM?*
   Once the most influential factors are know, they need to be controlled. This sub-question will provide measures that can be used to control the factors for the Royal BAM.

RESEARCH BOUNDARIES

Many stakeholders are involved in infrastructural projects, each with different possibilities of influence. The perspective and the possibilities of influence are therefore discussed first. Based on this information the research boundaries are discussed.

Perspective

An infrastructural project is influenced by different stakeholders who all have another interest in the project. This means that each actor has different opportunities to influence the project. Asset management defines three important roles, asset owner, asset manager and service provider (Figure 3). The asset owner is in this case the Dutch government (read: Secretary-general). His objective is to determine the future of the whole infrastructural network by determining the policy goals. The objective of the asset manager – RWS (Director-general) – is to optimize the functioning of the infrastructure by determining the tactical planning and program management. The service provider – Contractor (e.g. Royal BAM Group) – is the private party (mostly a consortium) that executes the construction and maintenance of the project. Between the three parties agreements are made about the performance of the asset. Figure 3 gives a simple overview of the relation. The ministry and RWS make agreements based on Service Level Agreements (SLAs). RWS makes in turn agreements with the service provider based on a performance based contract (e.g. DBFM). The service provider has to perform as agreed, that is by meeting the performance, efficient planning and defining budgets. The mission of the service provider can be generally defined as optimal execution of the realizations and maintenance of the project.

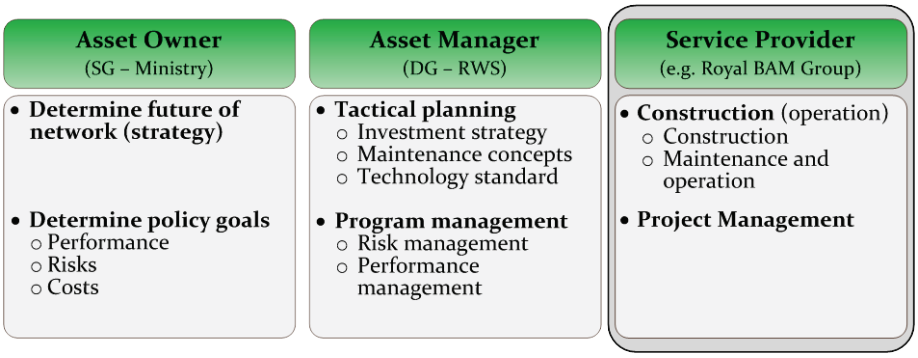


FIGURE 3: DIFFERENT ROLES FOR INFRASTRUCTURE ASSET MANAGEMENT (VAN DER VELDE, 2010)

This study is executed based on the perspective of the service provider, more specifically from the perspective of the project management. The maintenance department is responsible for maintaining the infrastructural asset but the project leader is responsible for the whole project. Project Management will be the actor that will benefit the most because the involvement throughout the project.

An integrated contract is a complex contract which is explained in detail in appendix B. For the purpose of this study the agreements made between the Special Purpose Company (SPC) and the maintenance contractor are taken as research boundary.

Single Infrastructural project

The maintenance phase in construction projects is becoming more important for construction companies due to the new market approach of RWS. Figure 4 gives a good indication on how the stages are studied. The figure shows the different possibilities of optimizing. The individual interventions can be optimized (e.g. is a maintenance task on this object worthwhile?), the

combination of tasks can be optimized (e.g. various life cycle activities for the same asset of activities on various components of an asset), and the activity program delivery, such as work bundling and resource levelling, can be optimized. In this study the life cycle of a single infrastructural project is analyzed, the optimization of the activity program of the service provider is not considered. That is, only the activities related to the project are considered, and not the optimization of similar activities of other projects. The specific maintenance processes for the project are analyzed by first designing a framework, with a focus on the maintenance phase.

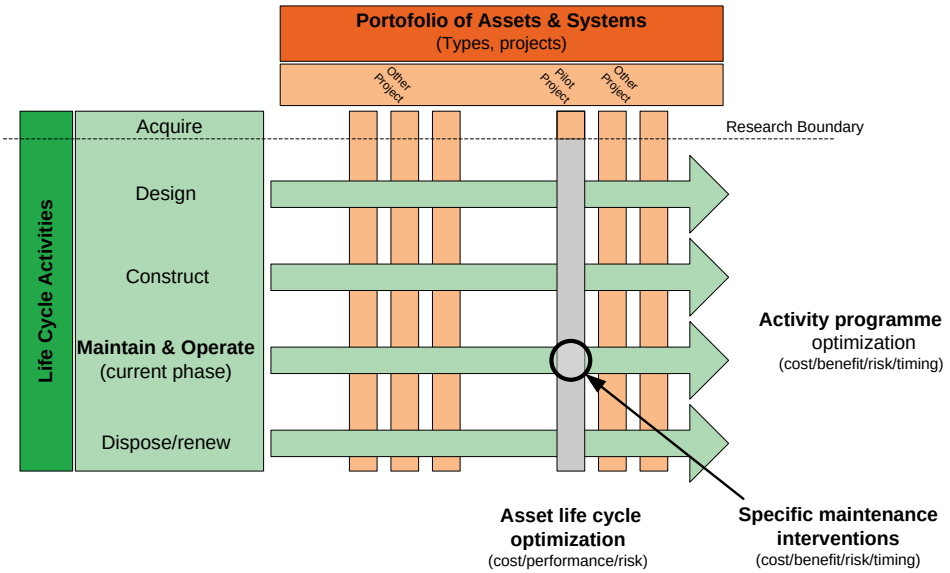


FIGURE 4: RESEARCH BOUNDARY (THE INSTITUTE OF ASSET MANAGEMENT (IAM), 2008)

2.2 TECHNICAL RESEARCH FRAMEWORK

The technical framework is described to give the methods that are used to realize the goals of the conceptual framework. Hence, this chapter answers the question of how the study is executed. This is done by first describing the research strategy. Thereafter the research methods are discussed.

The design of this study is a combination of a development- and design oriented approach (van Aken, et al., 2007). A development oriented approach is described as a step-by-step learning approach, each step is based on what is learned in the previous step. A design oriented approach can be described as a learning-before-doing approach. A dialogue with the BAM is used to get information on the problem, to get feedback on the proposed solutions and to develop acceptance. It was not possible to design a valid model of the future system and expected performance, therefore the use of a development oriented approach is used. The design of the first step is easier than producing the complete and final design, and thereafter the subsequent steps on the basis of experiences gained in the process. In this study a combination is used by designing a pilot implementation of the N31–Wâldwei to design the first step, followed by up-scaling the step to the PPS-A59 on the basis of the lessons learnt at the N31-Wâldwei. Another important dimension for this choice is the availability of data. It was reasonable to expect that data could not be made available because the little experience with integrated contracts and little availability of historic data. A development approach is therefore preferable.

RESEARCH STRATEGY

The research strategy defines the related decisions at large about the way the study is executed. The five most important strategies are according to Verschuren en Doorewaard (2007): survey, experiment, case study, a well-founded theory approach, and a desk research. In this study the case study and desk research are used. Literature is used as framework for studying the cases. For the gathering of data the principal of open data collection is used. The framework is developed

based on the experiences during the study. First an open-ended interview method is used for gathering information followed by a more structured interview for analyzing the data.

Desk Research

Desk research is firstly used to examine literature on performance measurement, maintenance strategies and other related topics to understand the current available knowledge and to create understanding for the situation of the cases. The desk research is also used to study the project documentation available at the BAM about the cases. The employees involved in the maintenance stage of the cases are limited which makes the desk research important to study the projects. Both the literature based knowledge and the practical knowledge are used to develop the framework for analyzing the cases.

Case study

A case study is used to get a profound and complete understanding of objects and processes of "real world" events. It is labour-intensive because often interviews with open ended questions are used, but it is an appropriate method because it is feasible within the available time (6 months). It is not necessary to have a high level of preliminary structure and it gives an interesting view on the case for a junior researcher. According to McCutcheon (1993) it is *"an objective, in-depth examination of a contemporary phenomenon where the investigator has little control over events"*. In this study the main focus is not to describe the maintenance situation but more on identifying decisions; why where they taken, how are they implemented and what is the result of the decisions. Using the terminology of Yin (1989) the cases in this study can be considered as "descriptive" as well as "explanatory". The potential output for "descriptive" case studies is the description of events and outcomes to understand the processes and environment. This is achieved based on conversational interviews with the operator. The research goals for explanatory case studies focus on the identification of factors that appear to influence a particular process, which is comparing the theory with the actual values. The more standardized open-ended interviews are used for this.

Case selection: N31–Wâldwei & PPS-A59

An important condition for selection of cases is that the project is an infrastructural DBFM-project in the maintenance stage. Furthermore, the availability of project documentation and the possibility of interviewing employees are important conditions. The selection of the cases is based on the following selection criteria.

- Infrastructural DBMF-project;
- Project is in the maintenance stage;
- Possibility to interview employees;
- Availability of project documentation.

For this study two cases are analyzed, N31-Wâldwei and PPS-A59. This is a small number, but these are the only two projects currently available based on the conditions mentioned above.

Case interviews

Relevant information is studied by using project documentation and by interviewing project employees of the project N31 and A59. In order to prevent "bias" it is chosen to interview employees of different management levels. This means that interviews are held with project directors and maintenance managers or operators (these names are used alternately).
There are different types of interviews that can be used to gather the desired information. The informal, conversational interview has no predetermined questions and should be as open and adaptable as possible. This type of interview is used to get a preliminary view of both cases. It can be seen as an incremental improvement strategy, with the next step based on the lessons learned in the previous step. An interview with the operator of the N31 and the A59 has been used to get a preliminary overview of the projects.

Thereafter, a more appropriate interview technique for identifying the aspects that need to be controlled in the maintenance stage is used, the standardized open-ended interview. This approach facilitates interviews that can be more easily analyzed and compared. For both projects the operators and project directors were interviewed. This makes it possible to compare the view

of the employees "in the field" with the view of the management. The management is involved in the design of the plans, whereas the employees "in de field" are involved in the execution.

Data analyses

For the analysis of the cases there are according to Verschuren and Doorewaard (2007) two possibilities: the hierarchical method and the sequential method. In this study the hierarchical method is used. First the separate cases are studied as if it is a singular case. The study of the cases is done based on a fixed pattern, this makes it possible to compare the two cases. In this comparison the similarities and differences are mapped and an explanation is searched. The results are discussed in expert meeting for validation of the results. Some aspects of the sequential method are also present in this study. First the project N31 is studied. Based on these results it is chosen to study the A59 also.

A disadvantage of this analysis is that the external validity is subjected to pressure. The use of two cases makes it difficult to explain the result in general terms. However, because this study is executed for just one organisation, the Royal BAM Group, it is not explicitly necessary to explain the results in general terms.

RESEARCH METHODS

The findings and conclusions in this study are based on different projects in a particular situation; it is therefore difficult to generate a general theory. The analysis of the cases will develop relevant problems, causes and consequences. That is, uncovering the causes of the problem (van Aken, et al., 2007). However, to justify the causes and the appraisal it is important to discuss the most important quality criteria: controllability, reliability and validity (van Aken, et al., 2007).

Controllability

The controllability is the description of how the study is executed to enable others to judge the reliability and validity of the study. The research strategy discusses how the data is collected. The employees selected for the interviews are selected based on their function in the projects as described in the research strategy. The questions that were used during these interviews can be found in the appendix. Based on these descriptions it is possible to check how this study is executed. Furthermore, this study can be controlled by the structure of the report. This makes it possible to trace the steps that are taken. The results and the literature can also be traced back to its source.

Reliability

Reliability is the consistency of measurements derived from repeated observations of the same subject under the same circumstances. Using multiple sources and writing down the sources of information will increase the reliability of the study. The usage of a tape recorder helped to make the information collected with interviews more reliable. For the interview a list of specific questions that must be kept in mind is used to collect the data. These questions can be found in the interview protocol (Appendix E).

Validity

Validity determines whether the research measures that what it was intended to measure. This is called construct validity. In other words, it is concerned with the study's success at measuring what is set out to be measured. Internal validity concerns conclusions about the relationship between aspects. By using multiple sources, e.g. interviews and documentation, the validity (construct and internal) can be increased. Review of draft versions of the case study information will also help to increase the validity. This is done in collaboration with the BAM and the university.

Another perspective of validity is the external validity. This is concerned with how generally applicable the conclusions are. It is difficult to draw conclusions just on a single case. The simplest way to improve the external validity is to increase the number of cases. However, due to the limited amount of available projects and time restrictions this is not possible. Therefore the expertise of a number of experts is used to improve the external validity. They have knowledge based on more cases which can be used for improving the external validity. Another way to 'improve' the external validity is by reducing the applicability only to projects at the BAM.

The external validity is based on just two cases and the perception of four experts. The results and conclusions have therefore little external validity. To increase the external validity it is chosen to arrange an expert meeting to validate the results and to discuss the opportunities for usage at other related projects.

Expert Meeting

To increase the empirical relevance of this study the results are presented and discussed with experts during an expert meeting. Different methods can be used to elicit insights and experiences of experts. For example, everyone in the same room compared to 'on the phone' or 'written', experts that are familiar with each other or do not know each other, or strive to consensus or not (swanborn, 1991). In this study an expert meeting is used where the participants will be in one room. The participants know each other and all work at departments of the Royal BAM Group. The results of this study are first presented by the researcher, followed by a point-by-point discussion. This is first of all done for validation reasons. Next to this, it creates the possibility to make additional comments and to discuss the possibilities for usage at other projects.

The results of this session are used to strengthen the conclusions and recommendations, and to make sure that the results are known by employees at the BAM. The protocol for the design-session is added in the appendix.

3 THEORETICAL FRAMEWORK

In this chapter the literature that is used for developing a framework to analyse the cases is discussed. First of all the topic "Performance management" (3.1) is discussed. This section gives an answer to the first research question which discusses the definition and necessity of performance management. Furthermore the current (Key) Performance Indicators (KPIs) found in literature are discussed. This gives an overview of the current level of performance measurement according to literature. Section 3.2 discusses what maintenance is about and discusses the different maintenance strategies and their effects on the performance of maintenance. This section gives an answer to the second research question. Section 3.3 discusses what processes can be found in the maintenance stage and how this can be modelled to measure performance. The last section (3.4) discusses which choices have been made for the development of a research framework that is used in this study.

3.1 PERFORMANCE MEASUREMENT

"*The performance management process is the process by which a company manages its performance in line with its corporate and functional strategies and objectives*" (Bititci, Carrie, & McDevitt, 1997). The process by which a company manages its performance can be defined as the quantification of the efficiency and effectiveness of actions (Neely, Gregory, & Platts, 1995). It determines how successful an organization is in attaining their objectives by monitoring and diagnosing (Atkinson, Waterhouse, & Wells, 1997). This means that the basis of performance measurement is that unless a score is kept, it is difficult to know whether you are winning or losing (Kutucuoglu, Hamali, Irani, & Sharp, 2001). It is the comparison of results against expectations with the objective to learn and do better (Paul Rouse & Putterill, 2003).

Performance, in this study, is defined as the choices that are made between the quality of a system and the needed (financial) means to attain the company objectives and targets. The performance of a system is primary defined in the contract and secondly in the corporate and functional strategies and objectives. A tight condition is that the contractual agreements are met at all times. According to Dell'Isola (1997) it is impossible to define maximal performance, only an optimal performance can be reached by minimizing costs and maximizing functionality and quality. The three parameters are derived from definitions of Dell'Isola (1997):

- *Functionality:* The specific function that fits the requirements of the contract. These are the tight conditions defined in the contract that need to be met.
- *Quality:* The expectations and requirements of the (end) users.
- *Cost:* The total maintenance cost

Quality can be seen from different perspectives, for example from the (end) users, the client, the environment, or the contractor. In this study the perspective of the contractor is used. What quality is and how it is controlled is defined in the maintenance strategy of the contractor. The two situations that lead to an optimal performance in this situation are reducing the cost or/while increasing the quality. In section 3.2 the strategies that can be used to reach this situation are discussed.

It has been acknowledged by many authors and practitioners that maintenance is a major contributor to the performance and profitability of manufacturing systems. However, for the construction industry only a few studies have reported on performance management, not to mention performance management on maintenance. The difficulty in the construction industry is the project-oriented procedures and the complexity of the projects. This makes it a difficult task to

align the company mission, strategy and the objectives by linking these throughout the organization and to make them measurable by reporting the critical success factors and other indicators. Nevertheless, performance measurement is valuable for various reasons that are discussed next.

VALUE OF PERFORMANCE MEASUREMENT

Tracking the performance of maintenance is a key management issue for organizations that spend a significant amount on the operating budget, like infrastructural assets. During a study of the APQC (American Productivity & Quality Centre) in 1996 two observations about performance management have been made which shows that companies that measure performance have lower maintenance cost and lower proportions of reactive maintenance (Tsang, Jardine, & Kolodny, 1999). The performance measurement makes them more aware about the influences on the maintenance phase. This example shows the importance of performance measurement. However, companies that do measure performance rely according to Nudurupati et al. (2007) mostly on traditional performance measures. The characteristics of the measures are dominated by financial or other backward-looking indicators such as profitability, return on investment, and utilization. Relying on these indictors makes that factors that created value are difficult to consider, and that little notion is taken about the asset creating, growth and maintenance. As a result, they have poor measurements of innovation, learning and changes, and they concentrate on immediate rather than long-term goals, which are important for the maintenance of assets.

According to Kutucuoglu (2001) is performance measurement about determining how successful an organization is in attaining their objective. Drongelen & Cook (1997) enlarge this definition by also including the acquisition and analysis of information. They also mention that the factors that influence that attainment can be included as well. That is, measurement is needed if a process needs to be evaluated based on what you want to achieve. If you want productive maintenance, then measurement of maintenance productivity is needed. If you want to achieve strategic maintenance, then constantly review of the strategic objectives is needed. If you want to get continuously improvement, then you need to compare the maintenance with peers and learn from the most successful peer. Comparing the actual cost to a 'static' standard cost is not compatible with the philosophy of continuous improvement. That is, setting a budget and try to stay within the budget is not an example of continuous improvement. Trends as well as deviations from the 'standard' could be identified. If a 'standard' is established, then it should be based on the best-in-class instead of the organizations historical performance level. The difficulty in the construction industry is that the best-in-class needs to be established first. This can be done by continuously improving the historical performance.

For integrated projects there is little information about the historical performance since only a few projects are on the market. The 'standard' could be to be set by determining deviations from the predetermined budget and considering the deviations in the expenditures for maintenance.

PERFORMANCE MANAGEMENT FRAMEWORKS

The simplest form of performance measurement is the Deming circle (Deming, 1994). This circle describes the four phases 'plan', 'do', 'check', 'act' which are needed for continuous improvement. There is not a general framework that measures performance as can be seen by the development of many frameworks by different authors in the past. A general aspect of all frameworks is that they try to integrate different factors that are critical to success of a business. The traditional financial perspective does not integrate all factors; therefore also non-financial factors are often included. Performance measurement frameworks that do include other factors are the Balanced Scorecard (Kaplan & Norton, 1996, 1998), Performance Pyramid SMART (Strategic measurement analysis and reporting technique) (Cross & Lynch, 1988), input-output framework (Brown, 1996), and Performance Measurement matrix (Keegan, 1989).

Each framework has its advantages and shortcomings, but they all focus on the measurement and comparison of levels and objectives based on the structure of organizations. Nevertheless, the performance frameworks are never complete, it is not possible to measure all the aspects from reality in the framework. The difficulty with maintenance is that it is cyclical which means that performance measurement is not a onetime only activity. It is a continuous process with

interrelationships between measures. This makes performance measurement difficult. For example, the output of maintenance activities has to meet different requirements. The question is which requirement is more important, the economic requirements or the environmental requirements? Furthermore, the measurement of quality needs more than only quantitative measures. The time before a maintenance activity is executed after reporting is not telling anything about the quality of the activity itself.

Before a suitable framework can be given, the maintenance stage should be analyzed first. The complexity of the framework depends on the number of inputs and outputs that are used. For single-input and output cases, the operational performance can be analyzed as the ratio of output to input. A complex case of different units of measures can occur with multiple inputs situations (or output situations). An example is comparing maintenance performance of highway systems. The inputs can include available kilometres or trips per day, traffic conditions, geometry of the highway or even contract conditions. Outputs could be maintenance cost per car or costs for routine maintenance activities. This example shows that the units of measures are diverse and complex. Tsang (1999) defines performance analysis as the measurement and comparison of levels of achievement of specific objectives. Before the framework used in this study is given, the measures and indictors available in literature are discussed.

MAINTENANCE KPIS FOUND IN LITERATURE

Many companies in the construction industry rely on traditional performance measures based on the 'iron triangle' such as profitability, return on investment (ROI), utilization, etc (Nudurupati, et al., 2007). Today indicators that consider client satisfaction, health and safety are also becoming important (Bakens, et al., 2005). Techniques such as Total Quality Management (TQM), benchmarking, business process re-engineering (BRP) and process management have shifted the focus from 'lagging' to 'leading' indicators (e.g. health and safety) (Kagioglou, et al., 2001). In the construction industry the use of Key Performance Indicators (KPIs) has been proposed to give benchmark information for finding the best in class. The result is that there are different programs in several countries that try to develop performance indicators.

The Construction Best Practice Programme (CBPP) launched 12 headline KPIs. These were broken down into KPIs at operational and diagnostic levels. The headline KPIs are used to measure the overall business state while the operational KPIs are used to measure specific activities that enable management to identify and focus on areas of improvement (Nudurupati, et al., 2007). Some authors criticize these KPIs because they are all lagging indicators that do not provide opportunities for change. The continuous process of maintenance makes these lagging indicators less useful in the maintenance stage.

In manufacturing industry literature an outline of common performance indicators is provided which usually represents the operational view of maintenance according to Kutucuogulu (2001). Maintenance is generally measured by the impact on flexibility, quality, costs, environmental and employee safety. Some other examples of performance ratios include availability, mean time to failure, manpower utilization and overall maintenance cost effectiveness. These measures can provide a balanced view of the maintenance system but are likely limited for the operational and tactical aspects of infrastructure maintenance. Next to this, the information needed for these indicators is not available. Other types of indicators consider the maintenance efficiency (e.g. total production time), task efficiency (e.g. number of completed tasks), organizational efficiency (e.g. time planned for scheduled tasks) or profit/cost efficiency (e.g. total maintenance cost) (Kutucuoglu, et al., 2001). Sharp et al. (1997) identified critical success factors associated with maintenance. They showed that improved maintenance performance can be achieved by the use of total productive maintenance. Total productive maintenance is about the overall equipment effectiveness (OEE) which is defined as a function of equipment reliability, quality rate and equipment performance efficiency (Kutucuoglu, et al., 2001).

Maintenance can also be approached from different perspectives according to Pintelon and Van Puyvelde (1997). Different perspectives need different indicators. Accountants will think of maintenance in terms of costs, top management is interested in budget performance, engineers will focus on techniques, and production will see performance in terms of equipment availability

and support responsiveness. This makes that an operator will need other indicators than the management of infrastructural projects.

PERFORMANCE MEASUREMENT AND MAINTENANCE

The development of performance measurement and related indicators is not simple as is seen in the previous section. A short preview into the characteristics of maintenance is described here to make clear that the performance measurement for maintenance is complex. These characteristics are the degree of complexity, the degree of independency, and the degree of recognisability (Schoenmaker, 2011). The complexity is caused by the choices that have to be made between alternative measures. The independency is influenced by the dependency of other parties in the project, for example for information and authorisation. The degree of recognisability is influenced by retrieving the sources of failures, the time and costs that are needed to repair the failures, and the probability of the necessity of future planned maintenance. Furthermore, the effects of maintenance activities are not always visible during the project. These characteristics will be further discussed in section 3.2 and 3.3. The development of performance indicators is difficult due to the multiple objectives, the objectivity, the measurability and transparency of maintenance.

The short outline above about the maintenance phase provides some KPIs that could be used for maintenance but none are about maintenance as a process. It is therefore difficult to point out how processes contribute to the performance of the maintenance stage. Nonetheless, the performance of processes is seen as one of the main contributors to the performance of maintenance projects. A simple analogy is the result of a football game. If only the score of the game is measured than this does not tell anything about how the game is played. The performance of the team is known but if the game needs improvement than it is difficult to optimize. The result (score) does not give any information about the used 'process' during the game (Kagioglou, et al., 2001). Research into the important processes of maintenance can therefore help to indentify maintenance related KPIs. Some construction companies do use process measures but they face difficulties in measuring the diverse and complex processes in construction and engineering activities (Herbert S. Robinson, Chimay J. Anumba, Patricia M. Carrillo, & Al-Ghassani, 2005). Difficulties for measuring performance of maintenance will follow in the next sections.

3.2 MAINTENANCE STRATEGY

In the previous section it is mentioned that performance measurement about determining how successful an organization is in attaining their objectives. In this section the second research question is discussed. First of all the objective of maintenance is described. This is done by first discussing what maintenance is. Thereafter different maintenance strategies are discussed together with their intended effects on the performance. The discussion shows what strategies can be used to reach an optimal performance of maintenance.

OBJECTIVE OF THE MAINTENANCE STRATEGY

The maintenance stage is a primary function of infrastructure management and is generally the longest phase of integrated construction projects. It is required from the moment the asset has been constructed and is ready for use. The maintenance stage is about ensuring that the assets are adequately maintained and protected to deliver the required level of service, condition and performance (Too, 2008). Maintenance is needed to compensate the effects of general use and external influences. External influences can be described as the ageing, the penetration of substances in materials by the use of salt, chloride or ultraviolet rays. The effects of general use can be seen by the wearing of parts, failures, and the decrease of performance (Schoenmaker, 2011). The predictability of these effects is difficult which makes the predictability of maintenance activities even more difficult.

In this study, the scope of maintenance is seen as indicated in Figure 5. This figure gives a schematic presentation of the relation between maintenance and preservation. The goal of preservation is to make sure that the requirements set by the client about the existing asset are met; this is done by the execution of maintenance activities, inspections, and rehabilitation of objects. Rehabilitation is essentially reconstruction of the assets. This view fits the responsibilities of a DBFM-contract with performance requirements.

