Verification process performance within large infrastructure projects

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MSc. Thesis
Construction Management & Engineering
Verification process performance within large infrastructure projects

A study of the influence of using different quality standards on the verification process performance within large infrastructure projects in the Netherlands.

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Preface

This thesis is the final piece of work concluding my time in Delft as a student. During the master program of Construction Management and Engineering at Delft University of Technology I became interested in the management of complex infrastructure projects. In particular the courses on project management and public-private partnerships inspired me to find out more about how these large infrastructure projects are managed. These aspects of my study combined with my personal interest in the construction sector leaded to the decision of investigating a specific aspect of integrated contracts in the infrastructure sector. The graduation research is performed at VolkerInfra, an organization within the VolkerWessels concern. I would like to thank the people from VolkerWessels which were always open for answering my questions. The open and informal atmosphere within the projects organizations contributed a lot to the ability to collect all the data. I would like to thank my graduation committee. Rogier Wolfert for keeping me sharp and focused on the goal and process of the research. Marian Bosch-Rekveldt for her time on the Friday mornings helping me structuring and defining my research. Rembrandt Kruyt for his recommendations with respect to the readability of the report. And last but not least, Ivo van Kempen whose office door was always open for questions and feedback. I would like to conclude with a more personal note by thanking my family for supporting me during the last months. I also would like to thank all my friends which supported me in the stressful moments.

Derk Hordijk

Rotterdam, January 2014
Summary

In the Netherlands public and private parties are working together on the construction of infrastructure projects using integrated contracts. To control the integrated contract with the contractors, Rijkswaterstaat uses the system based contract control method. This method tries to achieve that all activities which the contractor performs are executed according to the contract requirements. To control the performance of the project, Rijkswaterstaat obliges the contractors to use ISO quality standards