FIGURE 5: THE SCOPE OF MAINTENANCE (BASED ON (VONK, 2006))

Maintenance can be divided in regular and large maintenance activities on an operational level. On a strategic level choices about the maintenance strategy are made. This is described in the section about 'Maintenance strategy'. Regular maintenance activities are based on the repair of low severity defects, are carried out to reduce the speed of deterioration, and are necessary to keep the asset at the agreed functionality. These activities are performed on a daily basis. Example: the cleaning of the road and small repairs. For all these activities there is a yearly budget, and can also be called fixed maintenance. Large maintenance activities are aimed to repair the high-severity defects, are carried out on a regular basis (e.g. yearly) to restore the quality, and can be seen as an independent project. Example: resurfacing asphalt. These activities do not occur every year, in other words the activities are variable. These activities are mostly planned.

Figure 6 shows the interaction between regular and large maintenance on the quality of a road. The relation with maintenance costs is described next. A short interval of regular maintenance leads to high costs; an object is replaced while it could be repaired with little costs. The constant

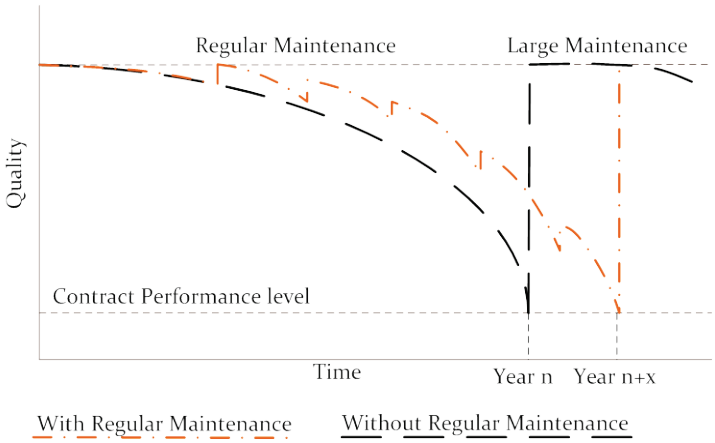


FIGURE 6: REGULAR AND LARGE MAINTENANCE (VONK, 2006)

execution of regular maintenance is only possible if the total maintenance cost of regular and large maintenance is minimal. If this is not the case, than the cost of regular maintenance is increasing faster than the cost of the replacement of the object. Therefore, the essence of maintenance can be described as: "*The essence is influencing the objectives that a company tries to reach with the system by executing maintenance or not, during the user phase of a system*". The strategic aim is to perform the right maintenance activities on the right time as to optimize the total benefit-cost relationships of a system over its lifetime.

MAINTENANCE STRATEGIES

The strategic choices that are needed by the planning of the different maintenance activities are based on different approaches. Traditionally, there are two primary approaches to achieve the maintenance objectives. Preventive maintenance is used to reduce the probability of failure in the time period after maintenance has been applied. Corrective maintenance strives to reduce the severity of equipment failures once they occur (Löfsten, 1998). The PASS 55 (The institute of Asset Management (IAM), 2008) describes corrective actions as actions that are used to eliminate the cause of a detected nonconformity or other undesirable situations. Preventive actions are used to eliminate the cause of a potential nonconformity or other undesirable potential situation.

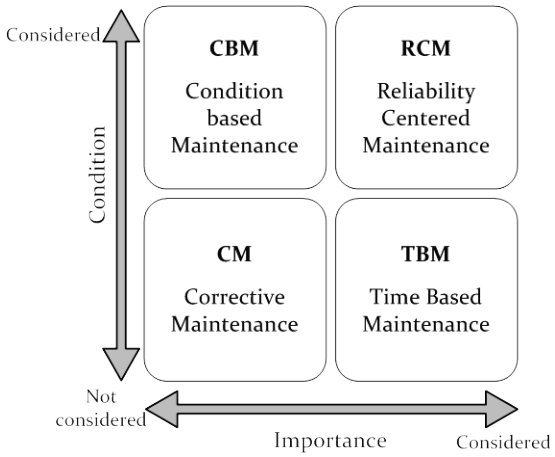


FIGURE 8: CLASSIFICATION OF MAINTENANCE. (SCHNEIDER ET AL., 2006)

The maintenance activities described above can be performed based on different strategies in order to reduce the possibility of a particular failure mode. They can be divided into different approaches which have great impact on the maintenance cost and asset availability. A variety of diagnostic tools is available to determine the maintenance regime required to deliver the appropriate levels of service at an accepted level of risk. The most simple maintenance strategy is based on a 2x2 matrix according to Schneider et al. (2006) (Figure 8). The classification is based on whether the condition of the component is considered on the one side and whether the importance of the component is considered on the other side. For this classification it is important to have a matching definition for 'importance' and 'considered'. Another but similar method is to define maintenance activities by the way they are initiated (Figure 7).

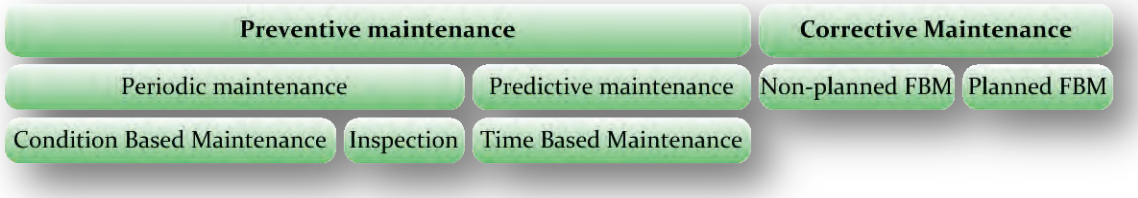


FIGURE 7: MAINTENANCE STRATEGY (BOUWCOMBINATIE WALDWEI, 2008)

Corrective maintenance

Corrective maintenance is the repair of one or more functions and objects with the goal to meet the requirements of the system. There are two main causes that can be distinguished for not meeting the requirements: incidents and accidents, and failures. Incidents and accidents are unforeseeable situations with regard to the system. The safety and accessibility of the system are in this case at issue. Failures are interruptions or a hampering which cause the system to fail in fulfilling its function; the safety and availability of a system are at issue.

TABLE 1: DIFFERENCE BETWEEN UNFORESEEN SITUATION AND FAILURES

Unforeseeable situation	Failures
Oil on the road	Unexpected collapse of the road surface
Tree that has fallen on the road	Fallen traffic sign
Cargo on the road	Damage of road (hole, crack, etc)
Accident	Light failure
Offensive graffiti	Subsided road

Failures can be reported by external parties, the client or during inspections. They can appear unpredictably and are therefore maintained by using failure based maintenance (FBM). An example is the replacement of a broken bulb. Sometimes it is a choice to use FBM for objects with a low risk and a short repair time. It is therefore possible to distinguish planned and non-planned FBM.

- Planned FBM: A choice is made to wait with maintenance until the failure occurs. This is done for objects with a low risk, a short repair time or because the variation in time to failure is too large or unpredictable to maintain the object based on inspections.
- Non-planned FBM: Used for objects that are maintained based on preventive maintenance but for some reason have a failure. This type of maintenance has high priority because the objects that are maintained preventively are mostly important objects for the functionality of the system.

Effects of the corrective maintenance
This strategy does not lead to the lowest total maintenance costs because the damages caused by the failures create more costs in the end than a different more appropriate strategy would cause. This strategy is only appropriate for non-critical elements with little consequences when failure occurs. This strategy needs little to no inspection.

The availability of the system is in danger when non-planned FBM occurs. Rapid responds is needed because the objects concerned with this type of maintenance are important objects for the functionality of the system. The safety of the user and/or the availability and accessibility of the system are at stake.

Preventive maintenance
Preventive maintenance is maintenance that is based on the prevention of failure (loss of function) by using inspection to decide when measures have to be taken. Preventive maintenance can be divided into Time Based Maintenance (TBM) and Condition Based Maintenance (CBM).

CBM is executed based on the condition of an object. This condition is identified by inspections that are executed during (half) yearly inspections and for example 5 yearly measurements. The CBM activities can be planned in ahead because the condition of an object will be improved after a certain time interval that is decided on by means of inspections. Based on these inspections a decision can be made when maintenance will be necessary. This is prescribed by the expected degeneration, based on the current condition of the object and the history (e.g. the measurement of cracks and the growth in time). The goal of the inspections is to extend the life cycle of an object/system. The decisions are based on predetermined intervention targets for example 'level of interest', 'observation', 'intervention', and 'critical level'.

Effects of the CBM
Advantage of this strategy is that unnecessary maintenance is prevented because the life cycle is used optimally. Disadvantage is the use of more equipment and personnel. The availability will be high with moderate maintenance cost. The condition is predicted based on inspections which results in fewer inspections and thus reduces maintenance costs.

With TBM an object is maintained or replaced after predetermined unities (e.g. running hours). For example, when the running hours of a bulb are known then replacement is done just before the critical running hour. This is mostly done for situations in which a failure is not allowed (e.g. because of safety reasons). Inspections are done periodically based on past experience or based on information given by the manufactures. It is difficult to correctly time the intervals. When the time to failure of an object is not certain or when the deviations are large, then failures can happen.

Effects of the TBM
This strategy needs fixed time intervals for inspections and for maintenance and is only appropriate for erosive or corrosive elements. The maintenance cost depends on the length of the intervals and the acceptable availability. Maintenance costs can be on the expensive side because unnecessary maintenance can be the case.

CLASSIFICATION OF MAINTENANCE OBJECTS

Maintenance management for large infrastructural assets may consist of hundreds, thousands or more maintenance activities that determine the success of the maintenance strategies. For managing and evaluation all the activities it is necessary to use some sort of classification system. The discussed maintenance strategies can be used on different objects, not every object needs the same maintenance strategy. A combination of both criticality and costs creates a profile for

maintenance activities (Figure 9) (Anderson, 2006). The International Infrastructure Management Manual defines a critical asset as an "*assets for which the financial, business or service level consequences of failure are sufficiently severe to justify proactive inspection and rehabilitation*". This definition is concerned with a perspective of the operations and maintenance phase of the asset life-cycle and a view from the perspective of the maintenance function of the organization.

Trivial: Maintenance activities with low cost and low criticality. The activities take little effort to execute and the impact on the organization is low. The effort to make changes to these activities may be significant.

Excessive: Maintenance activities with high cost but low criticality. These activities may cost more to execute over the lifecycle than the opportunity to reduce maintenance cost or asset failure.

Critical: Maintenance activities with low cost but high criticality. These activities are significant because of high impact of failure. There's little opportunity to reduce maintenance costs.

Strategic: Maintenance activities with high cost and high criticality. These activities are significant because of high impact of failure and the cost and effort associated with their execution.

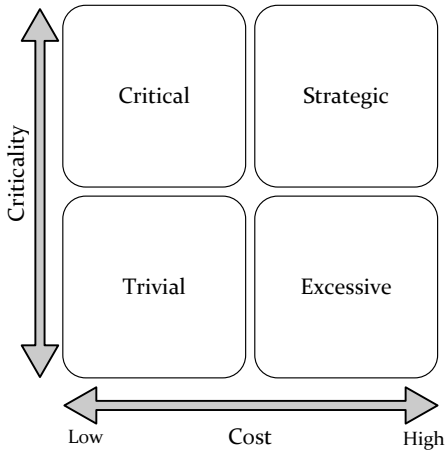


FIGURE 9: QUADRANT ANALYSIS MAINTENANCE ACTIVITIES (ANDERSON, 2006)

EFFECTS ON MAINTENANCE COSTS

The relationship between a preventive maintenance policy and a corrective maintenance policy is illustrated in Figure 11 (Woodward, 1997). A preventive maintenance policy reduces the downtime costs but more resources have to be used (more maintenance expenditure). A corrective maintenance policy reduces the maintenance expenditures but increases the costs of downtime. This means that a preventive maintenance policy can be used for objects that have high downtime costs whereas objects that have low downtime loss can be maintained by a corrective maintenance policy. The difficulty is to find an optimal level of maintenance frequency in order to be consistent with the objective of the company.

Figure 10 illustrates another perspective based on the life cycle (maintenance) costs. The objective of the company is minimizing the total cost of maintenance. By executing regular and periodic maintenance the expensive rehabilitation is delayed.

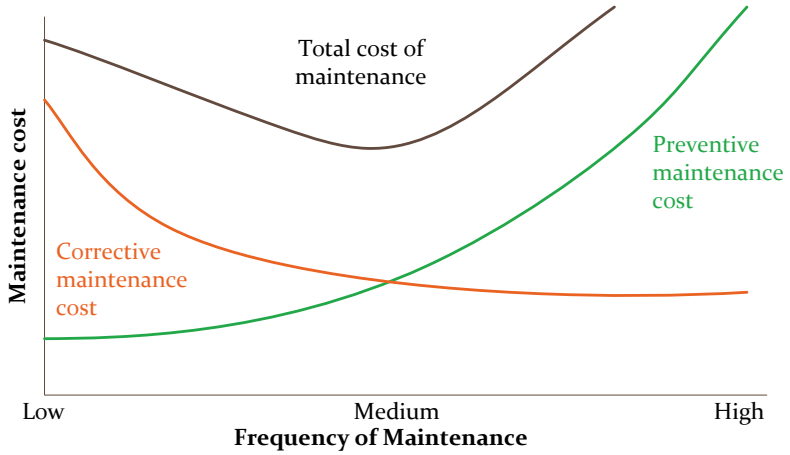


FIGURE 11: COST OF DIFFERENT MAINTENANCE STRATEGIES (WOODWARD, 1997)

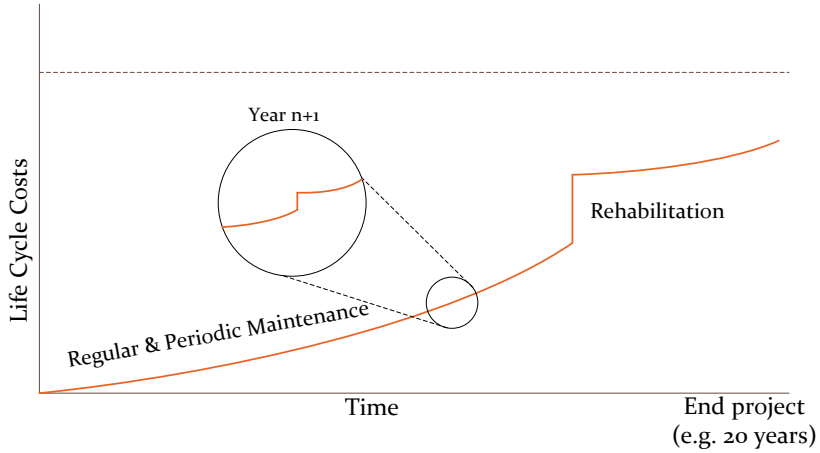


FIGURE 10: LIFE CYCLE COSTS FOR MAINTENANCE OF AN OBJECT

3.3 MAINTENANCE AS A CYCLICAL PROCESS

The previous sections show that maintenance activities are interrelated with each other, and that it is difficult to find an optimum for the maintenance costs. Using a more holistic view at the maintenance stage might make it possible to indicate what processes are important for supporting maintenance performance. This makes it necessary to see maintenance more as a process. This section discusses the processes that can be identified in the maintenance stage. Systematically controlling all the processes while the project progresses is needed if the whole project is to be effective (Haponava, 2009). This idea is based on the view of Dvir and Lechler (2004) that the processes form a chain that affects the achievement of project goals and its success. In this way the processes can be seen as an integrated system with inputs and outputs. For clarity, the maintenance stage will first be represented by a model that consists of four parts (Figure 12). The model is built up out of parts that interact with each other and consume resources to transform inputs into outputs. The maintenance stage takes place within a context that cannot be influenced.

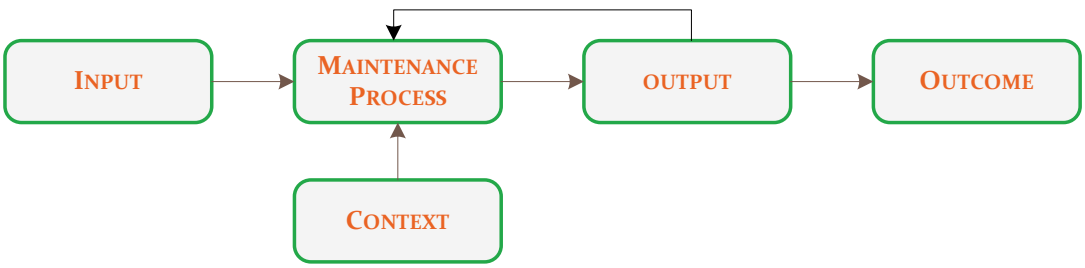


FIGURE 12: SIMPLE REPRESENTATION OF THE MAINTENANCE STAGE

The definitions of these terms in the model are defined as (Baird & Stammer, 2000):

- *Inputs* are the resources used by the organization, including money, people, material, and equipment. In some applications, inputs might also include "softer" resources such as influences or knowledge.
- *Maintenance Process* includes all of the activities and functions that transform the inputs (resources) into outputs (products and services) according to the maintenance strategy.
- *Outputs* are the results of the large and regular maintenance activities. These consist of different sub-projects that support the outcome of the integrated project. The conditions of output influence the maintenance process.
- *Outcomes* are when the outputs are delivered to the users. This is the result of the integrated project.
- *Context* can be described as the external factors that establish the boundaries within which the maintenance contractor can operate.

The input of the maintenance stage includes money, time, employees, and the facilities and equipment that are available to the contract. The input is also based on the output of the construction stage, once the maintenance stage commences there is no possibility to change the output of the construction stage. In effect, the maintenance stage in itself is an iterative process where 'upstream' processes become inputs for subsequent processes. The maintenance process can therefore be seen as a cyclical process that needs to be carried on by measuring, analysing, identification, scheduling, preparation and execution. More will be said on this iterative process when the component 'maintenance process' is discussed. The outputs of the maintenance stage can be defined as the result of separate maintenance activities or sub-projects like the miles resurfaced, acres mowed, signs replaced of number of inspections. All the outputs result in the outcomes like accessibility, safety and profit.

The external factors that establish the boundaries for the maintenance stage include law and regulations, the requirements set in the contract (demand of the client), the available technology, and the policies that are established by government. Understanding the limitations and authorities of the contract is necessary to know the boundaries of the maintenance stage.

MAINTENANCE PROCESS

Identifying and understanding the interactions within the maintenance processes is needed to be able to control them (Haponava, 2009). Within the maintenance process inputs are transformed into outputs. Too (2008) has indicated two interrelated core processes within asset maintenance and operation. There is the maintenance planning and the condition monitoring. Another segmentation is suggested by Komonen, Kortelainen & Räikkonen (2006), they divide the maintenance stage into the sub-processes maintenance planning, resources management and development, management of maintenance processes, and execution. The description of the characteristics in the maintenance process and the factors that affect them provide the foundation for the identification of sub-processes and control of these sub-processes. Figure 13 gives a representation of this systems approach.

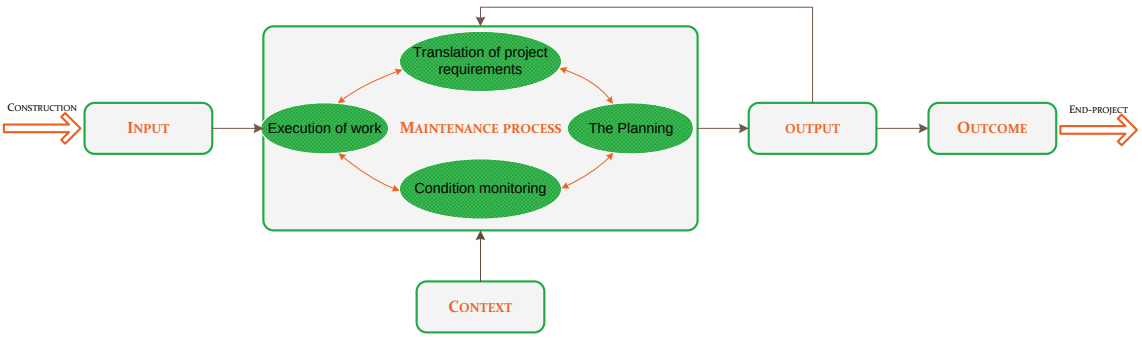


FIGURE 13: ADDITION OF MAINTENANCE PROCESS IN MAINTENANCE STAGE

A description of the maintenance stage is given by explaining the main characteristics of the maintenance stage. First of all the maintenance stage is divided into four sub-processes (Haponava, 2009; Komonen, et al., 2006). These sub-processes describe the maintenance stage by what needs to be done to ensure that the assets are maintained adequately and according the maintenance strategy. The sub-processes are not successive processes but can also be executed parallel.

After the construction stage is finished, the needed performance is given and needs to be maintained. The project manager should now effectively manage the maintenance activities. The translation of project requirements is about the identification and analysis of the tasks needed to meet the requirements set in the contract. This involves close cooperation with internal and external stakeholders. The internal stakeholders can be defined as subcontractors and suppliers while the external stakeholders can be defined as the client and the project environment. Often subcontractors are used if they have a specialty or are certified for certain activities. The difficulty of the maintenance stage is to control the required performance, which involves close supervision of the scheduled and executed activities. It is not just the execution of a prescribed activity, but it is the execution of an activity in order to get the best performance. This is especially the case with activities executed by subcontractors. Partnering might be a solution to get the subcontractor involved. Early involvement (of internal and external stakeholders) helps to minimize maintainability problems, claims and delays. A systematic interaction with the client and environment is necessary to meet the client expectations and concerns. These are often described in contractual agreements and the allocation of risks. The involvement of the environment is important to make sure the delays due to complaints can be prevented.

The development of the planning is about the planning, design, procurement, hiring and development of maintenance resources. The planning starts with the design of a (long and short-term) maintenance plan. The long-term plan is necessary because the maintenance phase is the longest phase of the construction project. Maintenance activities can be divided into periodical and regular maintenance. The maintenance plan defines when maintenance should be carried out. In order to make a suitable planning there is a need to coordinate the work with the stakeholders. It is a process of ensuring that the permits are applied for in time, of ensuring that stakeholders are involved and informed in time and the disturbance is as low as possible. Open access to information is necessary for transparency reasons. Successful information management will result in prevention of problems during the execution of activities. To ensure that this is achieved there should be good communication with the client, the surrounding stakeholders and other key stakeholders. There are different aspects of information exchange that can facilitate the communication. Open communication of the necessary information and to the right stakeholders is required. Also the response to questions and complaints is important for communication. A communication plan can be established to set the performance goals that can form the basis for the systematic exchange of information to the stakeholders (Haponava, 2009).

The previous processes describe the plans and schedules, but the project is influenced by many external factors that can cause faster deterioration of the performance than planned. The sub-process 'condition monitoring' is about inspections and updating the planning accordingly. To be able to control the quality of the project the project management should know the contract conditions in detail and point out the difficulties that could happen before deciding what maintenance activities should be used at what time. Understanding the day-to-day situation of the project is essential for the quality control. This is achieved by monitoring, inspection and testing of the different objects. The inspections are carried out to check whether the quality is still meeting the agreements. When this is not the case, then the contractor should carry out new maintenance. Monitoring is essential for successful asset optimization (Too, 2008). It provides the information needed to define the condition and performance, and it provides information about the life expectancy. This is the reason that condition monitoring is a crucial process in managing infrastructure. The process consists of different types of inspections like general planned inspection, planned audits, and time-based maintenance. The activities that are performed or are planned should be discussed with the client in order to proof that the agreed performance is still met.

The identification of the risk during the maintenance phase needs to be done on a regular basis. Mitigating measures have to be addressed to ensure the consequences of the risks are reduced. Generally the risks are identified and dealt with based on intuition, judgment and experiences of the operator. Preventing the risks is essential for the overall project, if there is a deviation between the current state and the assumed stage than rescheduling is necessary. Besides this deviation the asset is used during the maintenance stage which can cause unexpected situations like accidents. This means that smooth running of the project is never the case. It is important to have a pro-active attitude to quickly deal with the situations and identify the influence on the schedule and possible milestones.

Another aspect that needs to be facilitated is the examination by the client. The client has several predetermined stages when they want to check if the system, processes, or product is performing as agreed. The contractor is obliged to give the necessary information that is needed to check the performance (Kuijpers & Berg, 2007).

The execution of work is the process of executing the activities in such a way that the end-product performs conform the specifications. This is a difficult process due to the dynamic environment during the maintenance stage. The stage is influenced by external forces that cause constant changes. The production process needs to be controlled to meet the planned performance of the finished work. In the maintenance phase the maintenance activities can be seen as optimizing the performance of the project. The agreements about the availability of the road determine when and how a maintenance activity is executed. The contractor has to pay for every closure of the road which is an incentive to optimize the closures. For example, not the whole road is closed at once but sections are closed one after the other because the work cannot be done at the whole road at once. This will minimize the disturbance for the user and minimize the cost for the contractor. Many maintenance activities are executed when the road is still open. Therefore the need for safe work conditions is important to prevent accidents. Before this can be done the contract should be studied thoroughly to understand the responds needed and to understand the possible difficulties that can develop. There is a need for regular meetings with the project team and scheduling of audits.

3.4 PROCESS MEASUREMENT FRAMEWORK FOR MAINTENANCE

As described in literature is performance measurement the process of measuring if a company manages its performance in line with their functional strategies and objects. However, it is difficult to align the company mission, strategy and objectives by linking these throughout the organization and to make them measurable. As mentioned by Schoenmaker (2011) the separation of policy and maintenance execution increases the chance of neglecting the policy because the objectives of the maintenance do not fit the policy. For example, the dilemma of choosing between fewer disturbances versus lower maintenance cost. Next to this, the little amount of information about the historical performance of integrated projects makes the comparison of results against the expectations important to learn to do better.

This makes that the maintenance processes as described in section 3.3 are only part of the performance measurement framework. The other half is designed by the question 'What are we trying to accomplish?' This question defines the targets that the contractor tries to accomplish, and makes it possible to compare the results against the expectations. Baird and Stammer (2000) have developed a framework that interconnects both parts. First, the mission, vision and goals are used to define the desired outcomes of an integrated project (upper part). Based on these desired outcomes it is possible to determine the desired output target and processes targets. The second (lower) part, defines the input-output relation. The comparison of both parts makes it possible to measure the plans against the results. This is represented in Figure 14.

The model shows that the measurement of performance is very complex because many locations can be appointed to measure performance. Baird and Stammer (2000) have identified 19 separate "locations". As a result they conclude that a trade-off between the amount of locations is necessary because of the ability of managers to interpret the data, and the costs of measurement. Of course, measurement at one location does not give a balanced view on the performance of maintenance.

The goal in this study is to study the processes that support the management of changes in the maintenance strategy. The link between the processes and outputs identifies the processes that are important to steer the maintenance strategy and to optimize the outcome. This makes that measurement at three distinctive locations is necessary. Baird and Stammer (2000) define these locations as 'mission success measures' that addresses processes, outputs, and outcomes from the perspective of the organization's mission, vision and corresponding strategies and goals. These measures can be used to measure the process level and output level. The output level location is called the 'attainment of output targets' which is used to study the differences between the expected output and the realized output of sub-projects of the integrated project. The second location 'attainment of process target' is about the expected and realized process targets. The results of both locations are needed to focus on the linkage between maintenance process and the output. This makes it possible to identify those processes that most influence the output and eventually the outcome. The proposes model helps to define the various types of performance measures and illustrates the interrelationships (Baird & Stammer, 2000).

ATTAINMENT OF OUTPUT TARGETS

The attainment of outputs can be measured by comparing the actual outputs with the targets based on the mission and strategy of the contractor. An important KPI for a contractor is the realization of maintenance activities (sub-projects) within budget. In order to attain profit (outcome target) the maintenance budget can be assigned to different entries and can be controlled accordingly. A difficulty is that the entries are recorded differently in each construction project. That is, maintenance costs can be recorded based an a*ctivity level,* an *object level* or on *sub-contractor level.* Within each integrated project the maintenance activities (sub-projects) are recorder based on an agreed level. This makes the comparison of outputs between integrated projects difficult. In order to prevent the comparison of apples and oranges, it is necessary to decide on a general comparison level. The maintenance concept of a project is generally determined based on an object level. The comparison of actual cost against the budgeted costs can therefore best be done on an object level. Consequently, the budget control of the integrated projects needs to be transformed towards an object level. The objects and the related activities that can be defined for a highway system are shown in Table 2. Other maintenance costs that need to be considered are shown in Table 3.

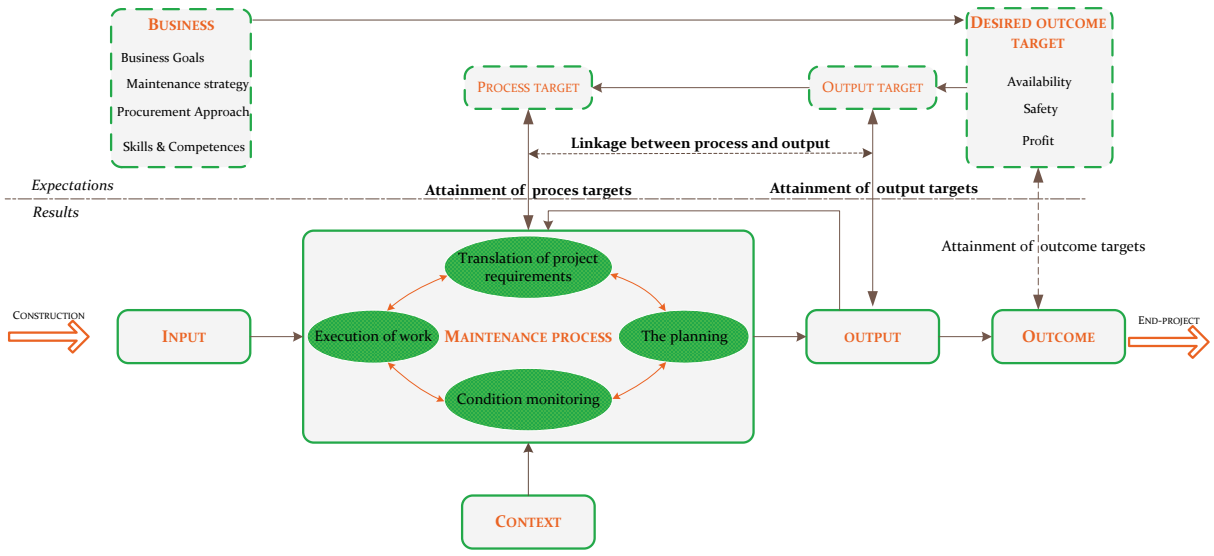


FIGURE 14: COMPLETE MODEL (BASED ON BAIRD & STAMMER (2000))

TABLE 2: THE HIGHWAY SYSTEM, OBJECTS AND ACTIVITIES

Highway System	Sub object	Activity
Substructure	Verge	Degrade Verge
	Ground body	Cleanse Drainage
	Dam	Monitoring groundwater level and quality
	Culverts	Inspection (sub objects)
	Drainage	
Superstructure	Foundation	Brushing (ZOAB)
	Gutter	Cleansing (ZOAB, gutter, sewer, etc)
	Sewer	Repairing (street work, sealing asphalt, etc)
	Cesspit	Relayer Asphalt
	Cables and Pipes	Inspections (sewer)
	Parking places	Asphalting roads
		inspection (sub objects)
		Little repair work
Traffic Facilities	Marking	Apply marking
	Crash Barrier	Repair (crash barrier)
	Public Lights	Cleansing (traffic signs)
	Trash bins	Inspections (sub objects)
	Traffic detection point	Painting sub objects
	Traffic signs	Little repair work (replace bulb, adjust signs etc.)
Landscape and environment	Planting	Mowing (Verges, Parking spaces)
	Fauna Facilities	Clipping
		Cleansing (banks and ditches)
Constructions	Sound barrier	Cleaning (constructions)
	Construction works	Maintaining mechanical and electrical
	Graffiti	Maintaining steelworks
		Removing Graffiti
		Repairing (joints, new and existing constructions)

TABLE 3: COST CONTROL ITEMS

Cost	Sub items
Salaries	Payments for the employees (e.g. project leader, planner, roadman, controller)
Supportive work	Temporary traffic measures and traffic management for incident management
Equipment	Equipment cost
Indirect	Costs for energy, telephone, rent etc
General	Interest costs, insurances
Profit and risk	Business risks, lane closure, penalties, repair or damages

Both tables are summarized in Table 4 in which the upper part provides actual information. The total maintenance costs in the last 5 years are represented in the lower part. This information can be used to understand how the current situation is developed. The framework provides information about how the maintenance costs develop throughout the project. It does, however, not provide any information about the causes of these costs, nor about the possibilities for improvement. The causes and possibilities for improvement are studied by the 'linkage of process and output'.

TABLE 4: FRAMEWORK FOR EVALUATING MAINTENANCE COST

	Budget at start of project (% of total)	**Forecast towards end of project** (% of total)	**% Budget overrun at the end of the project**
Salaries	…	…	…
Supportive work	…	…	…
Equipment	…	…	…
Sub-system costs	…	…	…
Substructure	…	…	…
Superstructure	…	…	…
Traffic Facilities	…	…	…
Landscape & environment	…	…	…
Constructions	…	…	…
Indirect	…	…	…
General	…	…	…
Profit and risk	…	…	…
Total	**100%**	**100%**	**…**

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Yearly budget	…	…	…	…	…
Total maintenance cost	…	…	…	…	…

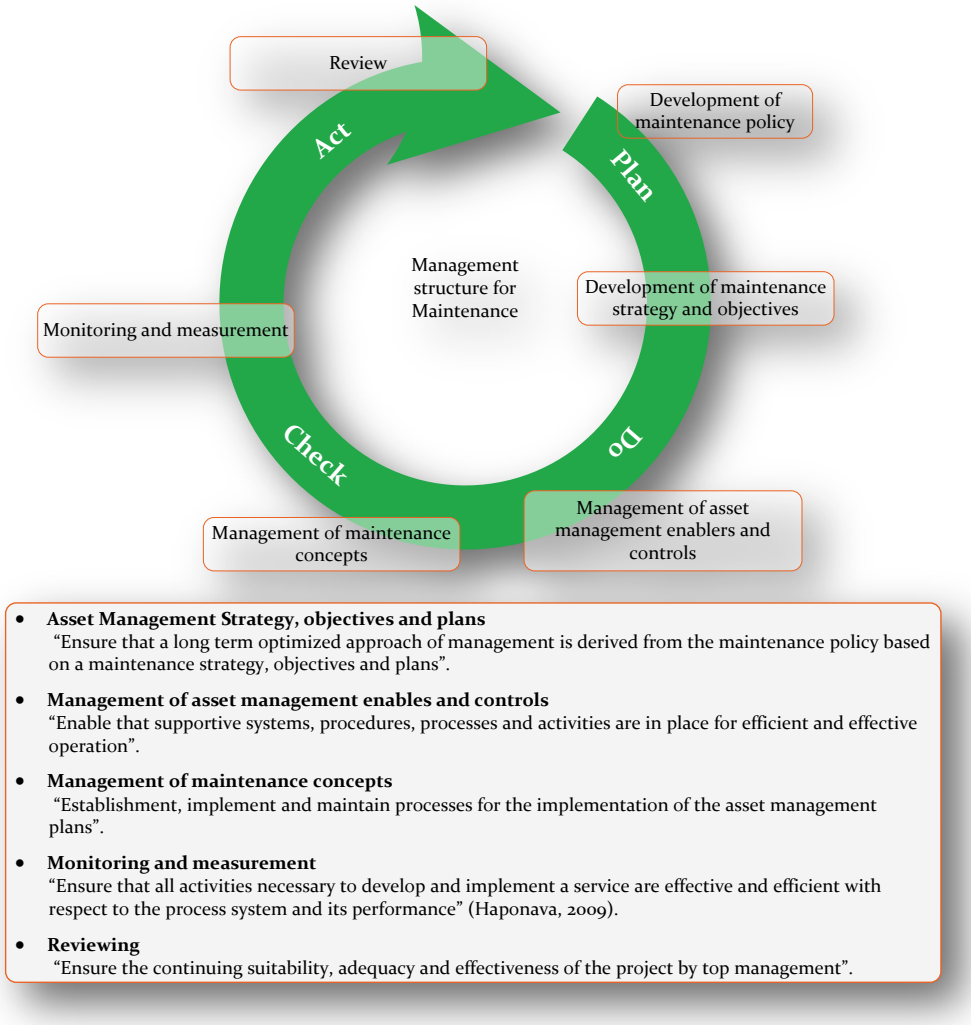


FIGURE 15: THE STRUCTURE FOR THE MANAGEMENT OF ASSETS BASED ON THE PAS 55 (THE INSTITUTE OF ASSET MANAGEMENT (IAM), 2008).

ATTAINMENT OF PROCESS TARGETS

The process targets can be defined as the processes needed for facilitating and co-ordinating the production of the necessary outputs (Kagioglou, Cooper, Aouad, & Sexton, 2000). Within a maintenance project (sub-project) inputs are transformed to outputs by a wide range of processes. An outline of the maintenance processes are described in section 3.3. However, it does not give a full perspective on the aspects that need to be controlled for successfully managing the maintenance of assets. For this reason the PAS55 (Publicly Available Specification) is used. This is a general accepted structure to optimally manage assets and asset systems (The Institute of Asset Management (IAM), 2008a). Based on this standard the key aspects that need to be controlled in the maintenance stage can be identified. It provides a checklist of all the aspects that need to be controlled for successfully managing the (maintenance of) assets. Therefore the Pass55 is used to check what processes are executed in the project and how they are executed (Table 5, Column 1). Based on this information it is possible to compare the actual situation with the plans described in the project information.

In order to fit the Pass55 in the framework it is necessary to identify the location of the Pass55 within the framework (Figure 16). The figure shows that the Pas55 covers the whole model. In appendix G the full checklist is provided. Figure 15 gives a summary of the PAS55.

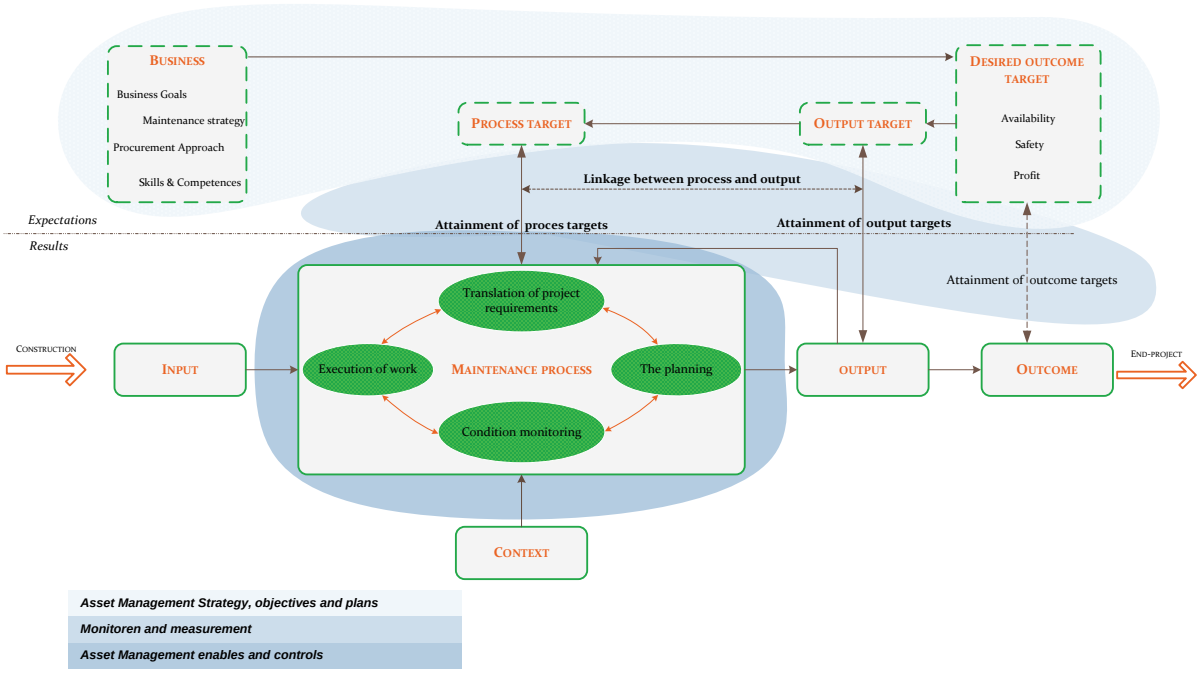


FIGURE 16: RELATION BETWEEN PAS55 AND FRAMEWORK

LINKAGE OF PROCESS TO OUTPUT

The influence of the maintenance processes on the maintenance performance (outcome) is based on the concept of Dell'Isola, there is no maximal performance only an optimal performance. Maintenance performance is defined in this study as: '*the choices that are made between the quality of a system and the needed (financial) means to attain the company objective and targets*'. This means that the supporting processes (described by the PAS55) are studied by their ability of supporting the project goals, targets, and the requirements of the client within the tight conditions defined in the contract. The processes will have an effect (positive or negative) on the maintenance cost and thus on the profit of the contractor. An optimal performance is reached if considerations are made between the costs and the ability of supporting the project goals. Many decisions and considerations about the executed maintenance activities are instinctively made. Therefore, an appropriate way to measure the influence of processes on the performance of maintenance is by using the perception of experts on the importance of aspects described in the PAS55.

Table 5 gives an overview of the framework that links the processes to the outputs based on the possibilities described above. The first column is used to check whether or not the aspects described in the PAS55 are present in the project by using the score given in Table 6. The second column is used for mapping the perceived relation of the processes with the attainment of the project goals and objectives (but not related with the cost) (Table 7). The same procedure is used for the third column. The last column links the company objectives with the processes. Although the most important company objectives are related to the productivity and cost, there are also other company objects that need to be considered. In the current business environment not only the iron triangle (time, cost, and quality) is important anymore, other objectives like social responsibility (MVO in Dutch) are also important. Therefore these company objectives are included by adding the last column which links the aspects with the 'soft' company objectives of the Royal BAM Group (See Appendix A and Table 8).

TABLE 5: RELATION BETWEEN PAS55 AND PERFORMANCE.

	Present in the project?	Relative weight for influence on...		Link with company objectives
		...the attainment of project goals and objectives (Important: No costs)	...the maintenance costs	
	{1-6}	{L,M,H}	{L,M,H}	{A,B,C,D}
Asset Management strategy, objectives and plans				
Sub-aspects	...	...	...	...
Asset management enablers and controls				
Sub-aspects	...	...	...	...
Monitoring and measurement				
Sub aspects	...	...	...	...

TABLE 6: EXPLANATION SCORE FOR PRESENT IN PROJECT (BASED ON HAPONAVA (2009))

Score	Explanation
1.	Not present in project
2.	Documented in the project/maintenance plan
3.	Structured process and coordinated with important internal- and external stakeholders
4.	Formal agreed process; continual control and is an integral part of the maintenance process

TABLE 7: EXPLANATION OF RELATIVE WEIGHT

Score	Explanation	
L.	Low influence	The aspect has little influence on the maintenance costs or goals
M.	Medium Influence	The aspect has medium influence on the maintenance cost or goals
H.	High influence	The aspect has large influence on the maintenance cost or goals

TABLE 8: EXPLANATION OF COMPANY OBJECTIVES

Score	Company objectives	Explanation
A.	Human & Society	• Safety of employees & sub-contractors • Safety of the direct environment of construction sites • Knowledge & experience sharing (know-how of the group) • Development of management potential • Diversity of employees as mirror of society
B.	Products & Concepts	• Development of new products and concepts
C.	Market	• Improvement of position in market
D.	Organization	• Improvement of the primary process & risk management • Lean construction management • Introduction of virtual construction and ICT-application • Social Responsibility (MVO)

4 INTEGRATED PROJECTS OF THE ROYAL BAM GROUP

Customers of capital intensive systems, like integrated contracts, are interested in the life-cycle costs for the investment they make (Stremersch, Wuyts, & Frambach, 2001). For contractors this means that they have to develop not only additional service components but also need to optimize the total operation and maintenance costs (Kujala et al., 2011). That is, the contractor gets more responsibility for long-term success and gets more opportunities for profit maximization and capturing a larger portion of the overall value stream. This chapter will start with a short description of the cases. Thereafter, both projects are elaborated on using the framework to describe the plans. This information used in this chapter is based on project documentation and the conversational interviews with both operators.

4.1 GENERAL DESCRIPTION OF CASE STUDIES

Although the N31–Wâldwei and PPS-A59 seem similar projects because they both are integrated projects using a DBFM-contract there are many differences between them. As an introduction into the cases a short description is given. Thereafter the cases are described based on the more in-depth project information in appendix C & D. This in-depth project information is based on the information found in the project documentation and conversational interviews.

N31 – WÂLDWEI

In Friesland between Drachten and Leeuwarden the N31 was reconstructed between 2004 and 2007. It is a DBFM-project for the reconstruction of a single (1x1) highway between Leeuwarden and Nijega to a dual (2x2) track highway. Next to this, the construction of an aqueduct, a bridge and the maintenance for 23 km is included. This project is the first DBFM-contract for RWS. The project is assigned to the consortium Wâldwei.com with a contract sum of about €80 million. The consortium consists of Ballast Nedam Infra, Dura Vermeer Group and Royal BAM Group.

TABLE 9: GENERAL PROJECT INFORMATION OF THE N31 – WÂLDWEI

Project Information	
Name	N31 – Wâldwei
Location	Drachten – Leeuwarden
Scope	Ca. 4 years of realization & 15 year of Maintenance
Principal	RWS
Contractor	*Wâldwei v.o.f. (SPC)* - Royal BAM Group NV - Ballast Nedam Infra BV - Dura Vermeer Group NV
Maintenance contractor	*Wâldwei BCWW* - BAM Civiel BV - Dura Vermeer Infrastructure BV - Ballast Nedam Infra BV
Contract	DBFM
Maintenance Contract	EPCM
Start Maintenance	December 2007
Maintenance term	15 years
Contract sum	€80 million (€60 million realization €20 million maintenance)

The client and principal of the project is RWS, which is owner of and controls the budget for managing the Dutch network of roads. This project is the first integrated project for RWS which makes that they want to get experience with this kind of contract. The N31 is assigned as a DBFM-project because the imposing budget was insufficient while the preparations for the execution of the N31 were already in an advanced stage. This latter aspects makes that the project needs a tight budget. The main reason for the expansion of the N31 is based on improving the traffic safety.

FIGURE 17: CONSORTIUM WÂLDWEI.COM (WALDWEI.COM, 2011)

PPS – A59

At the other side of the Netherlands, in the province of North Brabant, the N50 is reconstructed towards the A59 in 2003. In 2005, the construction of 9.1 kilometre of highway with 4 connections, a fly-over, 2 tunnels, 7 traverses and 10 kilometre of sound barrier was completed. After completion, the maintenance of this section until 2020 has started. The project is the first DBFM-project in the Netherlands that has been commissioned by the Province. The consortium 'Poort van Den Bosch' is assigned for the execution of the project with a contract sum of €218 million. This consortium consists of Royal BAM Group, Boskalis and Fluor Infrastructure.

FIGURE 18: CONSORTIUM 'POORT VAN DEN BOSCH' (POORT VAN DEN BOSCH, 2011)

At the A59 the principal is the province of Noord-Brabant. This is a rather unique situation because the province is not the owner of the road. To solve this problem special agreements have been made between the province and the ministry. The ministry is legally responsible but the realization of the road is temporally the responsibility of the province. At the project offer moment it became clear that the project budget provided by the ministry was not sufficient, the ministry was confronted with their financial responsibilities. The reason for this situation can be explained by different budget systems that are used (Provincie Noord-Brabant & Poort van Den Bosch, 2005). The main reason the principal put the PPS-A59 to tender can be described as improving the social surplus value for the region. The region benefits from the project by better accessibility, better traffic safety, improving environmental quality and improving economically (Provincie Noord-Brabant & Poort van Den Bosch, 2005). This makes that the region will be closely involved. Because this project is the first integrated contract, it is used as a learning project.

TABLE 10: GENERAL PROJECT INFORMATION OF THE PPS-A59

Project Information	
Name	A 59 Rosmalen – Geffen
Location	Rosmalen – Geffen
Scope	Ca. 3 years of realization & 15 year of maintenance
Principal	Province of Noord Brabant
Contractor	*Poort van Den Bosch* - Royal BAM Group NV - Boskalis BV - Fluor Infrastructur BV
Maintenance contractor	Maintenance organization "Poort van Den Bosch" (BAM Roads)
Contract	DBFM
Maintenance Contract	MTC
Start Maintenance	1 January 2006
Maintenance term	2005-2020
Contract sum	€ 218 million

4.2 CASE DESCRIPTION BASED ON PROJECT PLANS

Both projects are discussed by the three topics (Strategy, goals and objectives, enablers and control, and monitoring and measurement) that are found in the framework (Section 3.4) Describing the topics for both projects will give background information about the situation of the projects. The information used to describe the differences is based on the project information found in Appendices C and D and the conversational interview with the operators of both projects. This section ends with an outline of the project plans.

MAINTENANCE STRATEGY AND OBJECTIVES

Both projects have to solve an infrastructural problem by the (re)construction of a motorway and several constructions including maintenance. The maintenance at the N31 consists not only of maintaining new constructed assets, but also used assets. At the A59 the maintenance consists of new assets. This difference makes that the input quality of the assets differ. In other words, new constructed assets need another maintenance strategy than used assets. For example, newly build assets need less maintenance than older used assets. Besides this difference, the N31–Wâldwei is a motorway while the PPS-A59 is a highway. The rules and regulations for both types of roads differ.

The *strategic aim* of both projects is to achieve long-term benefits rather than bargaining for a certain profit margin in one activity. In the case of the N31 it is said that growth can be reach by optimizing the maintenance activities and by enlarging the scope during the project. At the A59 this can be reached when they improve and optimize the collaboration with their subcontractors. Besides this it is mentioned that the knowledge and experience gathered within the projects can be used to improve upcoming projects. At the A59 revenue is also created by sub-contracting only BAM-divisions for maintenance. This creates value not only for the separate division, but also for the parent company.

Both projects have taken a *life cycle approach* into account. In the case of the N31 the road is for example constructed by using stronger asphalt to extend the life cycle. The fact that the BCWW is responsible for the construction as well as the maintenance (by integration of the construction and maintenance into an EPCM-contract) made it possible to invest in the asphalt. At the A59 project the construction and maintenance are divided into two different contracts, an EPC and MTC contract. This has resulted in separation of the construction and maintenance for the first year of construction. By that time awareness arose that maintenance should be an integral part of the project. An example of this is that a service road to the central verge has been created in order to reduce the maintenance costs. It took some time to include this life cycle perspective at the A59. In the first years of the project, maintenance has not been a priority, which is still experienced in the maintenance today. An example is the cleaning of the drains in the tunnel. They are integrated in the barrier which makes it almost impossible to clean. These kinds of problems are also described at the N31.

All the maintenance activities are the *responsibility* of the contractor which means that a large part of their work consists of coordination. They are not only responsible for executing the maintenance but also for coordination of the work towards the stakeholders as well as more administrative work. Before the interaction with partners can be discussed it is important to describe the relationships with the SPC and the client of the project. The client for the N31 is RWS because that is they commissioned the project, whereas, in at the A59 the province is the client (see Figure 19 and Figure 20).

The organization of the N31-Wâldwei is designed by the development of a company (BCWW) that is a partnership between three companies. A discussion has taken place whether or not the project would be executed based on interaction between the parties or by working together under one flag. The BCWW is responsible for the maintenance as well as the construction and has an EPCM contract with the SPC. The BCWW has organized the maintenance by executing maintenance itself as well as outsourcing maintenance to subcontractors. They have two fixed subcontractors while the other subcontractors are chosen based on the needed maintenance activities. An internal maintenance crew is assigned for corrective maintenance activities. For small preventive maintenance subcontractors are assigned. For the large maintenance activities personnel and equipment of the three contractors is used (Bouwcombinatie Waldwei, 2008). This is done based

on predetermined fixed process on order to prevent internal discussion about the division of work. The organization of the A59 is designed by the development of a MTC 'Poort van Den Bosch'. This MTC is executed solely by BAM Roads. They have taken the responsibility for maintaining the A59 based on a MTC contract with the PvDB. The strategy that is used at the A59 can be described as mainly preventive maintenance. Corrective maintenance is only used for small maintenance activities. In order to execute the maintenance they work with fixed subcontractors for the whole maintenance period. The advantage of this structure is that it is possible to create a long term relationship with the subcontractors. In this particular case it is beneficial because the sub-contractors are all divisions of the Royal BAM Group.

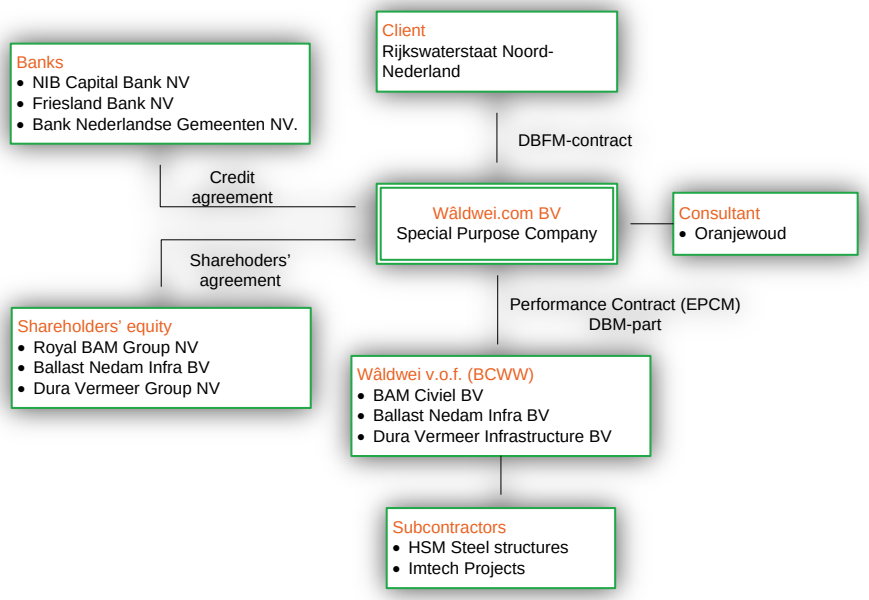


FIGURE 19: PROJECT ORGANIZATION OF THE N31 – WÂLDWEI

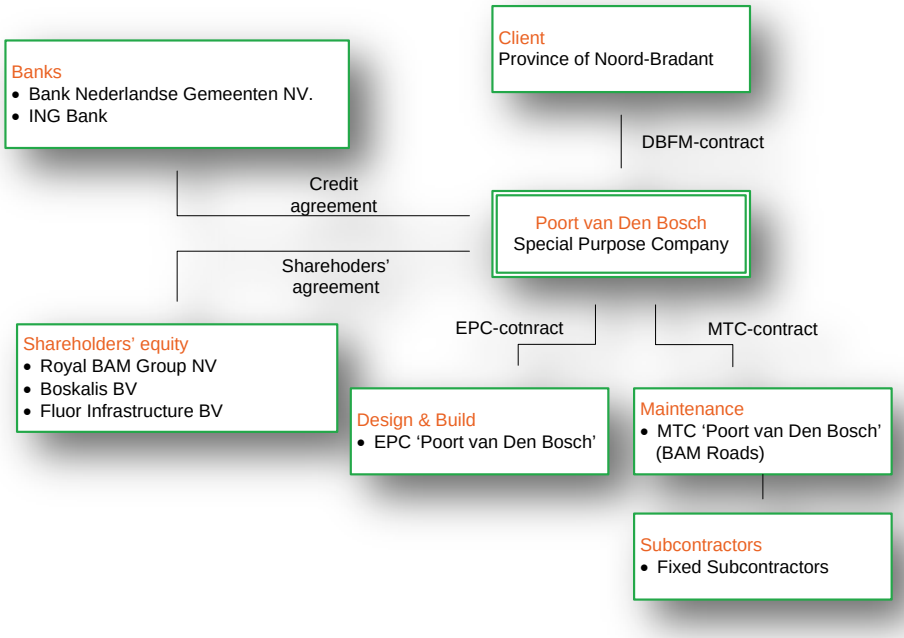


FIGURE 20: PROJECT ORGANIZATION OF PPS-A59

The value creation (from the contractors' perspective) in the project is achieved by several actors' in a balanced manner while keeping the value for the larger good in mind. There is a large span of stakeholders involved which makes this a complex task. The projects are too large to be executed

by just one contractor. In addition, these projects are the first DBFM-projects which make learning an objective in both projects; therefore the creation of knowledge about this kind of project can also be seen as value creation for the contractors. Next to this, the contractors need projects to survive in the competitive market. Profit can be created during the construction stage but also during the maintenance stage. The creation of profit in this latter situation is difficult because the performance depends on the quality of the design and construction. Integrating a maintenance perspective into the design and construction is therefore important. In a meeting with both maintenance managers the remark is made that the goal should always be to aim for a grade 'eight' instead of a 'six' for the quality of construction and maintenance.

ENABLERS AND CONTROLS

In both projects documents and procedures are found in the project documentation. These are used on the one hand for satisfying the client, (for example to proof that a certain performance level is met) on the other hand for keeping track of the work. An outline of the documents and procedures are discussed here.

- Risk management plan: The result of the process is to get insight into risks that are found in the project, and the measurements that can be used together with the effects.
- Incident plan: This plan describes the actions that have to be taken within the organisation in order to deal with incidents.
- Change management report: This plan describes the steps that need to be taken when a deviation from the plan occurs.
- Interface report: During the design and construction of the project many choices have been made by several parties. If more parties are involved by the choices than an interface is present. For each interface it has to be clear which party is involved and who is responsible.
- Communication plan: This plan describes the way to inform and communicate with stakeholders.
- Accessibility plan: This plan describes the way the traffic management is executed.
- Preservation plan: A preservation plan is designed based on the condition of the asset after completion of the construction phase. It describes the plans to keep the system at the desired maintenance level. The objective is bipartite. On the one hand the plan is about the preservation of the required maintenance level of the realized system. It states which activities are executed to preserve the required performance level of the asset. On the other hand, the plan is about the physical maintenance: meeting the requirements that are set to the system during the usage phase in order to guarantee and optimize the technical state and safety of the system for the user.

MONITORING AND CONTROL

The monitoring and control is executed to make sure that prove of meeting the requirements is given. The contract-requirements are mostly concrete enough to deliver proof based on inspections. The amount of inspections and preventive maintenance activities are written down in the preservation plan. The predetermined image, based on limited values, is used to execute the daily inspections. The results of the inspections are written down in reports to deliver the required proof.

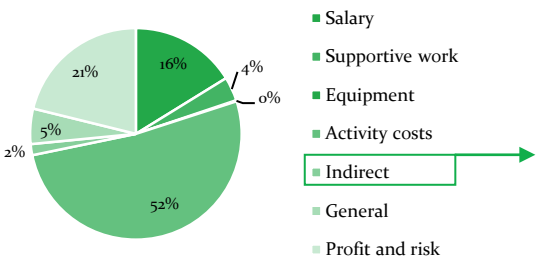
Next to the plans for monitoring of the condition of the road, a yearly budget is planned for the maintenance in both projects. The yearly budget is not constant over the years, but is tailored based on the maintenance planning. For example, resurfacing ZOAB is scheduled in the 15th year of maintenance at the A59. In that year the budget is increased towards €2.0 [3]million instead of €0.6 million. The objective of the maintenance manager is to keep the maintenance cost below budget as mentioned during the interviews. This is done in both projects by controlling the budget in a few entries. An overview of the situation based on information of the N31 is discussed next.

An indication of how the maintenance costs are budgeted in the maintenance stage is shown in Graph 1. The budget for the A59 has the same proportion as endorsed in the conversational interviews. The largest part of the maintenance cost for the N31 is found in the maintenance

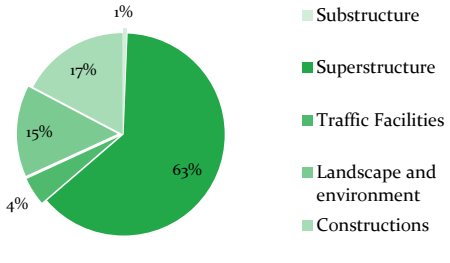
[3] Amounts give an indication.

activities (52%). Other entries for the maintenance stage consist of 'profit and risk' (21%), 'salary' (16%) and 'other costs'.

The maintenance activities are further divided into entries based on the decisions made in the financial model. These entries are based on an object level (as suggested in section 3.4). This makes it possible to understand which objects have the largest share of maintenance costs (Graph 2). The superstructure needs the largest part of the activity cost budget, followed by the constructions and landscape costs. This indicates that most of the maintenance budget is allocated towards the maintenance activities needed to keep the superstructure at the agreed level of performance. The landscape and environment have the second largest budget, closely followed by the budget for constructions. This allocation of the budget is highly dependable of the scope of the project. However, it is mentioned several times in the interview that the cost for landscaping are difficult to predict due to little knowledge of how to deal with the landscape.



GRAPH 1: MAINTENANCE COST N31 (2008)



GRAPH 2: PARTITION OF ACTIVITY COSTS (2008)

OUTLINE OF PLANS

Both projects have to (re)construct a motorway and several constructions including maintenance. However the input quality of both projects differs due to the maintenance of newly constructed objects at the A59 and the maintenance of used objects at the N31. The position of the contractor in both cases differs also due to the used contracts. The BCWW is responsible for the construction as well as the maintenance whereas the PvDB is only responsible for the maintenance. In practice this difference is much smaller because the employees involved are appointed in both places of the value chain. In both project a life-cycle view is used before the start of the maintenance stage. This is done through smart solutions to reduce maintenance. However, at the A59 some time elapsed before this awareness arose.

The maintenance strategies of both projects is based on executing preventive maintenance for keeping and bringing back the system towards the performance needed for fulfilling the required function according to the contract. This is achieved by always aiming for a grade 'eight' instead of a 'six' for the quality of the construction and maintenance. Corrective maintenance is only used for non-critical objects. In this way it is tried to achieve long-term benefits rather than profit margins on separate activities.

The contracts are only used to divide the risks for the projects in a different way. The relationship with the client is first of all mentioned to be contractual based. In the contract requirements of specific documents are written down (e.g. Risk management plan, communication plan, accessibility plan). Besides the contractual agreements, service delivery by interaction with the client is important. Therefore it is necessary to understand the needs of the customer and to be able to include flexible offering in various settings.

Inspections are used to monitor the condition of the road based on the contract-requirements. Based on the predetermined budget (based on a financial model) and inspections it is chosen what maintenance is necessary. This allocation of the budget is highly dependable of the scope of the project, however it is mentioned that the ratio between the entries is similar in both projects. The largest part of the budget is assigned to the entry "activity costs". Within the activity cost, most of the budget is available for the superstructure.

4.3 CASE DESCRIPTION BASED ON PROJECT RESULTS

The results described in the next section are based on the open-ended interviews with both the maintenance manager and project director of both projects using the same structure as the previous section. Based on these result the actual execution of plans are discussed.

STRATEGY, GOALS AND OBJECTIVES

The goal for the maintenance stage is described by the operator as well as the management of the N31 as '*keeping the road safely accessible, safely driveable and keeping the maintenance as low as possible*'. This all while meeting the contract requirements and guaranteeing the availability. The goal at the A59 is described from a more financial perspective by both the operator and especially by the management. The goal from the operators' perspective is 'to stay within *budget while keeping the road in a top-condition and to work together with the Province (as principal)'*.

At the management level of both projects the life cycle costs are calculated by using a so-called 'financial model'. The model is used to balance the construction-maintenance ratio as well as the maintenance itself. An assessment is made between the different construction methods and the maintenance concepts (changing the amount of maintenance). The outcome of the model is balanced based on financial considerations (receipts and expenditure), it is not based on prioritized goals. The contract states what activities are needed to be done; it states how much maintenance has to be done to meet the requirements (box 1.1).

> *"The schedule might indicate that the cleaning of the sound barriers need to be done twice a year. However, if the barriers do not need to be cleaned than it is not necessary to execute this activity. The contract requirements are leading in these situations because the contract might state that is needs to be done twice a year". (1.1 - Operator A59)*

During the maintenance stage the life cycle cost are considered when the yearly planning is made. An outlook is made towards the end of the project in order to understand the possible consequences for the end-project situation. An example of how the life cycle costing is considered at the N31 is given in the box 1.2. At the A59 the financial consequences for the end of the project are considered when preventive maintenance is executed. The actual necessity of the preventive maintenance is based on experience rather than facts.

> *"At a section of the N31 the road slopes gently. This is caused by a peat surface. During the construction is chosen to strengthen the surface instead of placing a sheet pile wall. This latter solution is more expensive but it would probably last longer. Now the road might need extra maintenance in order to meet the requirements". (1.2 - Operator N31)*

TABLE 11: INTERVIEW RESULTS OF STRATEGY AND OBJECTIVE RELATED ASPECTS BASED ON PAS55

	N31	A59
Maintenance strategy		
Is there a check on the organizational policies and strategies	...	...
Are Life Cycle Analysis made?	...	...
Is research on maintenance related risks executed?	...	...
Is the performance and condition of existing asset systems identified?	...	...
Is the desired future performance and condition mapped? (on a timescale)	...	...
Is a generally used method used to manage the assets?	...	...
Is communication about the strategy used towards all relevant stakeholders?	...	...
Are there criteria to prioritize the goals and plans?	...	...
Maintenance objectives		
Are (SMART) goals formulated?	...	...
Are the goals consistent with the maintenance strategy?	...	...
Is there communication of goals towards all relevant stakeholders?	...	...
Are the legal and regulatory requirements considered?	...	...
Are related risks mapped?	...	...
Is there a periodical review?	...	...
Maintenance plans		
Are the responsibilities clear?	...	...
Is a long-term replacement program available?	...	...
Is a short-term schedule available?	...	...
Are there criteria for the optimization of plans?	...	...

Results are not shown in this version

The risks are reviewed periodically in both projects with a crucial role for the operator. He has a large role in the identification of maintenance related risks. It is mentioned that the risks are about the division of the costs. Next to this, the risks are used to understand when maintenance might be necessary and are used for planning the maintenance according to both operators. However, according to the management it is not explicitly used for scheduling the maintenance. The risk management report is used to list the risks that are found during the project and discuss the possible consequences in the periodic meetings. The changes in scope during the project cause shifts in the risks. At the N31 the risks are scored in order to prioritize the risks based on safety and financial risks.

> *"Mowing the grass should be done twice a year according to the contract. However, the grass is already towards the critical point. This means that we have to mow before this activity is scheduled. A consideration is made between only mowing the critical areas and mowing the whole area. Based on a financial calculation it is chosen to mow the whole area". (1.3 - Operator N31)*

ENABLERS AND CONTROLS

The responsibilities of the parties involved in the N31 project are clear according to the operator. The parties that constructed the road are also responsible for the maintenance. As a result the interests of the parties are similar and the costs and incomes are divided in a similar way. At the A59 the responsibilities are also clear due to the outsourcing to fixed subcontractors based on a fixed price. It makes that the budget is controlled easily, but it might be possible to reduce the budget when fixed subcontractors are not used. A price is paid for this situation. The fixed subcontractors make it possible to invest in efficient communication, optimize activities and work methods because each party knows their responsibilities.

TABLE 12: INTERVIEW RESULTS OF ENABLERS AND CONTROLS RELATED ASPECTS BASED ON PAS55

Responsibilities		
Are all responsibilities clearly defined and communicated?	...	...
Outsourcing of activities		
Is there a structure for information and knowledge exchange available?	...	...
Are the responsibilities and authorities clear in the organisation?	...	...
Are the boundary conditions and scope defined?	...	...
Is the contract defined by the used of service level agreements (SLA's)?	...	...
Training		
Is there training to improve the Asset Management knowledge?	...	...
Communication		
Are the involved parties consulted and do they participate in meetings?	...	...
Is the communication bottom-up as well as top-down?	...	...
Documentation system		
Is a documentation system used to support the information management?	...	...
Information management		
Is the information authorized?	...	...
Is there periodical control?	...	...
Risk management		
Is there a method for the identification of risks?	...	...
Is a Criticality Effect Analysis made? Are critical assets identified?	...	...
Worden de risico's gebruikt als input voor activiteiten?	...	...
Legal and other requirements		
Are these requirements continually controlled?	...	...
Change Management		
Are changes communicated toward stakeholders?	...	...
Is there control on the project goals?	...	...
Is hierarchy present in procedures?	...	...
Is there a quality- and safety plan?	...	...
Contingency planning		
Are the risks for critical objects clear?	...	...
Are the measures mapped?	...	...
Is there training of knowledge for employees?	...	...
Is there communication towards all relevant parties?	...	...
Research to failures, incidents		
Is there an analysis toward the causes of failures? (reporting, evaluation and research)	...	...
Is the necessity of preventive actions researched?	...	...
Are the finished measures reported?	...	...
Is there preparation for emergency situations? (Incl. response and testing)	...	...

Results are not shown in this version

The maintenance activities at the N31 are hired from the three consortium partners based on fixed prices. This is done by hiring personnel and equipment. The three companies decided together who is doing what based on internal consultation.

> *"The team responsible for the crash barrier do always work on Monday during the maintenance period. The last time this had to change, so I had to consulate with them. I needed to know what the consequences would be because the flow plan has to be approved by RWS three weeks in advance. After the flow plan, it is possible to apply for the traffic measures. Collaboration with the province and RWS is crucial. The easiest way is to have all the right people in one meeting." (1.4 - Operator A59)*

The above example (1.4) shows that communication plays an important role. It is mentioned in both projects that using fixed contact persons is important for good and easy communication. There are periodical meetings with the principal, the management and with subcontractors.

The communication with the province is structured by meetings every 6 weeks at the A59. Next to the meeting, the communication is based on keeping each other up to date. This is positively influenced by have the fixed contact persons. At the A59 a different contract person is used at the province for the "inside" and "outside" jobs. This means that the work outside can be discussed as well as the preparations. Next to this, the subcontractors are consulted to discuss the damages and activities listed by the operator, but also to discuss their own scheduled activities. In these meeting the operator decides the timeframe for the activities. The subcontractor has to find a solution to execute the necessary activities. This is done because the operator needs the overview of the work in order to reduce the reductions based on closing the lanes (reduce availability).

A major advantage for this coordination and maintenance work is explained by being at or close by the project site. Special attention is however needed for organizing the maintenance activities at each subcontractor. Each subcontractor concentrates on a narrow part of the system with the different priorities related to the different parties. This can create a barrier to obtain the full benefit of the services provided. For example, internal communication can cause disruptions and conflicts when the responsible or executive party is not involved (early) enough. This causes misunderstanding and irregularities in goals and ambitions. In turn, this can be reflected on the trust level towards the different subcontractors and eventually the customer. It is mentioned by both maintenance managers that this is more the case when using fixed subcontractors.

The identified risks are documented in a risk report at both projects. This report is discussed in the yearly risk sessions that are held to identify and update the risks. There is no general system used during these sessions, it is based on experiences of the participants (principal is included). Next to this, the risks are written down in quarterly reports. The risks are not translated into special financial entries; they are only used to keep attention on these risks. "An ideal situation would of course be that the risks are based on a fail mechanism, a frequency and money coupled towards them" as mentioned in the interview with a project director. The result would be that a price will be calculated for the risk. This was not "common business" at that time, but today it is getting more usual. According to the management of the N31 this can still be improved.

In the current situation the schedule is not changed based on the identified risks. The available knowledge is said to be sufficient to make a solid schedule. The operator has experience in the field which is needed to make those schedules. The audits and inspections are used to check the performance of the project. The inspections are also used to check whether or not preventive maintenance is necessary. A long term maintenance plan is used to check if certain criteria will be met. "In order to check if this schedule is sufficient you try to look the other way around", according to the operator (1.5). There are no criteria for prioritizing the plans. All the plans and reports are important for the project. Every situation is different and has to be treated accordingly. In one situation the accidents on a part of the project is the reason for updating the plans, in another situation the amount of roes are becoming a risk. It is important to keep the administration as optimal as possible. This makes it possible to make analyses for the project.

> *"Asphalt can be resurfaced 6 year in advance to keep the condition at the required condition fort the end of the project. If the resurfacing is needed earlier, than the chance for another intervention increases. In this project the maintenance activities are not predetermined but are determined based on the present situation. The schedule does not state which preventive maintenance is executed when". (1.5 - operator N31)*

At the N31 the consortium uses a 'share point environment', but this is only used for internal purposes. The inspections and audits are kept here but there is not a system which allows others to use the information. It is mentioned that such a system can be useful, but only when it is created from the start. The system can used to check the requirements and link them to objects. However, it is also mentioned that such a system will not be used to look back on what is done. This is what might be useful for the maintenance stage. It might work when a portable device can be used to check the information in the field.

Many supporting processes are used in the project. However, the available knowledge and information is not exchanged on a structural manner. It is done based on the experience / understanding of the operator. At the N31 it is mentioned that knowledge is not an issue because the operator has three companies with a lot of knowledge behind him. It is, however, said that the employee on the project needs around 50-70% of knowledge. There are no specific trainings used to make sure that the operator has sufficient knowledge. General trainings as traffic controller and technical inspector are followed for practical reasons. Also knowledge of the CROW is needed to keep the information up to date.

MONITORING AND MEASUREMENT

The monitoring and measurement is in both project only done based on the inspection reports and verification reports. At the N31 a simple method is developed for proving fulfilment of the requirements. Reports are used to prove that the agreed conditions of objects are met. If this is not the case, or if the levels are close to the agreed level, then action will be taken. They make estimations about what has to be done. During the project the performance was sufficient. It might be possible to increase the inspection rate in order to prevent not meeting a requirement.

TABLE 13: INTERVIEW RESULTS OF MONITORING AND PERFORMANCE RELATED ASPECTS OF PAS55

	N31	A59
Performance and condition monitoring		
Is the progress continually controlled?	...	...
Is there reactive control?	...	...
Is there proactive control?	...	...
Are there leading and/or lagging performance indicators?	...	...
Are the results of measurements and activities written down?	...	...
Are performances indicators identified that predict the future performance?	...	...
Is a balanced scorecard used?	...	...
Is the maintenance budget translated into unit prices?	...	...
Evaluation of compliance		
Is there a procedure for periodically evaluation?	...	...
Auditing		
Are the requirements checked?	...	...
Are the procedures checked?	...	...
Is the effectiveness of the attainment of the strategy checked?	...	...
Are the checks used to identify measures for reaching the requirements?	...	...
Are the results written down?	...	...
Improvement actions		
Are there corrective actions?	...	...
Are there preventive actions?	...	...
Are the non-conformances and incidents analyzed?	...	...
Is there communication towards the management and relevant stakeholders?	...	...
Reporting		
Is there a complaint report?	...	...
Are the results of the identified risks reported?	...	...
Are there inspections, maintenance and calibration reports?	...	...
Is there an incident and non-conformance reports?	...	...
Management review		
Are there periodic reviews by the management?	...	...
Is this communicated internally and externally?	...	...

Results are not shown in this version

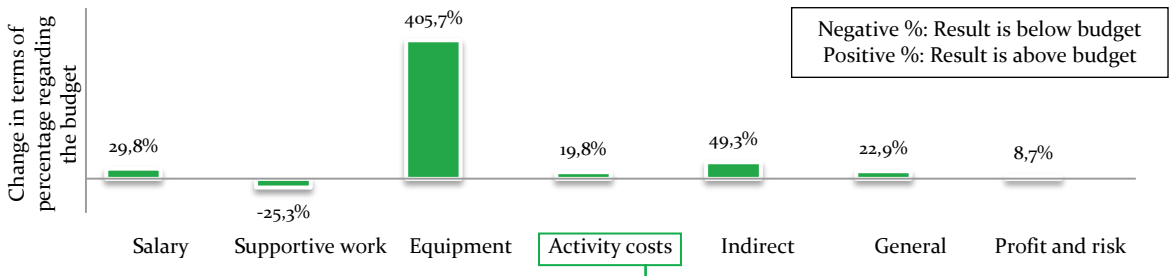
At the A59 the quality of the asphalt is for example known through inspections. This gives enough insight into the quality. The inspection reports might also be used for other projects as the producer is the same.

In both projects there is no usage of unit prices. The budget is controlled based on the yearly schedule and budget. The budget is split into entries to which the costs are controlled. There is no influence on the financial budget calculation, this is already done. The budgeting itself is relatively easy because the fixed prices for maintenance activities (N31)

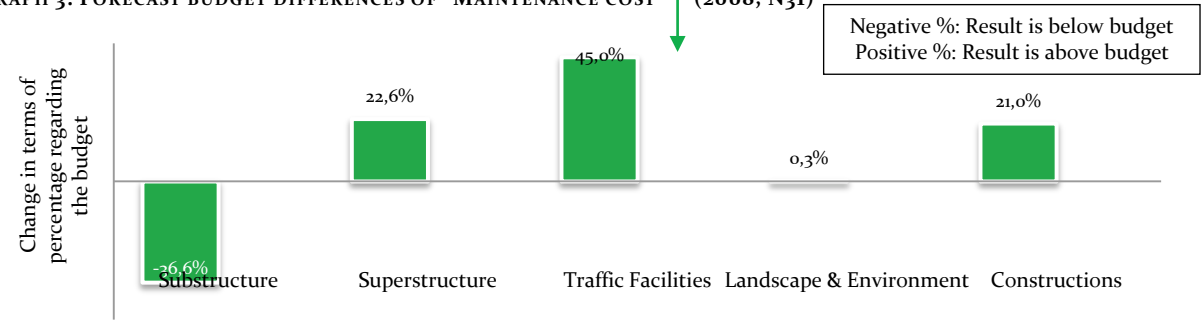
At the N31 the identification of risks are written down in the risk report, the risks are scored based on marks given for example safety and financial impact. Also the risks are discussed and reported in the annual reports and yearly inspection reports. Plans are made based on what is needed for that year and on the available budget. The maintenance schedule of both projects is similar. Both projects have almost the same amount of inspections and preventive maintenance. For example, mowing the verges is done twice a year and the brushing of ZOAB is done once a year. The difference in the schedule can be found in the area that needs to be maintained. This will cause, among other things, differences in budget.

The monitoring and measurement of the available budget is further elaborated on because the costs are chosen in the framework as an output target. In this section the budget situation of both projects is discussed. It is important to indicate that not all maintenance activities are executed to this very day because some maintenance activities are scheduled for upcoming years. Detailed budget information of the PPS-A59 is not known due to sensitivity of the information. Therefore the data of the N31 is primarily used.

This budget segmentation is compared with the result of the year 2008. The change in terms of percentage between the budget and forecast (Graph 3) gives an indication of how the costs change in time and gives an indication of which costs are difficult to predict or are budgeted based on false perceptions. The same can be seen for the 'activity costs' in Graph 4. The changes are only available for the N31 because the maintenance costs at the A59 are divided between subcontractors at a fixed price. This situation makes it difficult to get detailed information about the maintenance cost. Although the detailed information is not available, the variation in maintenance costs is little for the PvDB as mentioned during the interview. The agreed prices with the subcontractors are sufficient to do the work. The yearly maintenance budget is therefore sufficient for the PvDB.



GRAPH 3: FORECAST BUDGET DIFFERENCES OF "MAINTENANCE COST" (2008, N31)



GRAPH 4: FORECAST BUDGET DIFFERENCES OF THE "ACTIVITY COSTS" (2008, N31)

The most noticeable change in maintenance cost is the equipment cost with a change of 405%. This change is caused by the incident service that was not calculated in the original budget. The absolute change on the total maintenance cost is however minor because of the small share in the total maintenance cost. The activity cost on the other hand has 'only' a 20% change, but the absolute change on the total maintenance cost is much larger. Within the 'activity costs' (Graph 4), the costs based on the superstructure cause the largest absolute change. The costs in the superstructure are caused by activities as brushing (ZOAB), cleansing (ZOAB, gutter, sewer, etc), repairing (street work, sealing asphalt, etc), relayer asphalt, inspections (sewer), asphalting roads, inspection (sub objects), and little repair work. The traffic facilities have the largest change in terms of percentage but the change in the activity costs is smaller. During the interview this change is also explained by the difficulty of predicting the traffic intensity and duration.

OUTLINE OF RESULTS

The goal at the A59 is described as keeping the road in top-condition while at the N31 this is further specified by keeping the road safely accessible, driveable, and available. Staying within budget is in both projects mentioned as important and has a large influence on the maintenance planning. The budget is predetermined in the financial model. During the maintenance stage the life cycle cost are considered by keeping focus on the end-project condition. The executed preventive maintenance is also related to the condition of the end-project. However, the need for the preventive activities are said to be assessed based on experience rather than a solid foundation of knowledge.

The documentation system is used for only internal purposes, it is used to store the inspection and audit reports. It cannot be used to check the requirements and link them to objects. It is mentioned that communication and coordination is important and is positively influenced by having fixed contacts. The operational tasks need to be executed with different stakeholders that all concentrate on a narrow part of the system. The operator needs to coordinate all the needed maintenance activities and schedule them in a predetermined period. Risk management is done on predetermined moments and is documented in the yearly reports. The identified risks are however not identified on a structured manner but rather on the experience of the participants. The risks are not explicitly used to calculate the financial consequences but are only used to keep attention on the identified risks. Up to today the identified risks did not results in a reschedule of the planning. The inspections are used to identify the needed maintenance activities based on the situation at the end of the project. The schedule is designed every year based on the available budget and expertise of the operator. This means that mentioned enablers and controls are used but the needed information and knowledge is not clearly controlled. In other words, the activities are executed based on the schedule as well as on experience and the results of the enablers and controls are clear but not explicitly controlled.

The result of the budget situation of both projects shows that the budget is to this very day sufficient to keep the project at the required performance level. It is said that the available knowledge is sufficient to make a solid schedule for the maintenance activities. The largest variation in the maintenance costs is found in the maintenance activities, especially the activities needed to keep the superstructure at the required performance level. Besides the superstructure, the traffic facilities cause also variation in the maintenance costs. During the open-ended interviews with the maintenance managers the causes are explained by the difficulty to predict the traffic intensities and the needed traffic measures.

Most processes listed in the PAS55 can be found in both projects. Table 14 gives an outline of the aspects that are not considered in the projects according to the operators. Based on the results it seems that the processes are described but that it is based on experiences rather than standardized steps and information is used. The financial model is used to determine the best fit with the available budget. Assessments are made to determine how much budget is needed to keep the project at the required performance. These assessments are made based on the experiences in the past rather than data is analyzed. No prioritization of plans and goals are used that could support the decisions made. This makes it difficult to review the objectives during the project.

5 IMPORTANT PROCESSES AND IMPROVEMENTS

The goal of this study is to indicate which processes are important for controlling the maintenance stage performance of integrated projects at the Royal BAM Group. In this chapter shows the results of semi-structured interviews with employees of the N31 and A59 about their perceived importance of processes described in the PAS55. This chapter is structured by first dealing with the influence of these processes on the maintenance costs in section 5.1. In section 5.2 the influence of these processes on the attainment of project goals is given. Section 5.3 elaborates on the processes that are perceived important but are not controlled in the maintenance stage of the projects. The last section (5.4) gives the result of the discussion with experts about the results found in the section 5.1, 5.2 and 5.3.

Tables 15 and 16 are the result of the answers given by the operators of both projects (Appendix G). To establish the degree of influence the operators were asked to assess the relative importance of the listed aspects on the maintenance costs and project goals. The degree of influence could be assessed as low, middle, or high in predetermined cells of an Excel-sheet. The three step scale is later converted into numbers of 2, 5.5 or 9 for analyzing the results. Calculated average scores below 4 are seen as having low (L) influence, scores between 4 and 7 as having average (M) influence, and above 7 as high (H) influence. Tables 15 and 16 only show the aspects with a high of low influence. The aspects with an average influence cannot be found in these tables. However, table 17 does show aspects with an average influence as these aspects are not under control. Due to time restrictions of the interview, only the important aspects were discussed with the operators. Interviews with the project directors were held to check the results given by the operators.

Afterwards, the results given in this chapter are discussed in an expert meeting. The outcomes of this session are given in section 5.4. Hence, the first three sections of this chapter are based on the interviews whereas the last section is based on the expert meeting.

5.1 INFLUENCE ON THE MAINTENANCE COSTS

Table 15 gives an overview of answers given by the operators on the influence of processes described in the PAS55 on the maintenance costs. The perceived importance is established by the average score given by the employees of both projects. That is, no distinction is made between the projects. The structure of the PAS55 is used to order the aspects in three groups: Strategy, goals and objectives, Enablers and controls, and Monitoring and measurement. Only the important factors are discussed during the interviews with the operators and project directors. The discussed factors are presented below.

First of all it is important to mention that the financial picture of the maintenance stage is determined by using a financial model as described in section 4.3. This model determines how and when the maintenance budget is allocated. This means that the *long- and short term schedule* is influenced and is partly the result of this financial model because the needed maintenance activities are based on the available budget. In order stay on schedule it is important to know which activities have to be executed, how they fit together, and how to make the schedule. In order to build these schedules *communication with the subcontractor* is important for effectively executing the maintenance. At the A59, the needed maintenance activities are consulted with the subcontractors based on the findings of the operator and the subcontractor himself. The operator decides on what activities should be performed in a specific time frame. This prevents difficulties with reductions due to the closure of lanes, the so-called lane-reductions. An efficient schedule will result in fewer lane reductions. A related aspect is the traffic intensity on the roads. It is mentioned that the available working hours have decreased due to increasing traffic intensity. At the start of the maintenance stage the work could be executed after 8:00, but now they can start

TABLE 14: RELATIVE IMPORTANCE TOWARDS INFLUENCING MAINTENANCE COSTS

* Also found in table 17	Relative Importance	
	High	**Low**
Strategy, objectives and goals	▪ Research maintenance risks and mapping risks* ▪ Long- and short-term schedule	▪ Control on business goals ▪ Life cycle analysis ▪ Method for risk management ▪ Prioritize of goals ▪ Criteria for optimize plans ▪ Clear responsibilities ▪ SMART goals ▪ Updating plans
Enablers and controls	▪ Structure for exchange of knowledge and information* ▪ Risks as input for activities ▪ Communication towards stakeholders by changes and incidents ▪ Identification of critical objects	▪ Clear responsibilities ▪ Training ▪ Communication and consultation ▪ Documentation ▪ Information management ▪ Method for identifying risks ▪ Criticality Effect Analysis
Condition monitoring and improvement	▪ Continuous progress measurement ▪ Reactive control ▪ Periodic evaluation ▪ Inspection, maintenance and calibration reports	▪ Using balanced scorecard ▪ Using unit prices ▪ Auditing the attainment of the strategy ▪ Communication of improvement actions toward stakeholders ▪ Report the results of identified risks

after 9:00. In order to make an effective schedule the operator needs to know the working speed and has to make a time-road diagram[4] instead of a more traditional block-diagram. The situation at the N31 is a little different compared to the situation at the A59. The operator at the N31 has to deal with the three consortium partners whereas the operator at the A59 has fixed sub-contractors (all divisions of the BAM). The operator of the N31 hires employees and equipment of the consortium partners, but holds the coordination and responsibility of the work. This prevents the construction of the substructure by one partner while another partner constructs the superstructure. Discussions about responsibilities could occur because of the possibility that the quality of the substructure influences the superstructure. Therefore the consortium keeps the coordination and responsibility. The communication with the 'subcontractors' at the N31 is important but different in comparison with the A59. At the A59 the coordination is also the responsibility of the operator, but the subcontractors are responsible for the execution whereas at the N31 the operator is also responsible for the execution.

The aspect '*research maintenance risks and mapping risks*' has a large influence as the mapped risks can influence future maintenance costs. The example of the N31 (see page 36) about the peat surface is an example of a possible risk that influences the maintenance costs. The importance of risk management is in this situation explained by the allocation of technical risks. These technical risks are reviewed periodically because scope (legal and environmental) differences can cause changes. The maintenance activities are determined based on the identification of these risks, the condition of the object and the available budget. However, the budget is fairly fixed. The financial means needed for large maintenance is only available when the entry is totally built up (which takes several years). If the budget is needed earlier approval from a technical advisor is needed. At the A59 the high influence is explained by the use of preventive maintenance to extend the life of the road and to be able to stay on schedule. The resurfacing of the road (A59) is now scheduled for the 15th year of the maintenance period. The needed budget is calculated for this corresponding year. If the resurfacing is needed before or after the 15th year, this will affect the maintenance costs. First of all the financial model builds up the budget accordingly to the 15 years. Secondly the prices might change which has to be dealt with accordingly. It is important to understand the possible risks that can affect the future situation.

[4] This diagram makes it possible to identify the (schedule) difficulties to time and location.

TABLE 15: RELATIVE IMPORTANCE TOWARDS INFLUENCING MAINTENANCE GOALS

* Also found in table 17	Relative Importance	
	High	**Low**
Strategy, objectives and goals	▪ Research maintenance risks and mapping risks* ▪ Knowing the performance of the system* ▪ Know the performance through time* ▪ Communication towards stakeholders	▪ LCC ▪ Prioritizing goals ▪ SMART goals ▪ Clear responsibilities ▪ Optimization criteria of plans
Enablers and controls	▪ Risks as input for activities ▪ Control on project goals ▪ Risks of critical objects known ▪ Communication of unforeseen events towards stakeholders ▪ Analysis towards the causes of failures ▪ Write down the finished measures	▪ Define responsibilities ▪ Contract based on SLA's ▪ Training ▪ Authorisation of information ▪ Method for identifying risks
Condition monitoring and improvement	▪ Write down the results of activities and measurements ▪ Periodic evaluation ▪ Preventive maintenance actions ▪ Using a complaint report ▪ Report the results of identified risks ▪ Inspection, incident and calibration reports ▪ Incident and non-conformance reports	▪ Proactive control ▪ Using a balanced scorecard ▪ Using unit prices

5.2 INFLUENCE ON THE PROJECT GOALS AND OBJECTIVES

Table 16 gives an overview of answers given by the operators on the influence of processes described in the PAS55 on the maintenance goals. The perceived importance is established based on the average scores of the employees of both projects. That is, no distinction is made between the projects. Only the important factors are discussed during the interviews with the operators and project directors. The factors are discussed below. The project goal in both projects are interpreted the same as described in section 4.3.

Communication with stakeholders is indicated as important. A remark is made by both projects that fixed contact persons influence the communication positively. At the A59 the communication is based on 'keeping each other up to date'. This means that changes and issues are addressed if they are interesting for the province or for the consortium. The policy at the N31 is focused on keeping smooth contact with RWS. It is said that if the contract requirements are met then the contact will run smoothly; there is an interaction between the requirements and the contact. Besides the communication it is important to know what needs to be done and what actually is done. *Knowing the condition and performance of the system* is also mentioned as an important aspect. The required condition is written down in the contract. If the contract does not clearly describe what needs to be done, discussions will occur about who is responsible for the consequences. This will have a negative influence on the contact and relation with the stakeholders. In order to meet with the project goals it is important to stick to the requirements, to the original question of the principal. If possible, it is beneficial to optimize the maintenance concept within these boundaries. But important is that the work is done on time and to keep the end condition of the project in mind. Another aspect that is mentioned is to think about what can happen on specific locations and how this can be prevented. This helps to align upcoming work with the principal.

5.3 FACTORS TO BE CONTROLLED

In sections 5.1 and 5.2 the aspects with a high or low influence on the maintenance costs and project goals are listed and discussed. Furthermore, section 4.3 indicates that many aspects of the PAS55 are used in both projects, but that most aspects are based on knowledge and experiences rather than systematic steps and information. This could be explained by the remark that "maintenance itself is not really difficult, it is no rocket science". However, to improve the maintenance stage of both projects this section discusses the aspects are considered important.

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6 DISCUSSION

In this chapter the important processes to improve performance by the attainment of the projects' goals and budget are discussed. A holistic view, by using an input-process-output-outcome perspective, is used to analyze the two projects: the PPS-A59 and the N31-Wâldwei. This makes it possible to avoid the contextual differences of the projects and to describe the current state of maintenance at the Royal BAM Group. This chapter starts with the discussion of the attainment of the maintenance budget in section 6.1 followed by the attainment of the project goals in section 6.2. Finally, section 6.3 discusses to what extent the results of this study can change the maintenance performance.

The results of this study show that a large proportion of the described processes in the PAS55 can be found in both projects. Furthermore both projects are considered successful because they are within budget and on schedule. Based on this situation it can be argued that the experience and knowledge of the operator is sufficient to control the maintenance stage and make it successful. However, improving the maintenance stage is difficult when only the results are visible rather than knowing and evaluating the steps that are taken. This first situation makes it difficult to improve the supporting processes because little information is gathered during the execution of the project.

6.1 MAINTENANCE BUDGET

First the current situation is discussed. Thereafter the processes for improvement are discussed.

CURRENT SITUATION

The success of the maintenance stage for the BAM is mainly determined on a financial basis. The goal is to stay within the available budget. Looking at the available budget the financial result is sufficient considering the first five years of both projects. Some caution should be noted because the large and expensive maintenance activities have not been executed yet. A large part of the available budget is needed for these large maintenance activities that will largely determine the performance of the maintenance stage. After the first five years, the variation in the budget is mainly caused by the maintenance activities needed for the superstructure. This can be explained by the fact that the superstructure is mostly affected by environmental influences, traffic conditions, and by unforeseen damages like cracks and deformation. Currently, the road in both projects is behaving better than expected. Therefore, the current variations in the budget by the maintenance activities do not affect the maintenance strategy. The available financial entries in the maintenance budget are considered to be sufficient for executing the required maintenance activities for the entire project.

However, the available budget is based on considerations made in the financial model that is developed before the start of the maintenance stage. As a result, the available budget is considered as basic principle for scheduling the maintenance activities and is used to execute preventive and corrective maintenance activities. The current knowledge to design a long-term schedule to keep the project at the required condition is considered sufficient because the projects stay within budget. In other words, there is no real incentive to cut-price of maintenance when maintenance stays (rather simple) within the budget. This schedule is developed based on the knowledge and experiences of the operators, there is no information available to support the schedule-decisions. Knowledge and data about the degeneration process is currently not available which causes uncertainties about the timeframe when maintenance is needed. This makes it hard to determine whether or not the maintenance actions are actually needed to achieve the required (end)

Road-train
The so-called "maintenance train" is mentioned in both project as improvement to optimize the work hours of maintenance. This is a concept in which sequential parts of the road are closed while all the needed maintenance activities are executed at the same time. For this optimization it is necessary to understand the work speed for all activities. This will reduce the total time the road needs to be closed.

condition. The cause-effect relations cannot be determined, it is therefore debatable if all preventive maintenance activities are needed to extend the lifetime of an object.

Another possibility for the current positive financial result of the chosen maintenance strategy is the use of safety ratios in the calculation of the budget. At the start of the project there was little knowledge about the design of the maintenance schedule. During the project optimizations have been implemented by using experiences as teacher. An example is the use of the 'road-train' (see box). This optimization aspect was learned during the project and is now implemented.

Based on this analysis it can be observed that the maintenance costs are mainly controlled by the available budget. This leads to project success in both projects, but there is no organizational learning to optimize the project performance. The cost reductions will not be developed which will make it more difficult to win upcoming tenders.

PROCESSES FOR IMPROVEMENT

The PAS55 is used in this study to get understanding of which processes are important to manage and are actually managed in both projects. It seems that many processes are used. However, most processes use experiences rather than standardized steps and information as input. A financial model is used to design the best allocation of available budget. The allocated budget is then used to keep the project at the required performance. What and when activities are needed is based on the contract conditions and the schedule made by the operator. For the scheduling of activities assessments are made based on the experiences of the operator rather than based on a structured analysis of data. The schedules are made without predetermined prioritization of plans and goals that could support the decisions made. This makes it difficult to review the objectives during the project.

This situation is not easily improved as there is no information and data available to make decisions. Investigating the necessity of preventive and corrective maintenance can help to find an optimal ratio of preventive and corrective maintenance (See Figure 10). This could be achieved by the process of monitoring and inspection to reduce the uncertainty about the degeneration process of objects. Knowledge about this process could first of all be gathered by understanding the current condition of the objects. Thereafter knowledge about the possible development of the degeneration process is necessary. Finally, it might be possible to predict when the failure value will be reached.

Although the budget is sufficient to keep the projects at the required condition, keeping the budget as basic principal for scheduling the maintenance activities will not lead to continuous improvement and cutting prices of maintenance. Comparing the original budget with the results is necessary for learning purposes (creating feed-back). However, in the current situation of both projects it is difficult to evaluate the budget because there is no helpful structure available. That is, it is difficult to find the causes for budget variations because the processes that could be responsible are not systematically executed. Furthermore, the basic principles for creating the budget are difficult to recover.

6.2 MAINTENANCE GOALS

First the current situation is discussed. Thereafter the processes for improvement are discussed.

CURRENT SITUATION

The main goal of the projects is to keep the road available and at the required condition while staying within budget. The budget part of this goal is discussed in the previous section. The other goal, the availability and condition, is related to the service levels that are prescribed in the contract. However, the availability has a financial component by the reductions assigned to road-

closures due to maintenance activities needed to keep the road at the required condition. Furthermore, the availability is closely related with the quality of maintenance. Better quality could lead to better availability because maintenance activities can be postponed. The results of this study show that the choices made between cost and quality have a quality-perspective. The interviewees support this perspective because the penalties for not complying with the contract requirements are very large. Furthermore, the employees are committed to the project and are willing to keep the project as successful as possible within the available budget. This situation is supported by their assessment on the financial result.

In other words, the execution of maintenance is highly budget-oriented. The required service levels are considered important while the available budget is used to execute maintenance activities that keep these service levels as high as possible. The condition of objects is monitored by using inspections (reports) and audits. These reports provide evidence towards the principal about the condition of objects. Furthermore, the results of the inspections are used to make a plan for the upcoming years of maintenance with the main point for the short-term schedule. However, the objectivity and experience of the operator are used to classify the condition. Asking another operator, inspector or auditor will lead to different results. This makes it almost impossible to explicitly point out what could improve the performance of the maintenance stage.

PROCESSES FOR IMPROVEMENT

The processes that should support the attainment of project goals and decisions in the maintenance stage are described in documents and procedures. However, the information and methods needed for these processes are less clearly controlled. This can for example be seen in risk management. The risks are periodically reviewed, but without a structured method. The available knowledge and information exchange is also unstructured. The operator is important in this process because of the coordinative tasks. The operator uses his knowledge and experience to execute and coordinate the work. The absence of a documentation system for exchanging information poses a risk when the operator is replaced. Furthermore, the project goals are not periodically reviewed or monitored which makes it difficult to determine the performance of the project and to make decisions that support the attainment of the goals.

The success of the maintenance stage largely depends on the experiences of the employees and the contact with the principal. This indicates that there is no clear maintenance strategy about achieving the project goals and financial results. In the maintenance strategy it is described how sub-goals are achieved, like the replacements of light bulbs, but the goal of profit is not supported by structured steps. Only when processes describe how to reach the goals makes it possible to start optimizing the (internal) goals. Hence, the process of learning is not under control. There is no learning from damage patterns or learning when damages will occur.

6.3 IMPROVEMENTS

Currently, the main focus is on demonstrating that the required condition is met using the available predetermined budget. That is, the maintenance stage is highly budget-oriented. From a project-oriented perspective this is correct as long as the required contractual conditions are met. From an organisational-oriented perspective this budget-oriented view does not align with the strategic agenda of the Royal BAM Group where aspects as continuous learning and knowledge sharing are pursued. Next to this, this view does not align with their company philosophy consisting of offering the principal value and a close relation.

The results found in this study give an indication of what processes the Royal BAM Group needs to the control and improve in the maintenance stage to be able to keep the lead over the competition. They can choose two ways for achieving this improvement. They can reduce the maintenance costs (while meeting the required service levels), or they can increase the quality of maintenance. Either way, it is important to understand the cause-effect relations of their actions. Relaying on the knowledge and experiences of their employees can result in successful maintenance. However, the outcome of the project is then difficult to control. The steps that are taken by their employees cannot be followed which makes it almost impossible to start a process of continuous improvement at an organisational level. Furthermore, the processes described in the projects are executed but the steps that are taken are not traceable. Improvement of the

maintenance stage could be obtained if the processes needed in the maintenance stage are identified and controlled, if the company objectives are aligned, if (degeneration) trends are analyzed and used for steering purpose, and if KPI's are identified and analyzed. With these improvements it is possible to identify cause-effect relationships that can be used to improve KPIs, steer the maintenance stage based on these KPIs, and to continuously improve the maintenance stage. The ultimate goal is obtain predictable processes by designing measurable and controllable processes.

7 CONCLUSIONS AND RECOMMENDATIONS

In this chapter the results of the case study are combined in order to present the conclusions of this study. This chapter starts with considering the research goal followed by answering the research questions and the main research question. This chapter ends with recommendations for the Royal BAM Group and recommendations for future research.

7.1 CONCLUSION

The objective of this study is *"to study the processes that need to be controlled in the maintenance stage to influence the maintenance strategy and to improve the performance of the maintenance stage for the BAM."* In order to reach this objective the main research question is formulated: "*Which processes does the BAM need to control in the maintenance stage of an integrated infrastructural system to improve the performance of the maintenance stage?*"

To answer this research question literature is studied to execute the study on the N31–Wâldwei and PPS-A59. Literature shows that performance measurement in the construction industry, and especially in maintenance, is a complex task. This is caused by the small amount of information and knowledge that is currently available and the complexity of the maintenance requirements. A framework is used that relates the objectives of the BAM with the results of the studied projects. The case studies are analyzed by studying project documentation and by conducting several interviews with operators and project directors. The analysis of the cases has resulted in the aspects that need to be controlled. In an expert meeting the results are validated and the improvements for other projects and the Royal BAM Group are discussed.

What is performance and how can it be measured?

It is difficult to define a maximal performance because there is no single best solution to infrastructural problems. Instead, the desired performance can be defined if choices are made between the desired quality and available (financial) means for attaining the company objectives and targets. Using this desired performance as baseline makes it possible to track how the performance of the project develops throughout the project. Therefore, performance is in this study defined as the outcome of the actual choices that are made between the quality of a system and the needed (financial) means in relation to the desired performance.

For the BAM, tracking of performance is a key management issue because they spend a significant amount on the operating budget. In the construction industry there is however no framework available that supports the measurement due to the little available information about maintenance activities. Furthermore, there are no indicators for measuring the needed information due to the complex nature of maintenance. This complexity is caused by the choices that have to be made between alternative measures, the dependency of other parties in the project, the difficulty of retrieving the sources of failures, and the time and costs that are needed to repair the failures. The development of performance indicators is difficult due to multiple objects, the subjectivity, immeasurability and untransparent nature of maintenance. Furthermore, indicators in literature are mostly lagging indicators that are less useful for the continuous process of maintenance. It is therefore difficult to point out which processes contribute to the improvement or evaluation of the maintenance performance based on the available information. There is no quantification of the efficiency and effectiveness of actions as recommended by Neely, Gregory and Platts (1995). To be able to measure performance in this study, the perceived influence of processes on the project goals and maintenance costs is used instead.

Which maintenance strategies can be found in literature and what are the effects on the performance of an infrastructure system?

The maintenance stage is about ensuring that the assets are adequately maintained and protected to deliver the required level of service, condition and performance. Maintenance is needed to compensate the effect of general use and external influences. The strategic aim is to perform the right maintenance on the right time as to optimize the total cost-benefit relationship of infrastructure over its lifetime. The objective of the BAM is to reduce the total maintenance costs while fulfilling the requirements set in the contract. This planning is defined in a project specific preservation plan that is developed based on their experiences and knowledge.

Traditionally there are two approaches to achieve the maintenance objectives, preventive maintenance and corrective maintenance. Corrective maintenance is about reducing the severity of failures once they occur. Preventive maintenance is used to reduce the probability of failure in the time period after maintenance has been applied.

Causes for corrective maintenance activities are incidents and accidents or failures. Incidents and accidents are unforeseeable situations with regard to the infrastructural system. Failures are interruptions or hampering which cause the system to fail in fulfilling its function. A difference can be found between planned and non-planned failures. For objects with a low risk and short repair time it is possible to wait until the failure occurs. Non-planned failures are more severe because these failures occur by important objects for the functionality of the system.

Preventive maintenance can be divided into time based maintenance (TBM) and condition based maintenance (CBM). TBM is used for objects where failure is not allowed. The difficulty is to time the intervals of inspections and replacements that prevent failure. The maintenance costs will depend on the length of the intervals and the acceptable availability. CBM is executed based on the condition of an object. These activities can be planned ahead because the condition of an object will be improved after a certain time interval that is decided on by means of inspections. This is prescribed by the expected degeneration of the current condition of the object and the history. The effect of CBM on the costs is that unnecessary maintenance can be prevented. Disadvantage is that it uses more equipment and personnel which increases the costs.

The described literature approaches are found in the project documents of the BAM. However, there is little experience and knowledge in the construction market about the development of long-term maintenance. This makes that the effects of preventive and corrective maintenance on the performance are not known, and not monitored.

Which processes that influence the performance of an infrastructure system can be controlled?

The interrelation of maintenance activities makes the control of the performance difficult. On the other hand, processes form a chain that affects the achievement of project goals and its success. Using a more holistic view at the maintenance stage makes it possible to indicate what processes are important for supporting the maintenance performance. This view is based on input-process-output-outcome. Input for maintenance consists of all the resources used by the BAM. The maintenance process is used to keep the required functions available at the agreed level. Output is formed by the delivered performance that has to meet the required demands. The outcome can be defined at the time the maintenance stage has ended. This study focuses on the processes that transform inputs into outputs. External factors establish the boundaries within which the BAM can operate.

Performance measurement as defined in this study makes it important to measure if a company manages its performance in line with their functional strategies and objects. Therefore the alignment of the company's mission, strategy and objects is used as baseline. In this study the link between the processes and outputs is used to identify the processes that are perceived important for influencing the maintenance performance (attainment of project goals and costs). The first step is to investigate the expected and realized output by studying the 'Attainment of maintenance costs'. The second step is to study the expected and realized process targets by studying the 'Attainment of process targets'. This is done by using the PAS55, a general accepted structure to optimally manage assets and asset systems. This structure is furthermore based on comparable widely adopted standards such as ISO 14001 and OHSAS 18001. The PAS55 defines what has to be done to optimally manage assets and is therefore used to map what processes are used in the

maintenance stage of both projects. The PAS55 uses the PDCA circle which combines the plans with the results, and thus makes performance measurement possible.

What measures can be taken to improve the performance of the maintenance stage at the BAM?
The previous question showed that the processes in the PASS55 are used as check-list. In both projects many of the described processes are used in the projects. The perceived influence of the processes on the maintenance costs and project goals is analyzed to find those aspects that are considered important. Interviews with the operators and project directors show that the following aspects are perceived having a high influence on the maintenance costs and project goals.

TABLE 16: ASPECTS THAT ARE PERCEIVED TO INFLUENCE THE MAINTENANCE COSTS AND PROJECT GOALS

Maintenance costs	Project goals
▪ Communication towards stakeholders when changes and/or incidents occur; ▪ Continuous progress measurement; ▪ Inspection, maintenance and calibration reports. ▪ Long- and short-term schedule; ▪ Periodic evaluation; ▪ Reactive control; ▪ Risk management (as input for activities, for knowing critical objects, research maintenance risks, reporting identified risks); ▪ Structure for information and knowledge exchange by outsourcing;	▪ Analysis towards the causes of failures; ▪ Communication towards stakeholders (also by unforeseen events); ▪ Control on project goals; ▪ Reports (Incident and non-conformance report, Inspection, incident and calibration reports, Complaint report); ▪ Knowing the performance of the system (also through time); ▪ Periodic evaluation; ▪ Preventive control; ▪ Risk management (as input for activities, for knowing critical objects, reporting identified risks); ▪ Write down the finished measures, and the results of activities and measurements;

The available data and information provided in this study are not sufficient to conclude that the four above mentioned aspects are aspects that the BAM needs to control in all their projects. However, the four mentioned aspects are considered important taking the two projects into perspective. During an expert meeting the absence of a general maintenance policy is mentioned as cause for the absence of these four aspects. Maintenance is now executed ad-hoc and the decisions about maintenance are based on the experiences and knowledge of employees. A general maintenance policy can be used to make clear what goals should be achieved supported by predetermined structured processes. The current situation makes it impossible to define a 'baseline' which is needed to support decision-making about why maintenance is necessary. Furthermore it prevents learning by the organisation which is needed to keep the lead over the competition. Improvements can be found in increasing knowledge about the degeneration process by the establishment of damage-patterns, the process of determining when damages will occur, and the process of inspection with fixed instructions. This is a first step into improving the internal processes that support the attainment of project goals and maintenance costs.

The main findings of this study could be used to increase the chance for project success. The results can help the BAM to focus on controlling their performance by using a strategic perspective on performance measurement. The objective of this study is partially achieved because important aspects have been indicated. However, their influence on the performance cannot be fully supported as this is based on perceptions of employees. Furthermore, the maintenance stage is affected by external factors that cannot be controlled. The question remains whether process control will lead to better responses on these external factors. Important is to react on time to uncontrollable factors and to deal with the effects by having well founded and structured processes that support the business objectives.

7.2 RECOMMENDATIONS

Both projects are currently executed within budget and are executed according to plan. There are, however, still opportunities for improvements. Improving the maintenance performance is necessary if the Royal BAM Group wants to be competitive with these integrated contracts. The recommendations in this section are divided into recommendations for the Royal BAM Group and recommendations for future research.

RECOMMENDATIONS FOR THE ROYAL BAM

This study has indicated that maintenance itself is not that difficult. However, developments in the maintenance environment increase the importance of providing evidence about the execution of processes. Furthermore, maintenance is becoming more important if the Royal BAM Groups wants to stay competitive with maintenance. During this study it was difficult to point out how profit is created in the maintenance stage or how the strategy is translated into certain targets. Many activities are executed based on experiences which mean that each project is executed without any clear direction. There is no clear link between the original plan and execution. The given recommendations are divided between recommendations on organisational level and on project level.

Recommendations on organisational level:

- Arrange project-evaluations for learning-purposes
  In both projects inspection reports are used for ad hoc checking of the condition. The reports are not compared to understand the development of the condition. This makes that there is no learning within projects throughout the project development. As a result, each project has to re-invent the wheel. Storing and updating this information periodically can help to learn from projects and makes it easier to evaluate the projects, understand cause-effect relationships of decisions, and when necessary to steer or adapt to the lessons learned. The lessons learned can be summarized by writing evaluation reports and discussing difficulties and improvements. Within these evaluations it is recommended to include process evaluations of risk-management, performance measurement, information exchange, and practical improvements like the 'maintenance train'.

Recommendations on project level:

- Extent the use of performance measurement system
  This system could, however, also be used towards internal optimization or continuous monitoring of for example asphalt (has the largest maintenance cost, but this can be project specific). This latter example makes it possible to play with variables, and makes the condition monitoring more objective. The condition of objects is currently measured based on visual inspections which have some degree of subjectivity. Different inspection methods are used by the operator and the principal with different results. Internal optimization is about analyzing and evaluating data to determine the suitability and effectiveness of processes and to start continuous improvements. Examples are listing all the identified risks and the risks that actually have happened, data about degeneration processes, or work processes. Furthermore, the internal optimization can be combined with some sort of capability level to understand what level you want to achieve. This data gathering will increase the competitive position of the BAM, and it could help to develop better tenders.
- Research the opportunities for innovative design.
  This recommendation is not closely related with this study, but it could help to optimize maintenance activities. For example, the marks of the kilometres and the reflectors need to be placed in the verge according to the current regulation. These objects constitute a major obstacle when mowing. Some thought is given to change the design of the road and integrate this information into for example the road. However, the current regulations prevent this kind of innovation. It would be a major improvement if these kinds of design changes were allowed by the government. For the BAM this is difficult to change but when more maintenance projects will be put out to tender it might be cost-effective to invest in these kinds of changes. Changing regulation takes a lot of effort and time.

RECOMMENDATIONS FOR FUTURE RESEARCH

During this study the following points for future research have been determined.

- The maintenance of integrated infrastructural projects is still in its infancy. This makes that there are many possibilities for future research, for example into the material use

and the related degeneration processes, or the usefulness of preventive maintenance. Knowledge about the degeneration process is important to be able to make better estimations about when the failure level will be reached. If this is known better, then it will be possible to make better decisions about what and when maintenance is necessary.

- In this study important processes are identified for these specific projects. Extending this study with other similar projects will increase the general applicability. Using this knowledge makes it possible to research general KPIs for maintenance and develop a set of KPIs that organisations can use to select appropriate ones. It might also be possible to research the link between the process performance and the overall corporate goals.

- The ultimate goal of finding KPIs is improving decision-making and work processes. During this study important aspects for improvement of maintenance are identified. The exact influence of these processes is however not clear. It is recommended to examine the effects of improving the processes and the corresponding quality improvements. This will increase the understanding of business costs and performance drivers.

- The results of this study are based on the execution of 5 years of maintenance. As a result, the outcomes of the largest maintenance activities could not be evaluated. It is therefore recommended to execute another evaluation after another 5 or 10 years.

- Establish the relationships between the various (sub) processes. This will enable an analysis of the cause-effect relationships and understand the interactions and often overlapping sub-processes.

8 LIMITATIONS

This study is executed in a limited period of time and with a limited availability of data. Therefore, this chapter discussed the limitations of this study.

The purpose of this study is not to study all possible relationships between the organization´s input, process, outputs and outcome but to ensure that some key relationships for improvement are identified using a holistic perspective. The objective of this study is to examine the processes that are important for improving the performance of maintenance by evaluating the project goals and maintenance costs. The processes found in this study are based on just two projects and have an explorative character due to the pragmatic reason that only two DBFM-projects (in the maintenance phase) are available in the Netherlands. This situation leads to an one-sided view because the available data is limited. The results are therefore specific for these two cases.

Limitations of this study are further:

- Usage of PAS55
  The PAS55 is used as checklist in this study. The PAS55 is a general applicable and accepted structure that can be used for all kinds of assets. However, infrastructural assets have different characteristics which might not all be considered. If another kind of structure (e.g. ISO 14001:2004 or ISO 9001:2000) would be used this might lead to other results. Disadvantage of the PAS55 is that there is no classification about how well an organisation is performing. Using the PAS55 for benchmarking is therefore difficult. It is, however, possible when several evaluations are executed and results are compared.
- Interviews
  The interviews that have been conducted for the case studies are based on a predetermined structure. The little availability of time in regard to the many aspects described in the PAS55 made it necessary to select what aspects were discussed. It is therefore possible that the respondents are influenced in their response. However, the topics were broadly defined and possibilities for respondents to mention own aspects minimized the influence as much as possible.

  The data gathered in the study is mostly based on the perspective of the operator. The operator has the best total view on the execution of the maintenance. The conclusions of this study can therefore be based on too much operational knowledge. The project directors were used to check the information. For validations reasons the results are discussed in an expert meeting in which the results were supported.
- Expert meeting
  The results presented to the experts have indicated that the identified processes are important and that these could be improved by making them traceable and easier to control. However, some similarities as well as differences in the experts' perceptions were present with regard to risk control and information exchange. These differences mainly occurred between the employees on operational level and the management level. The process of risk management is considered important but the applicability towards the maintenance stage is debatable. The exchange of information is useful but the experience of employees is considered just as important.
- Maintenance stage
  This study is based on the first 5 year of maintenance. As a result not all the maintenance activities are executed; the largest part of the maintenance stage is still to come. This means that many (important) maintenance activities are not yet executed. Predicting if the maintenance budget is sufficient for the whole project is difficult. This might lead to the identification of other important processes.

- Infrastructural DBFM-projects
  In this study only infrastructural DBFM-projects have been considered. This might give a more limited image about maintenance than when also other maintenance based projects would have been studied. However, the choice for DBFM-project is made because of the specific characteristics of this contract.

  Another important limitation is that the contracts used today contain different requirements due to the experienced gathered with this kind of contracts. Other requirements will lead to totally different circumstances. This can influence the maintenance strategy and contract with the principal or environment.

- Broad view on projects
  The broad view is chosen because little knowledge and information is available about the topic. This resulted in a descriptive study of the subject matter. The conclusions of this result can be used for more in-depth research.

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APPENDIXES

A BAM INFRACONSULT

This study is commissioned by the cluster Inspection, operation and maintenance of BAM Infraconsult. In this section the organization of the BAM is discussed in order to be able to put the assignment into perspective.

Organization Structure
The Royal BAM (Bataafsche Aanneming Mij) Group is built up of different operating companies. They are active in the sectors construction, property, civil engineering, public private partnerships, mechanical and electrical contracting, consultancy and engineering, and facilities management. BAM Infraconsult is the firm of consulting engineers for the sector Infra of the Royal BAM Group. They have around 170 employees and their offices are situated in Gouda (Head office), Apeldoorn, Den Haag, Breda, Utrecht and Singapore.

Mission and Vision
The mission of the Royal BAM Group is to become one of Europe's finest construction groups, known for its collective force as well as the local services. They believe that by taking responsibility for people and planet, the Group will meet expectations of both current and future stakeholders in a fast-moving world of economic, political and environmental change.

Their vision is that the existing stock of the built environment determines a large part of Europe's energy need. Climate change, and halting it, has significant impact on the design and construction of buildings and infrastructure. The Group should not just deliver services and products, but should contribute actively to society by the way operation companies' act in the supply chain by taking responsibility for the consequences of their action.

The primary processes focus on obtaining and completing projects in as efficient and effective a manner as possible. In addition to cost and risk management, there is a growing emphasis placed on cash management.

Activities of Infraconsult
A major part of their services are used to support sectors of the BAM especially BAM Civil, BAM Roads, BAM Rail and BAM Infratechnique. The other parts of the services are used as support for other sectors of the BAM Group and for external parties. Their services include the planning-, design-, calculation-, construction and maintenance phase of the construction process. In more detail their services include management consultancy services, consulting, design and engineering, inspect and advise for management and maintenance, manage permits, project, contract-operating and risk management and RAMS-analyses.

BAM Infraconsult has some experience with integrated contracts, for example the N31 (DBFM-contract) and the HSL-Zuid (DBFM-contract). Despite their experience with integrated contracts more knowledge about maintenance management is required for optimization of the construction process and to face the competition. In construction projects not only the critical goals about the budget, schedule and quality are important anymore. The market change, not only from the government but also from the public, makes other goals also important. These goals include client satisfaction, safety, sustainability, availability and other aspects. This makes the optimization of the construction process a difficult task and calls for the need of process-based performance indicators that measure performance during the project.

Corporate objectives
The corporate objectives of the Royal BAM Group is discussed in the Strategic Agenda of the Royal BAM Group (Koninklijke BAM Groep, 2010). Five different topics are distinguished: Financial, Market, Product and Concepts, Organization, and Human and Society. Table 19 gives the topics that are relevant for this study together with an explanation.

TABLE 17: COMPANY OBJECTIVES

Score	Company objectives	Explanation
A.	Human & Society	• Safety of employees & sub-contractors • Safety of the direct environment of construction sites • Knowledge & experience sharing (know-how of the group) • Development of management potential • Diversity of employees as mirror of society
B.	Products & Concepts	• Development of new products and concepts
C.	Market	• Improvement of position in market
D.	Organization	• Improvement of the primary process & risk management • Lean construction management • Introduction of virtual construction and ICT-application • Social Responsibility (MVO)

Human & Society

- Safety for employees as well as for sub-contractors is important, just as the safety for the direct environment of the construction sites.
- Sharing knowledge and experiences is necessary in order to survive in the market of tomorrow. Therefore measures will be taken to fully benefit from the know-how of the whole group.
- The development of sufficient management potential in all levels of the company.
- Diversity of employees is important for the group as a mirror of society.

Products & Concepts

- New products and concepts are developed in order to meet the demand for a complete solution of the client and to fulfil the requirements of today's society regarding the energy consumption, waste- and water management.

Market

- In a fast moving world, the society asks for solutions to complex problems. Based on good entrepreneurship and flexibility can BAM improve their home market in three ways:
  1. Autonomous by explanation of BAMs activities in the current markets, by the improvement of the regional basis and by the growth as soon as an opportunity arises.
  2. Development of new activities in the current market by using the knowledge that is present in the group
  3. Bundle the knowledge of the group in order to serve the client with new ideas, for example by the development of concepts and initiatives early in the construction process.

Organization

- Improvement of the primary process and strengthening of the risk management by using the expertise of the subsidiary companies and by using 'Lean Construction Management'.
- Introduction of Virtual construction and ICT-applications for:
  - Communication with clients
  - Collaboration with design and work preparation
  - Communication within the company and projects
  - Sharing of knowledge
  - Managing, sharing and storing of information
- Social Responsibility: Develop initiatives to draw attention to sustainability in the whole supply chain.

B CLARIFICATION OF DBFM-CONTRACT

This appendix gives an outline of the DBFM-contract.

B.1 *DBFM-CONTRACT AND PROJECT STAGES*

The characteristics of an integrated contract differ from the traditional contract. The use of a DBFM contract includes all the project stages into one contract which makes the understanding of the project stages important for understanding the situation in the maintenance stage. The project stages before the maintenance stage are seen as boundaries for this study because during the maintenance stage they cannot be influenced anymore. The project stages of infrastructure have numerous definitions but they can be divided according to the stages in a DBFM-contract. Before the characteristics of the stages are discussed, this section will start with the explanation about a DBFM-contract.

DBFM-contract

In building law various contract models are distinguished. The models are distinguished based on the extent of influence of the client and the corresponding liability. The different models are the traditional model, the building team, the integrated model, and the alliance form (Boot et al., 2008). An integrated contract is an agreement in which the contracting authority puts more than one task to the same party. That is, the party is responsible for two or more integrated tasks (e.g. the design task and the construction task). It is an umbrella for many variants like design and construct, turn-key, design build finance maintain & operate (DBFMO) and all kinds of variants on these. The tasks for DBFM-projects can be divided into a design (D), construction (B), finance (F), and maintenance (M) task. Table 20 shows the differences and similarities between a DBFM-contract and a traditional contract for infrastructural projects.

TABLE 18: CHARACTERISTICS OF DBFM- AND TRADITIONAL CONTRACTS (BASED ON HOBMA (2009))

	DBFM-contract	Traditional Contract
Risk Transfer	Risk transfer to contractor	Client responsible for coordination
Client	(Usually) National Government	(Usually) National Government
Financing	By contractor (Special Project Vehicle)	By client
Optimization	Design – Built - Maintain	Strict separation of phases
Inspection by client	In between	After construction
Payment	Periodical payment by client from the moment the infrastructure/service is delivered	Payment by completion of each phase
Specifications	Output specifications in advance laid down by client	Technical specifications in advanced laid down by client
Contracts	One between client and contractor	Individual contracts between client and contractors
Disadvantages	More preparation time needed	Coordination problems Unnecessary high failure costs Schedule delays

Besides the above described differences there are some other aspects of integrated contracts that are important to discuss.

Supply chain integration

The integration of the activities into one contract leads to one responsible party. For the contractor the integration of tasks has several threats and opportunities. The integration of tasks has the advantage of the incorporation of 'buildability' in de process, improving coordination and communication, improving decision making, and fewer risks to the client of cost and time slippage (Favié, 2010). This can also result in better maintainability and more efficient design. The contractor has one contract with the client for the whole project, which has the advantage of less coordination difficulties with the client. The coordination within the business of the contractor will in contrast become more important. The contractor has an incentive to use more innovation because this can result in better project performance or for example faster production time. This latter example will benefit from financial incentives as will be discusses later. A system of payment

incentives coupled with the availability of the project will encourage the contractor to get payment as early as possible.

Allocation of Risks

The integration of the construction stages into one contract makes that the allocation of risks between the parties will be distributed differently. This topic needs special attention because of its importance. With the traditional contract many risks such as the coordination of tasks is the responsibility of the client. The contractor is only responsible for the execution of the agreed tasks. With the integrated contract the contractor is responsible for more risks because the coordination between the different phases is allocated to the contractor. The allocations of some (not all) other risks are negotiable in the negotiation phase. It is a process of who is willing and able to bear the risk and what the financial benefit is.

Stimulation of innovation

The specification of the requirements is also different between the contracts. Integrated contracts are generally closed based on functional requirements. This is done to give the contractor opportunities for designing different solutions. To be able to give the contractor these design choices, he must have some freedom in the contract. Therefore the client will specify the outcomes in advanced based on what the output must be. To stimulate this innovation a specification that consists of several levels is introduced (Jansen, 2009):

- *Functional requirements:* Requirements that describe the object in terms of what it should do in which circumstance. It leaves design freedom for the way the function is designed.
- *Object requirements:* Technical requirement for specific objects. These requirements prescribe exactly what the minimal performance of the object should be and which solution should be used.
- *Aspect requirements:* Requirements that are needed to come to a specified quality of user satisfaction.
- *Interface requirements:* Requirements for the connection with respect to the different parts of the project.
- *Process requirements:* Requirements for the design of the process that will lead to the output.

The desired level of specification is difficult to determine because it is influenced by the conflicting demands of the client. On the one hand to have a lot of design freedom what gives design responsibilities to the contractor and on the other hand to make design choices to exclude the risk of failure.

Performance based payments

The foundation of the payments to the contractor is the performance based specification. This is contrary to the payments in traditional contract where payments are made based on the type of performed work (e.g. hours). The contractor will periodically receive payments based on an availability payment related to the delivered performance. If the agreed performance is not met then penalties will be given as a reduction on the availability payment. This topic is further discussed in the *Finance* section of this chapter.

Economically Most Advantageous Tender

After closure of the tender a preferred bidder is appointed based on the economically most advantageous tender. This is the tender with the most favourable proportion of price and quality. The quality is defined prior to the tender and is about subjects that are important to the client.

B.2 *PROJECT STAGES*

Each project in the construction industry is unique but the process stages in each project are similar (Wegelius-Lehtonen, 2001). The stages in a DBFM-project are similar to the stages in a traditional project, only the integration of and the responsibilities within the construction stages are different. The stage at which the contractor is contracted differs from a traditional contract. In the traditional contract the client develops the design and specifications of the final design. The contractor is contracted just before the construction phase. In the DBFM-contract the contractor develops part of the design, which means that the contract has to be signed at an earlier stage. The contractor is also responsible for financing which means that the contractor needs to be

contracted before the design phase. This shift is clearly presented by the decoupling point described by Favié (2007) in Figure 21

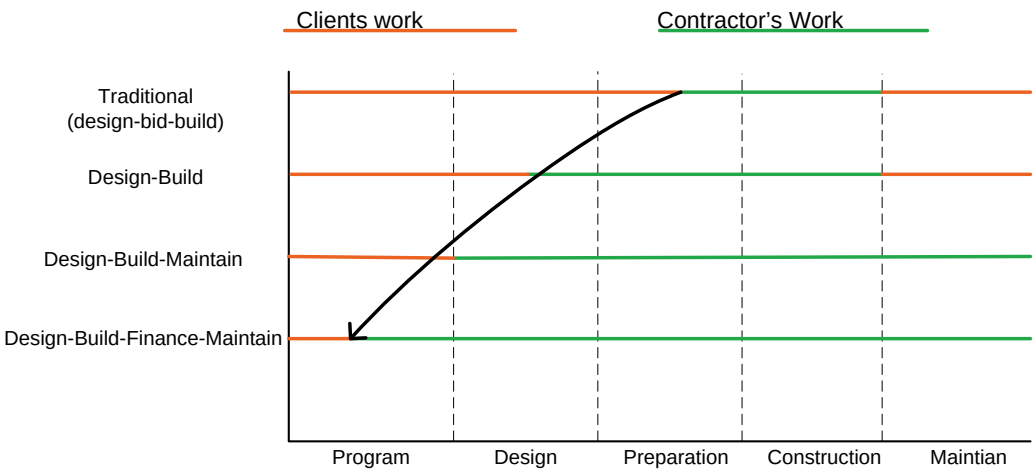

FIGURE 21: THE DECOUPLING POINT OF DIFFERENT INTEGRATED CONTRACTS (FAVIÉ, 2010)

It is commonly believed that the early stages of construction are the most important stages because these stages define what and how is built. The integration of stages in the construction industry makes the understanding of each phase and the relation to other stages a strategic task. Each stage can be divided into sub-processes that form a chain that ultimately affects the outcome of a project (Haponava, 2009). The sub-processes can be seen as production processes that consume inputs to produce outputs (P. Rouse, 2002). The output of one process is the input for a successive process.

The input for the start of every project is the official announcement of the project by the client. From this moment on different parties can apply for the project. In order to reduce the transaction costs the client can decide to reduce the amount of parties by using a competitive dialog. After this dialog the chosen parties are asked to present a final offer. The 'preferred bidder' is chosen and contract closure and financial close will take place. The following section describes the main characteristics of the stages after closure in a DBFM project and is presented in Figure 22. The requirements in the contract are now worked out into solutions.

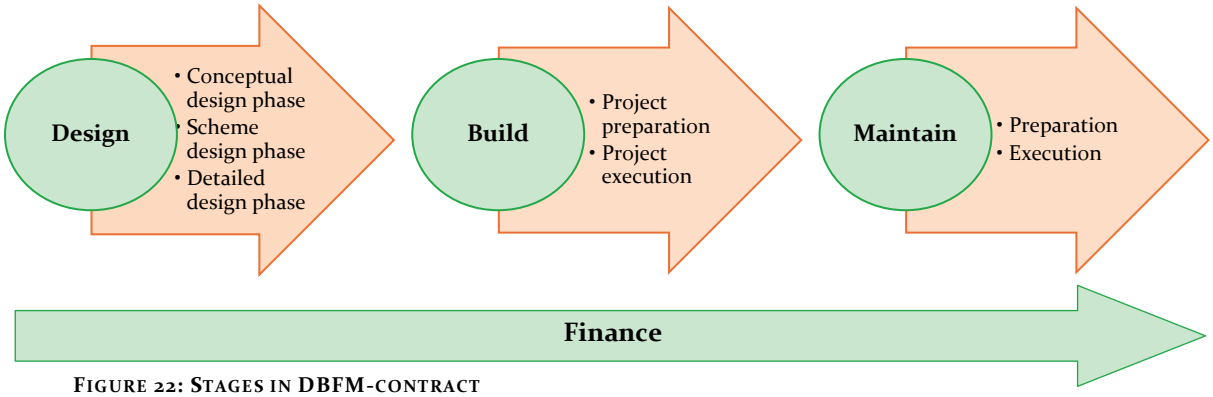

FIGURE 22: STAGES IN DBFM-CONTRACT

Design

The design stage can be defined as the translation of the project ideas into technical and functional requirements, and design requirements for project management. The design stage defines the object that will be built. The output of the design stage has great influence on the subsequent processes. Designing is about finding a solution to the demanded requirements. It is a process that is often unstructured and difficult to control. Haponava (2010a) divided the design stage into three main phases based on extensive literature review; Conceptual design phase, Scheme design phase, and Detailed design phase

The conceptual phase is about translating the preliminary design into potential design solutions. These are analyzed and the best solution is selected in the scheme design phase. The best solution is worked out in detail in the detailed design phase. This is done in terms of technical and functional requirements as desired by the client.

Build

The construction phase (Building phase) can be defined as the definition of the project plan, planning, production and the cooperation with stakeholders. The main elements that are managed in this phase are project time, cost and quality. With the use of integrated contracts, also some other elements are managed but they almost all focus on the end-product and not on the process. This latter aspect is needed to control the process while it's still running. Based on literature research Haponava (2010b) divided the construction stage into two phase: Project preparation phase and project execution phase.
The preparation phase is about forming the project plans based on the production information. The forming of the plans is coordinated between the design and the construction disciplines. In the execution phase the finalized plans are executed.

Finance

The financial aspect of a DBFM-contract can be defined as the structuring of the financing as foundation for the project financing. With the use of a DBFM-contract the contractor is responsible for the finance of the project. Payment by the client takes place from the moment the service is delivered and in proportion to the delivered services. This way of financing results in a situation where the client does not pay the initial investment but this investment is spread out over the lifetime of the project by means of an 'availability payment'. The contractor has to obtain the initial investment. This is normally financed by making financial agreements with a financial actor like a bank.

The financing agreements are build up of credit agreements, accounts agreements, direct agreements and securities (Kenniscentrum PPS, 2003). The account agreements make sure that the consortium will put enough budgets at special accounts. When the different accounts have sufficient liquid assets, then the rest of the benefits are allowed to be paid out to the shareholders. That is, the account agreements reduce the risks for the banks. The banks have a large influence on the contract early in the tender because they make agreements about the financial structure. During the project the bank wants to be updated regularly in order to check whether certain ratios are met.

This financial actor has an interest in the delivery of the services by the contractor. That is, if the services are not delivered then the financial actor will not receive the payments. In a way, the financing is a mean for the performance based payments. The payment regime is the agreements made between the client and the contractor about the way the activities of the contractor are paid. In an integrated contract, the payment regime will be based on an availability payment because payments will be made based on the delivered performance. If the performance is lower than the beforehand determined performance then the payments will be discounted. These discounts form an incentive for the contractor to perform as agreed. Mostly, the system is based on the principle of how more severe the problem, the higher the discount. This can be translated into the following formula:

Gross availability payment – sum of all discounts = net availablity payment

Besides the financial actors, the participants in the project invest via their shareholders in the project. This is mostly done by the establishment of a Special Purpose Company (SPC) of Special Purpose Vehicle (SPV) (Figure 23). The SPC is established because of the involved risks and the partnerships between companies.

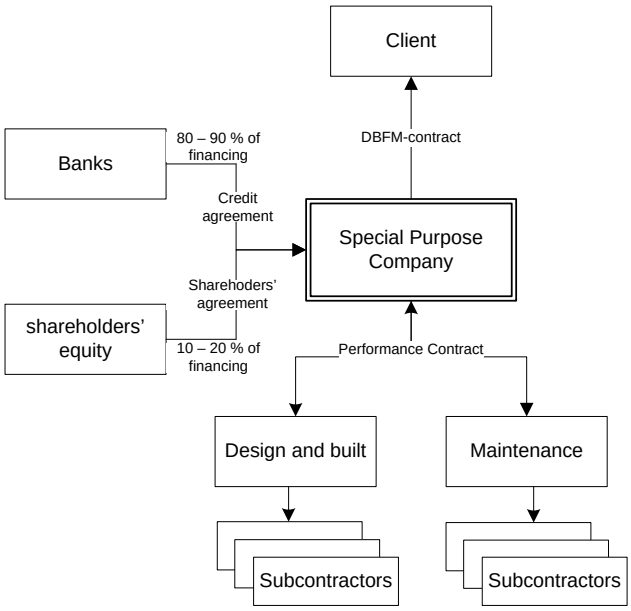

FIGURE 23: SCHEMATIC PRESENTATION OF SPC ((RIJKSGEBOUWENDIENST, 2008)

The difference on the payment regime between the traditional contract and the integrated contract is shown in Figure 24. The payment regime forces the contractor to think about the life cycle cost of a project. The investment cost for the design and maintenance should be recovered as early as possible while keeping the cost for maintenance in mind. This a a challanging task because the contractor is responisible for the whole process. A tradeoff has to be made between the investement costs and the maintenance cost. Higher investmentcost could result in lower maintenance cost and vica versa.

The payment regime has influence on the maintenance of a project because the client is paying for the availability of the project (so the client pays for a service instead of a product). This means that the contractor will try to schedule the maintenance in a way that the disturbance is minimal. The maintenance will be scheduled in the low-peak hours. Another solution is to design the project in such a way that maintenance activities do not need closure of a lane.

Maintain

The maintenance phase is about the planning, organization, and controlling that it takes to accomplish the standard that is required after the construction phase. Very simply stated is maintenance about the activities that keep an asset performing to the standard that is required. The traditional view of maintenance is to fix objects when they are broken. This perspective leads to a reactive approach for repair or replacement and is called reactive maintenance, breakdown maintenance or corrective maintenance. Knowing the impact of integrated contracts on businesses, this perspective is too risky. A broader view is defined by Geraerds (1985): *"All activities aimed at keeping an item in, or restoring it to, the physical state are considered necessary for the fulfilment of its production function"*. This view has a more proactive perspective, which is about routine servicing, periodic inspection, preventive replacement, and condition monitoring. This view is better in line with the strategic dimensions discussed before.

The Maintenance Engineering Society of Australia (MESA) recognizes this broader view and defines the maintenance function as: *"The engineering decisions and associated actions necessary and sufficient for the optimization of specified capability"*. "Capability" is the ability to perform a function within a range of performance levels that may relate to capacity, rate, quality, and responsiveness. They also include the decision-making into the maintenance function. The scope of maintenance management process should therefore cover every stage in the life cycle of technical systems. When perceived in this wider context, the maintenance function is also known as physical asset management (Tsang, et al., 1999) and supports the performance based maintenance that is required in integrated contracts.

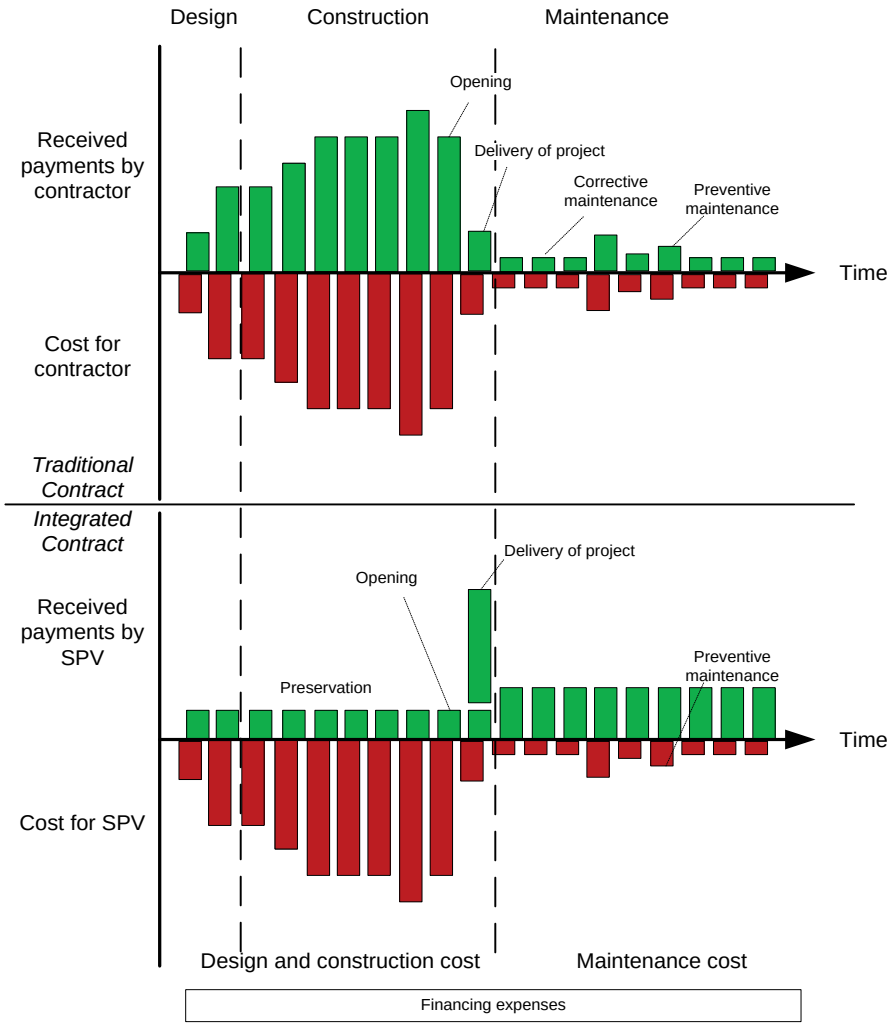

FIGURE 24: DIFFERENT PAYMENTS REGIMES (PPS KENNISPOOL RIJKSWATERSTAAT, 2010)

The purpose of maintenance management process is to reduce the adverse effects of breakdown and to maximize the system availability at minimum costs. Traditionally, there are two primary approaches to achieve such a purpose. The objective of preventive maintenance is to reduce the probability of failure in the time period after maintenance has been applied. Another is corrective maintenance, which strives to reduce the severity of equipment failures once they occur (Löfsten, 1998). These two approaches can be compared with the approaches used by Rouse (2009). In his study the life cycle of a road is shown in Figure 25. The quality in terms of serviceability declines due to traffic, climate and geology stresses (the environment in Figure 5). Periodic maintenance aims to repair high-severity pavements defects and is carried out on a regular basis to restore the pavement quality. Routine maintenance aims on the other hand on the repair of low severity pavement defects and are carried out to reduce the speed of deterioration. The strategic aim is to perform the right maintenance activities on the right time as to optimize the total benefit-cost relationships of a road over its lifetime. Routine maintenance is less costly but has a shorter lifetime than periodic maintenance.

Maintenance is one of the last steps in asset management and is therefore difficult to include in the overall business process.

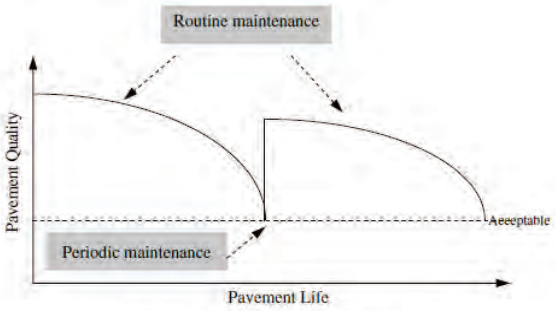

FIGURE 25: LIFE CYCLE OF A ROAD

C CASE STUDY N31 – WÂLDWEI

This appendix provides an overview of the project N31. Successively the characteristics, contract, organization, planning and construction, financing, risk allocation and the maintenance strategy are discussed.

C.1 CHARACTERISTICS OF N31

The DBFM project Wâldwei (N31) consists of the reconstruction of the single track (1x1) highway between Leeuwarden and Nijega to a dual track (2x2) highway, the construction of an aqueduct (Langdeel), a bridge (Fonejachtbrug) and, the operation and maintenance of 23 kilometres of the N31 between Leeuwarden and Drachten (Figure 26).

FIGURE 26: SECTION OF N31 - WÂLDWEI

TABLE 19: GENERAL PROJECT INFORMATION OF N31 – WÂLDWEI

Project Information	
Name	N31 – Wâldwei
Location	Drachten – Leeuwarden
Scope	Ca. 4 years of realization & 15 year of Maintenance
Principal	RWS
Contractor	*Wâldwei v.o.f. (SPC)* - Royal BAM Group NV - Ballast Nedam Infra BV - Dura Vermeer Group NV
Maintenance contractor	*Wâldwei BCWW* - BAM Civiel BV - Dura Vermeer Infrastructure BV - Ballast Nedam Infra BV
Contract	DBFM
Maintenance Contract	EPCM
Start Maintenance	December 2007
Maintenance term	15 years
Contract sum	€80 million (€60 million realization €20 million maintenance)

C.2 THE CONTRACT

The contract is signed on 10 December 2003 between the Ministry of Transport and Public Works, RWS Noord-Nederland and Ballast Nedam Infra, Dura Vermeer Groep, Royal BAM Group, Dragados, Imtech Projects and Oranjewoud. The rights and duty of the contract are transferred to Wâldwei.com B.V. The design, maintenance and operation are carried out by the consortium. This is a participation of Royal BAM Group, Dura Vermeer Group and Ballast Nedam Infra.

During the contract RWS will periodically pay an amount to the consortium based on the availability of the Wâldwei. In other words, the consortium is responsible for the quality and availability of the N31. If the consortium decides to close a part of the N31 for maintenance, than the discount they receive on the allowances will be influenced. The discount is dependent on the intensity of the traffic at the moment of closure. Besides the discounts, penalties are given in the sphere of safety and internal process control.

The financing of the project is also the responsibility of Wâldwei.com. Part of the financing is delivered by the stockholders, but the major part is delivered by a combination of banks, NIB Capital Bank NV, Friesland Bank NV, and Bank Nederlandse Gemeenten NV. Part of the allowances will be used to pay back the loans of Wâldwei.com.

The contract included 5 milestones with corresponding financial consequences as indicated in Figure 27:

- The commence certificate (AC), (01-03-2004)
- The in-between-availability certificate (TBC)[5], (09-06-2005)
- The availability certificate (BC), (13-12-2007)
- The completion certificate (VC), (13-12-2007)
- The conveyance certificate (OC)

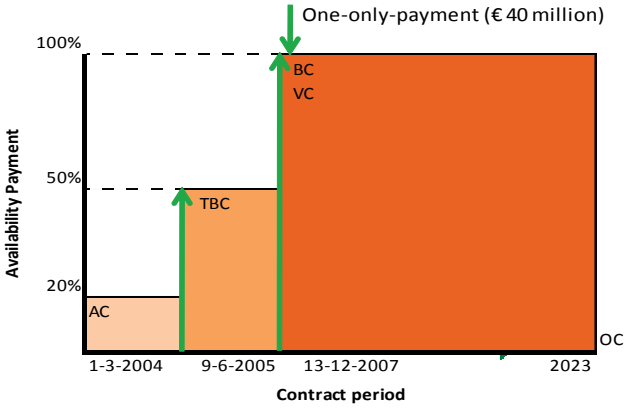

FIGURE 27: PAYMENT DIAGRAM

The availability payment consists of:

- Basic payment of €1 million;
- Extra payment / reduction of payment based on a higher/lower availability of the road.
- Penalties if the performance is not met

RWS puts the contract to tender and prescribes the contract conditions. The scope of the contract can be summarized by the following four bullets (Buck Consultants International & John Cooper Consulting, 2004):

- Period of 20 year including construction time. This period is long enough for optimization reasons and not too long to keep flexibility.
- Payment regime: private financing, but hold the lid on the financing cost by a payment after construction (one time only).
- Hand tasks over to contractor, but keep the tasks of black-ice prevention and accident management.
- The relationship with other authorities (municipalities and the Province of Friesland) runs through RWS and not directly between the contractor and the other authorities.

The negotiation procedure during the tender consisted of a procedure with preannouncement. Opportunities of this procedure for the BAM are interaction with the principal (RWS) and fewer competitors due to the pre-selection. The project N31 falls within the UAR (Uniform Aanbestedingsreglement) which means that the negotiations are restricted because a distinction is made between 'negotiation' and 'consultation'. The consultation phase is about the clarification of the concept program of requirements and the concept contract. The consultation is only about the execution of the work and not about the price. In the negotiation phase the price is negotiable, just as the allocation of risks.

C.3 ORGANIZATION

For the project N31 – Wâldwei two project organizations are involved: Wâldwei.com BV and Building Consortium Wâldwei v.o.f.

Wâldwei.com is a private limited company (Ltd) with the Royal BAM Group NV, Ballast Nedam Infra BV and Dura Vermeer Group NV as shareholders. They act as a Special Purpose Company (SCP) for the project N31 – Wâldwei.

Building Consortium Wâldwei (BCWW) is a general partnership consisting of Ballast Nedam Infra Bv, Bam Civiel BV and Dura Vermeer Infrastructure BV. Their partnership is based on an

[5] Not a standard milestone. This milestone is deliberately included to motivate the contractor for faster opening the road

Engineering Procurement Construction Maintenance (EPCM) structure. This is a partnership of different companies that are also involved as shareholders of the project.

Wâldwei.com has contracted the DBM-part of the DBFM-contract out to BCWW. Within the scope of the execution of the DBFM contract Wâldwei.com is and stays responsible for (irrespective of the activities of BCWW):

- Reporting to RWS about all the aspects concerning the DBFM-contract;
- Financing the project and all the contractual aspects with RWS.

The most important subcontractors are: HSM Steel Structures and Imtech Projects. The following structure shows the different stakeholders involved in the project N31 – Wâldwei.

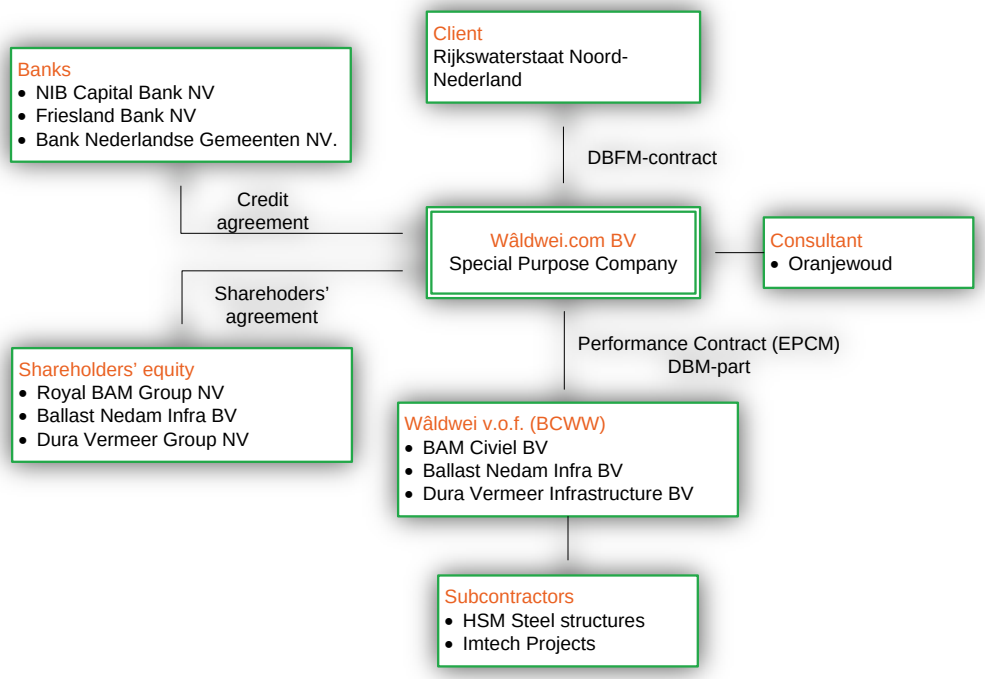

FIGURE 28: SCHEMATIC REPRESENTATION OF CONTRACT STAKEHOLDERS

C.4 *PLANNING AND CONSTRUCTION*

The work was finished four months earlier than planned. The project would be delivered by the end of February 2008, but this became the end of October 2007. The project is also finished within budget (Rijkswaterstaat, 2008).

TABLE 20: CHRONOLOGICAL EVENTS OF WÂLDWEI
(BUCK CONSULTANTS INTERNATIONAL & JOHN COOPER CONSULTING, 2004)

Date	Milestone
1 March 2002	Publication of the tender
17 April 2002	Deadline of the application, 7 combinations have shown interest
25 June 2002	4 candidates are appointed
9 July 2002	Introduction meeting for candidates. The tender process is explained
26 February 2003	The candidates have submitted their tender report, and the assessment starts
8 May 2003	Two candidates are invited for the negotiation phase
22 July 2003	Best and last tender report submitted by two candidates
10 September 2003	Waldwei.com is appointed as Preferred Tenderer
10 December 2003	Signing of the contract
2004	Start of construction
13 December 2007	Receive completion certificate
December 2007	Start maintenance

C.5 *RISKS ALLOCATION*

TABLE 20: ALLOCATION OF RISK

(BUCK CONSULTANTS INTERNATIONAL & JOHN COOPER CONSULTING, 2004)

	Wâldwei.com	Principal RWS
Information	insufficient, incorrect or unsuitability of data provided by RWS before and after contract closure except data that is guaranteed by RWS (e.g. soil drilling)	Responsible for correct and the availability of drilling information
Site	Conditions and state of the construction site, utilities, etc.	
Permissions	Obtain permissions, decisions, allowances, releases on time except several building permits, described by RWS	Timely obtainment of construction permits for the Fonejachtbrug, the aqueduct Langdeel and the sound barrier, and for large soil clearances for the aqueduct
Design, construction and maintenance	The risk of the suitability of the design, construction, and maintenance.	
Finance	Based on payment regime with availability payments	
Schedule	The risk of not meeting the required delivery date with the allocated penalties.	Timely delivery of available construction site, permits by RWS and changes in special legislation, soil pollution, not known archaeology, explosives, etc.
Cables and pipes	The risk related to getting approval of the owners of the cables and pipes. Thereafter the agreements are made by RWS. Costs for the removal or movement of cables are at costs of RWS.	Costs for removal and movement of cables and pipes which are agreed upon with the owners
Traffic management	All measurements needed for an optimal accessibility of users. Exception is incident management and black-ice prevention.	Black-ice prevention and incident management
Insurances	Responsible for Construction All-Risk (CAR) for material damage, losses, destruction of work, Third party insurance for companies.	
Archaeology	Costs and damages related to known archaeology	
Information and quality	Based on contract requirements towards RWS	
Legislation	Risk for changes in legislation, except specials legislation as described under RWS risks.	Unusual Legislation, especially related to construction, maintenance or availability of the roads or when it is not allowed to use the lane for work while the adjoining lane is opened for traffic.
Damages	Damages are responsibility of Wâldwei.com until a certain maximum. Exception: unforeseeable damages by third parties	Sudden and unforeseen damages on the road
Damages of third parties	Damages of third parties by execution of work or usage of the road are responsibility of Wâldwei.	Force Majeure; War, terrorism, explosions, large accidents, nuclear disasters, earthquakes, flood, and large damages caused by third parties before the finish of construction.
Changes by client		Costs that are caused by changes of the contract on request of RWS.

C.6 *MAINTENANCE STRATEGY*

The essence of the maintenance strategy for the N31 is to keep and bring the system back toward the performance needed for fulfilling the required function according to the contract by executing maintenance or not during the user phase of the system. The maintenance philosophy is based on Asset Management as described in chapter 3. Lifecycle management is used to reduce the total cost of ownership, which means that decisions are taken to optimize the construction cost and maintenance cost altogether.

Point of departure for the maintenance is based on the actual quality of the objects. For every object an expected degeneration curve is made. By cyclic inspections the accuracy of the expectations are improved. The inspection period or maintenance period is based on the chance that the object fails. The point of departure is prevention of failures by planned inspections. No attention is paid to the risks (chance x consequences) of failure (Risk based maintenance). This latter strategy does not only consider the condition of the system components, but also considers the impact on the performance of the system. It can also be used to rank the replacement and refurbishment activities. Bad equipment conditions lead to the question whether it is more economical to do further maintenance or replace the equipment. This strategy also makes it possible to take economical consequences (like penalties) into consideration.

A 6-year plan is used to keep the right track in the operative planning. A yearly schedule is used to gain better insight into the yearly maintenance activities. Different document (compelled and not-compelled) are used in the maintenance stage: risk management plan, incident plan, document with changes, interface plan, communication plan, accessibility plan and a maintenance plan.

More specifically, for non critical objects corrective maintenance is used unless the risks related to the availability are too large. For critical object preventive maintenance is used.

D CASE STUDY A59 ROSMALEN - GEFFEN

This appendix provides an overview of the project N31. Successively the characteristics, contract, organization, planning and construction, financing, risk allocation and the maintenance strategy are discussed.

D.1 CHARACTERISTICS OF A59

The DBFM-contract of the A59 consists of the reconstruction of the N50 (1x1 highway) towards the A59 (2x2 motorway). The project consists of the construction of 9.1 kilometre of highway with 4 connections, one fly-over, one tunnel for cyclists, one game-tunnel, 7 traverses for animal and almost 10 km of sound barrier.

FIGURE 29: SECTION A59 (PROVINCIE NOORD-BRABANT & POORT VAN DEN BOSCH, 2005)

TABLE 21: GENERAL PROJECT INFORMATION OF A59

Project Information	
Name	A 59 Rosmalen – Geffen
Location	Rosmalen – Geffen
Scope	Ca. 3 years of realization & 15 year of maintenance
Principal	Province of Noord Brabant
Contractor	*Poort van Den Bosch* - Royal BAM Group NV - Boskalis BV - Fluor Infrastructur BV
Maintenance contractor	Maintenance organization "Poort van Den Bosch" (BAM Roads)
Contract	DBFM
Maintenance Contract	MTC
Start Maintenance	1 January 2006
Maintenance term	2005-2020
Contract sum	€ 218 million

D.2 THE CONTRACT

The contract is signed in February 2003 between the province of Noord-Bradant and the Poort van Den Bosch (PvDB). The consortium PvDB consists of the Royal BAM Group, Boskalis and Fluor Infrastructure. Figure 30 gives an overview of the three periods that can be defined.

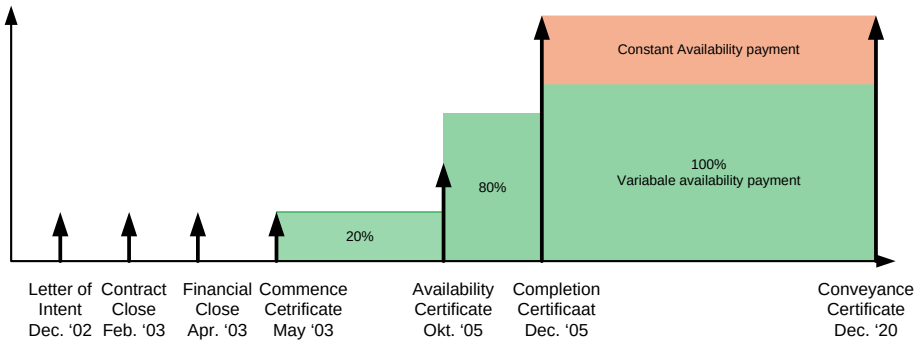

FIGURE 30: PAYMENT DIAGRAM (ZACHARIASSE & SLOT, DECEMBER 2003)

- Pre-availability period: The period from the moment the contractor can start with the construction until the moment the province has concluded that the A59 is available.
- In-between availability period: this is the period from the moment the new road is available until the province has concluded that the road complies with all the requirements and is thus completed.
- Availability period: the period from the moment that the province concludes that the road is completed until the contract has ended.

(Zachariasse & Slot, december 2003)

The constant availability payment is used to give the contractor a constant payment that is not reduced by penalties. The variable availability payment can be reduced by penalties. The reason for this situation is that a large part of the service will be given after two years (construction of the road). Next to this, a guaranteed availability payment can lead to a cheaper financing by banks. This will lead to a reduction of the availability payments and thus makes it better payable.

Two agreements can be appointed for financing the project. The agreement between the ministry and the province for the Long-range Infrastructure and Transport budgets (Dutch: MIT), and the agreement between the province and the PvDB.

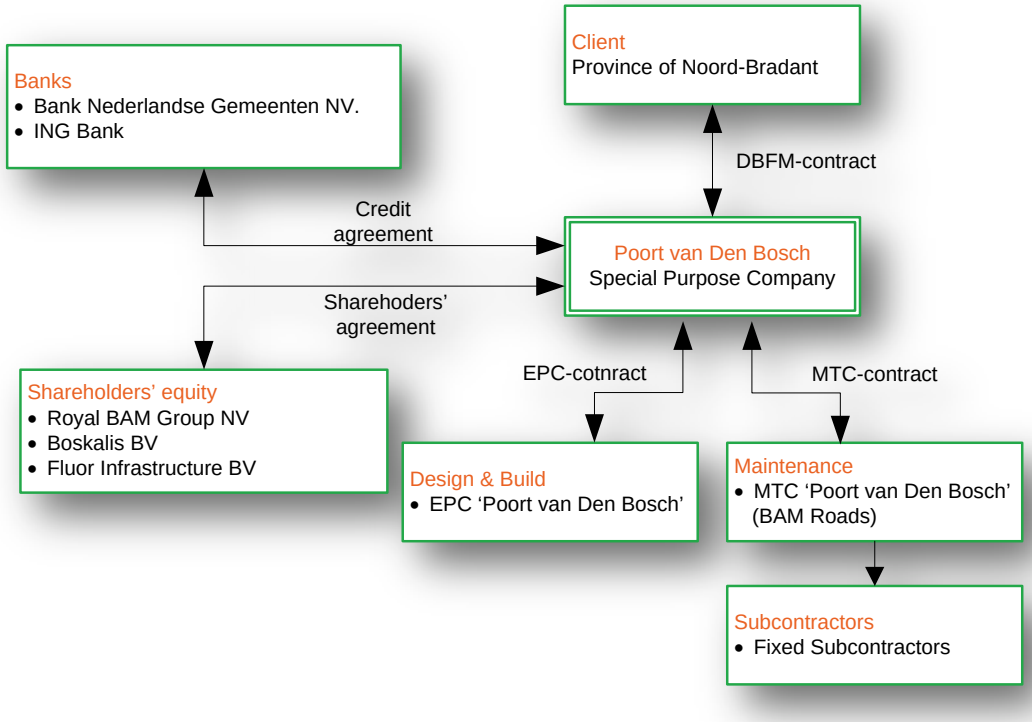

FIGURE 31: PROJECT STAKEHOLDERS

D.3 ORGANIZATION

The BAM is responsible for the construction of the construction works, the sound barriers, the roads, the green areas and the planning and execution of traffic measurements. Boskalis is responsible for the groundwork and the soil sanitation. Fluor is responsible for the project- and risk management, traffic management, permits and the project communication.

Province Noord-Bradant is the public party that acts as principal for the project. The PvDB is the private party that acts as contractor responsible for the design, construction, finance and maintenance of the project. The contract lasts 15 years after completion of the construction. (Provincie Noord-Brabant & Poort van Den Bosch, 2005)

The division of roles between the province and V&W is special. Although the ministry is responsible for the network of roads, the province was client for the construction of the A59. The

agreement between the province and the ministry did not have the character of a partnership agreement. The ministry did not want to be involved too much, but in the end they found out that this could not be the case. In the end the ministry is and stays responsible for the financing.

For the maintenance of the project a MTC contract is signed between the SPC and BAM Roads. BAM Roads has taken the responsibility of the maintenance of the project. In turn, they have made arrangements with fixed subcontractors for several maintenance activities. This resulted in the advantage of close cooperation and understanding of the responsibilities of each party. Based on this understanding synergy is created.

D.4 *PLANNING AND CONSTRUCTION*

TABLE 20: CHRONOLOGICAL EVENTS OF A59 (ZACHARIASSE & SLOT, DECEMBER 2003)

Date	Milestone
October 2000	Province and Ministry sign agreement, province become the principal
November 2000	Start tender PPS-A59
January 2001	Province selects 5 candidates
February 2001	Start of consultation phase
June 2001	Cintra withdrawals
September 2001	4 candidates submit their offer
February 2002	Province selects two best offers.
Mei 2002	Minister expands the budget for PPS-A59
June 2002	Two candidates are invited for the negotiation phase
September 2002	Best and last tender report submitted by two candidates
November 2002	"Poort van Den Bosch" is appointed as Preferred Tenderer
4 February 2003	Signing of the contract PPS-A59
August 2003	Start of construction
10 December 2005	Receive completion certificate
January 2006	Start maintenance
31 December 2020	Return of A59 to province (and to ministry)

D.5 *RISKS ALLOCATION*

The project organization (province) wants to put the risks at the party that can bear the risk the best.

TABLE 22: ALLOCATION OF RISK

	Poort van Den Bosch	Province Noord-Brabant	Ministry
Information	PvDB is responsible for the communication with third parties. E.g. information meetings for the neighbourhood and information towards the users of the road.		
Site	Conditions and state of the constructions		Risks with respect to the soil sanitation regarding soil that is not examined or below the road surface.
Permissions	Obtain permissions, decisions, allowances, and releases on time.	The province is responsible to improve the changes of obtaining the permissions.	Obtainment of ground, if greater than €12 million.
Design, construction and maintenance	The risk of the suitability of the design, construction, and maintenance.		
Finance	Based on payment regime with availability payments	Changes in interest rates regarding the availability payment.	Risks with respect to fluctuation of interest rates.
Schedule	The risk of not meeting the required delivery date with the allocated penalties.	Risks with respect to the delay of activities are shared with the contractor for max. €600.000	
Cables and pipes	The risk related to getting approval of the owners of the cables and pipes.		The risk with respect to cable and pipes above the €3.54 million.
Traffic management	PvBD has to provide an optimal accessibility for the residential, commercial and recreation areas. The black-ice prevention is the responsibility of RWS		Black-ice prevention
Archaeology	PvDB is responsible for possible archaeology findings.		
Legislation	Risk for changes in legislation, except specials legislation as described under the	Risks with respect to changes of legislation of the local	Risks for the changes in the VAT-tariff. Risks with respect

	risks for government.	government.	to changes in legislation.
Damages of third parties	Damages of third parties by execution of work or usage of the road.	Large damages caused by third parties larger than €1 million and not covered by insurance of contractor or third party.	Risks with respect to Force Majeure.
Changes by client		Costs that are caused by changes of the contract on request of the client.	

D.6 *MAINTENANCE STRATEGY*

The essence of the maintenance strategy for the A59 is to keep and bring the system back towards the performance needed for fulfilling the requirements. A list with the frequency of maintenance activities is made in which also the yearly small maintenance activities are included. Furthermore, the strategy includes preventive, corrective, time based and condition based maintenance.

E INTERVIEW PROTOCOL

Interviewees

Who	Function	Project	Organisation
Dhr. Beuving	Maintenance manager	N31	BAM
Dhr. Bruining	Project Director SPC	N31	BAM
Dhr. de Pinth	Maintenance manager	A59	BAM
Dhr. van Griensven	Maintenance manager	A59	BAM
Dhr. Mali	Project Director	A59	Fluor

Inleiding

Voor de afronding van mijn Master Construction Management & Engineering doe ik onderzoek naar de processen die beter onder controle gehouden moeten worden in de onderhoudsfase bij geïntegreerde contracten. De N31 en A59 worden gebruikt als casus omdat dit een van de weinig geïntegreerde contracten zijn die nu in de onderhoudsfase verkeren.

Doel, grenzen en duur

Met behulp van dit interview wil ik een beter zicht krijgen in de onderhoudsactiviteiten en processen. Hierbij richt ik mij op de veranderingen ten opzicht van het oorspronkelijk plan. Voor dit onderzoek neem ik de situatie na de bouw als uitgangspunt. In dit interview zullen verschillende aspecten worden behandeld. Het interview zal ongeveer een uur in beslag nemen.

Wat wordt er met de resultaten gedaan?

De resultaten van dit interview worden gebruikt voor mijn afstudeeropdracht waarbij de resultaten gebruikt worden voor analyse. Ik zal een uitwerking van het interview u doen toekomen voor controle. Voordat ik verder ga, heeft u er bezwaren tegen als dit interview opgenomen wordt?

1. **Interviewvragen**

Project gegevens

Datum en tijd: _____
Locatie: _____
Naam: _____
Functie: _____
Project: _____

Project doelen (5 min)

a. Wat zijn/is de doelen/doelstelling van het onderhoud?
   (Prestatie, beschikbaarheid, veiligheid, winst, budget, partnerschap)
b. Wat wordt er gedaan om dat te bereiken en te controleren? Zijn hiervoor subdoelen?
c. In hoeverre wordt er nu aan de doelen voldaan? Wat is de huidige stand van zaken?

	Budget (% of total)	**Forecast end** (% of total)	**% Budget overrun end**
Salaries	…	…	…
Supportive work	…	…	…
Equipment	…	…	…
Sub-system costs	…	…	…
Substructure	…	…	…
Superstructure	…	…	…
Traffic Facilities	…	…	…
Landscape & environment	…	…	…
Constructions	…	…	…
Indirect	…	…	…
General	…	…	…
Profit and risk	…	…	…
Total	**100%**	**100%**	**…**

	Year 1	Year 2	Year 3	Year 4	Year 5
Budget	…	…	…	…	…
Total maintenance cost	…	…	…	…	…

Context (5 min)

a. Waarom is er gekozen voor een EPCM / EPC & MTC contract?
b. Onderhoud wordt uitgevoerd door het consortium BCWW / BAM. Hoe wordt dit ervaren? Leidt dit nu tot extra discussie (bijvoorbeeld wie doet wat?), of biedt het juist kansen?
c. Hebt u het gevoel dat de doelstellingen van alle partijen in het onderhoud op een lijn zitten? Zowel binnen het consortium als bij onderaannemers?
d. Heeft bovenstaande invloed op het vertrouwen/ de samenwerking tussen partijen?
e. Hoe zijn/worden de onderhoudsactiviteiten aanbesteed, steeds dezelfde partijen?
(basis van prijs, kwaliteit, ervaring), (welke activiteiten worden uitbesteed?)
f. Hoe zou u de relatie met de klant omschrijven?
(contractueel, vertrouwen, open, etc.)

Afwijkingen in planning (10 min)

a. Kunt u voorbeelden geven van afwijkingen op de planning?
b. Wat was de oorzaak van de afwijking?
(storing, onvoorziene gebeurtenis, slechte planning, ontwerpfout, interventiewaarde bereik, etc)
c. Wat was de motivatie voor ingrijpen?
(Contract, budget, prestatie)
d. Waaruit bestaat de procedure om het probleem aan te pakken?
e. Wie is verantwoordelijk voor de oplossing en was dit duidelijk?
f. Welke knelpunten hebben zich voorgedaan bij het oplossen?
g. Hoe is ervoor gezorgd dat de planning weer aangehouden kan worden?
(bijvoorbeeld Preventief, correctief onderhoud)
h. Is het beoogde effect bereikt?
(ja/nee, meer actie nodig)
i. Kans dat verwachte levensduur nu bereikt wordt?
j. Welke objecten presteren beter dan gepland, hoe kan dit?

Afwijkingen in planning (proces) (5 Min)

a. Welke processen zijn volgens u belangrijk om weer op de geplande planning te komen?
b. In hoeverre heeft de relatie met de opdrachtgever/stakeholders invloed op de wijzingen in de planning?
c. Welke processen spelen een belangrijke rol om binnen de planning te blijven?
d. Welke processen zijn nog niet goed uitgewerkt in het onderhoudsproces?
e. Zijn er ook processen die weinig toegevoegde waarde hebben?
f. Als blijkt dat onderhoud nog niet nodig is, wordt het dan alsnog (preventief) uitgevoerd?
g. PMI systeem processen beschreven, hoe?

Invloed van afwijkingen op budget (output) (5 min)

a. Wordt er bij afwijkingen gekeken naar de invloed op onderhoudsbudget (levenscyclus), hoe?
(scenario's?),(is LCC budgettechnisch lastig?)
b. Hoeveel boetepunten zijn er opgelopen reden & consequentie?
(ingecalculeerd, bijvoorbeeld door scenario planning)

Overige (5 min)

a. Wat heeft de komende drie jaar de meeste impact op de verbeteringen van onderhoudprestatie?
(vervangingen, aanpassing van onbetrouwbare onderdelen, aanpassing van onderhoudsplannen, uitvoeren van de bestaande planning, verbetering van training beheerder, verbetering van onderhoudstraining, meer onderhoudsmiddelen, meten en controle van prestatie, verbetering van planning, uitbesteding)
g. Aanpassing in strategie nodig?
h. Ideeën voor komende projecten/verbeterpunten?

F EXPERT MEETING PROTOCOL

Experts

Who	Function	Organization
Dhr. Beuving	Maintenance Manager	BAM
Dhr. Bruining	Project Director	BAM PPP
Dhr. de Pinth	Maintenance Manager	BAM Roads
Dhr. Kersten	Project- / Tender manager	BAM Roads
Dhr. van Heumen	Project manager	BAM Roads
Dhr. Vos	Sr. Advisor Asset Management	BAM Infraconsult

1. Opening

Voorstellen en inleiding

Deze bijeenkomst maakt deel uit van mijn afstudeeronderzoek aan de Universiteit Twente. De opdracht vindt plaats bij BAM Infraconsult. In de aanloop naar deze bijeenkomst heb ik twee projecten bestudeerd, de A59 en N31. Het doel hierbij was het opstellen van indicatoren voor onderhoud. Tijdens de uitvoering is dit bijgesteld naar het achterhalen van belangrijke processen die helpen de onderhoudsfase succesvol uit te voeren en af te ronden. Door middel van een aantal gesprekken zijn er aspecten gevonden. In deze bijeenkomst wil ik deze graag aan jullie presenteren en daarna een discussie voeren.

Doel & duur van bijeenkomst

Een onderdeel van mijn opdracht is het terugkoppelen van mijn resultaten met als doel het valideren van de resultaten. Daarnaast is het bedoeld om de waarde van resultaten voor de toekomst te bepalen.

Hiervoor worden eerst de resultaten door middel van een korte presentatie weergegeven. Daarna kan er over de resultaten gediscussieerd worden aan de hand van een aantal punten. De bijeenkomst zal maximaal 2 uur duren.

Omgang met resultaten

De resultanten van de bijeenkomst zullen gebruikt worden in het afstudeeronderzoek. Voordat de resultaten verwerkt worden zal een uitwerking ter controle worden rondgestuurd. Het afstudeeronderzoek zal publiekelijk inzichtbaar zijn via de website van de Universiteit Twente. Indien er tijdens de workshop vertrouwelijk informatie besproken wordt dan zal dit vertrouwelijk behandeld worden.

2. Presentatie

Een korte presentatie van de resultaten uit het onderzoek.

3. Discussiepunten

1. Herkenning van resultaten
2. Geschiktheid van de PAS55
3. Bruikbaarheid van resultaten voor toekomstige projecten
4. Verbeterpunten voor projecten
5. Belangrijke punten bij een overdracht? Wat staat er beschreven, en wat is ervaring

4. Afsluiting

Ter afsluiting van deze bijeenkomst nog een laatste vraag: Zijn er volgens u nog zaken die niet aan de order zijn gekomen, of wilt u nog iets benadrukken?

Hierbij wil ik vriendelijke bedanken voor uw aanwezigheid en openheid. Het verslag van deze bijeenkomst zal ik uitwerken en ter controle aan u voorleggen.

G CHECKLIST PAS55

The list that is used in the interviews for linking the processes of the PAS55 with the performance of the projects.

Dit eerste blad geeft aan welke antwoordmogelijkheden per kolom gegeven kunnen worden. Daarnaast wordt ter verduidelijking een voorbeeld gegeven. Daaronder volgt de tabel met vragen. (Gelieve blauwe cellen invullen)

Kolom 1 Geef aan of de genoemde aspecten aanwezig zijn in het project door middel van een score 1 t/m 4.

Betekenis	
1	Niet aanwezig
2	Gedocumenteerd in het project/onderhoud plan
3	Gestructureerd proces en gecoördineerd met belangrijke interne en externe teamleden
4	Formeel overeengekomen proces; staat onder continue controle en vormt een integraal onderdeel van het onderhoudsproces

Kolom 2 Geef aan hoe groot de invloed van de genoemde aspecten is op het bereiken van de project doelen (let op: hier geen kosten). Dit kan zowel betekenen dat het aspect nodig is om de doelen te handhaven als om de doelen te bereiken. (voor antwoordmogelijkheden zie tabel beschreven bij kolom 3)

Kolom 3 Geef aan hoe groot de invloed van de genoemde aspecten is op de onderhoudskosten. Wanneer het aspect veel invloed heeft op de onderhoudskosten dan vult u 'H' in.

Score	Betekenis	Voorbeeld
Laag	Lage invloed	Het genoemde aspect heeft weinig invloed op doelen / kosten
Middel	Gemiddelde invloed	Het genoemde aspect heeft een gemiddelde invloed op de doelen / kosten
Hoog	Hoge invloed	Het genoemde aspect heeft een veel invloed op de doelen / kosten

Kolom 4 Geef aan of de genoemde aspecten bijdragen aan het bereiken van bedrijfsdoelstellingen. Als u bijvoorbeeld vindt dat het aspect een bijdrage levert aan het bereiken van het doel "Mens & Maatschappij" dan vult u een A in. Meerdere antwoorden zijn dus mogelijk.

Bedrijfsdoelstellingen	
A. Mens & Maatschappij - veiligheid van medewerkers & onderaannemers - veiligheid van directe omgeving van bouwplaatsen - Delen van kennis en ervaring (know-how van de groep) - Ontwikkeling van management-potentieel - Diversiteit van medewerkers als spiegel van maatschappij	**B. Producten en Concepten** - Ontwikkeling van nieuwe producten en concepten **C. Markt** - Versterken van marktpositie in de thuismarkten
D. Organisatie - Verbetering van het primaire proces en versterking van risicomanagement - Toepassing van Lean Construction Management - Introductie van virtueel bouwen en ICT-toepassing - Maatschappelijk Verantwoord Ondernemen	**E. Financieel** - Focus op cash management - Vermindering van het werkkapitaal en bedrijfsgebonden kosten. - Vermijden van verliesgevende activiteiten - Verkennen van innovatieve financiering
F. Niet van toepassing	

Aandachtspunten:

1. De focus van de vragen ligt op de onderhoudsfase van het project.
2. Gelieve alle blauwe cellen invullen, ook als het aspect niet in het project aanwezig is.
3. Sommige vragen worden meerdere malen gesteld. Dit komt omdat de vragen onderdeel zijn van een bepaalde subgroep die dik gedrukt is. Alle vragen onder de subgroep hebben alleen betrekking op deze subgroep.

Bijvoorbeeld:

1.1 Onderhoudstrategie (subgroep)
a. Is er controle op bedrijfsdoelen en beleid?
Vraag 'a' heeft betrekking op de onderhoudstrategie.

1.2. Onderhoudsdoelen (subgroep)
a. Zijn er (SMART) doelen opgesteld? (KPIs)
Vraag 'a' heeft betrekking op de onderhoudsdoelen

Voorbeelduitwerking

2.7 Risico Management
a. Is er een methodiek voor het identificeren van risico's? [4 H H D]

Uitleg:
Er is een risicomanagementplan expliciet in het contract geëist. In dit plan wordt een gestructureerd proces beschreven om inzicht te krijgen in de project gerelateerde risico's en de bijbehorende beheersmaatregelen. Het plan wordt op gezette tijden herzien. Er is daarom sprake van (4) een formeel overeengekomen proces, staat onder continue controle en vormt een integraal onderdeel van het onderhoudsproces.

Het plan heeft veel invloed op het behalen van onze projectdoelen, het heeft daarom een hoge invloed op het bereiken van de projectdoelen.

Het onderhouden van het plan zorgt voor extra onderhoudskosten maar het beschermd ons tegen faalkosten en calamiteiten. Relatief gezien levert het plan ons meer op dan dat het financieel gezien kost, het plan heeft daardoor een hoge invloed op de onderhoudskosten.

Het plan versterkt het risicomanagement en draagt daardoor bij aan de bedrijfsdoelstelling D. Organisatie

H PRESENTATION EXPERT MEETING

UNIVERSITY OF TWENTE.

THE IDENTIFICATION OF KEY PROCESSES TO CONTROL INFRASTRUCTURAL MAINTENANCE STRATEGIES

INCREASING THE MAINTENANCE PERFORMANCE OF DBFM-CONTRACTS BY IDENTIFICATION OF KEY PERFORMANCE PROCESSES, BASED ON AN EVALUATION OF THE N31 AND A59

Jeroen van der Meer

AGENDA
WELKOMSTWOORD

- Introductie
  a) Doel en duur van deze bijeenkomst
  b) Omgang met resultaten
  c) Korte voorstelronde
- Presentatie onderzoeksresultaat
- Puntsgewijze discussie
- Afsluiting

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ONDERZOEKSRESULTATEN
PROBLEEMSTELLING EN DOEL

Probleemstelling
Het ontwerp van een onderhoudstrategie is lastig vanwege de toekomstige invloeden op de prestatie van het systeem en de onzekerheid over welke processen (beter) gecontroleerd moeten worden om de prestatie van het onderhoud te verbeteren.

Doel van onderzoek
Onderzoek de aspecten die de BAM moet beheersen om de onderhoudsstrategie te beïnvloeden ter verbetering van de onderhoudprestatie.

Hoofdvraag
Welke aspecten moet de BAM in de onderhoudsfase beheersen die de onderhoudstrategie beïnvloeden en de prestatie van het systeem verbeteren?

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ONDERZOEKSRESULTATEN
SCHEMATISCHE WEERGAVE VAN ONDERHOUDSFASE

- Input zijn de middelen die gebruikt worden bij de organisatie zoals geld, mensen, materiaal en materieel. In sommige situaties kan input ook 'zachte' middelen bevatten zoals invloed en kennis.
- Onderhoudsproces bevat alle activiteiten en functies die de input (middelen) veranderen in output (producten en diensten).
- Output zijn de producten en diensten van de organisatie.
- Outcome is wanneer de output aan de klant geleverd is.
- Context kan beschreven worden door de externe factoren die de grenzen vormen waarbinnen de organisatie kan werken.

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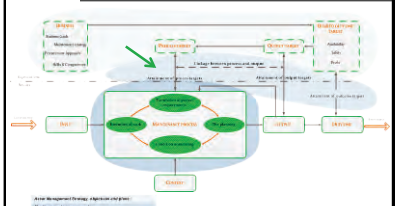
ONDERZOEKSRESULTATEN
SCHEMATISCHE WEERGAVE VAN ONDERHOUDSFASE



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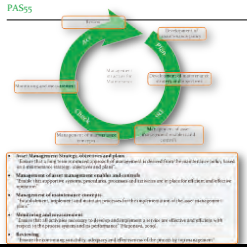
ONDERZOEKSRESULTATEN
PAS55



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ONDERZOEKSRESULTAAT
DEELCONCLUSIE

"Onderhoud is geen Rocket-Science"

- Binnen budget
- Volgens planning
- Procesresultaten zijn zichtbaar

Of is het toch lastiger?

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DISCUSSIEPUNT 1
ONDERHOUDSKOSTEN

Resultaat studie:
- Onderhoudsbudget leidend voor activiteiten;
- Noodzaak van preventief onderhoud;
- Variatie in budget en resultaat voor onderhoudsactiviteiten;

Discussiepunten:
- Hoe kan een betere koppeling tussen beleid en uitvoering bereikt worden?
- Wat is er nodig voor het bereiken van een optimale mix van correctief en preventief onderhoud?
- Welke sturingsmogelijkheden zijn er mogelijk voor het plannen van onderhoudsactiviteiten?

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DISCUSSIEPUNT 1 (VERVOLG)
INVLOED OP ONDERHOUDSKOSTEN

- Communicatie naar belanghebbende (in geval van veranderingen of incidenten);
- Continue meten van de voortgang;
- Inspectie, onderhoud en kalibratie rapporten;
- Lange- en korte termijn planning;
- Periodieke evaluatie;
- Reactieve controle;
- Risico management (als input voor activiteiten, voor identificatie van kritieke objecten, onderzoek naar onderhoudsgerelateerde risico's, rapporteren van geïdentificeerde risico's);
- Structuur voor uitwisselen van informatie en kennis (bij uitbesteding);

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DISCUSSIEPUNT 2
PROJECTDOELEN

Resultaat studie:
- Vooral extern gericht, gericht op opdrachtgever
- Geen duidelijke methode voor het bereiken van de doelen.
- Informatie en methoden voor uitvoering niet transparant (bv risico management, coördinatie)
- Inspectie en monitoren is subjectief

Discussiepunten:
- Welke processen zijn relevant voor interne doelen?
- Hoe worden de gestelde doelen gecontroleerd?
- Geven de plannen voldoende structuur om dit te bereiken?

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DISCUSSIEPUNT 2 (VERVOLG)
INVLOED OP PROJECT DOELEN

- Oorzaak analyse van de fouten;
- Communicatie naar belanghebbende (ook bij onvoorziene situaties);
- Controle op de projectdoelen;
- Rapporten (Incident en afwijkingen rapport, Inspectie, incident en kalibratie rapport, klachten rapport);
- Inzicht in de prestatie van het systeem (ook in de tijd);
- Periodieke evaluatie;
- Preventieve controle;
- Risico management (als input voor activiteiten, voor overzicht van kritieke objecten, rapporteren van geïdentificeerde risico's);
- Bijhouden van afgeronde maatregelen, en de resultaten van activiteiten en metingen

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DISCUSSIEPUNT 3
FACTOREN DIE ONDER CONTROLE GEHOUDEN MOETEN WORDEN

- Structuur voor het uitwisselen van informatie en kennis
- Onderzoek naar onderhoudgerelateerde risico's en methoden voor de identificatie van risico's
- Opschrijven van de gewenste prestatie en conditie in de tijd
- Criteria voor het prioriteren van doelen en plannen.

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AFRONDING
AFSLUITENDE VRAGEN

- Relevantie van resultaten voor toekomstige projecten
- Verbeterpunten voor projecten
- Overige zaken?

Bedankt!

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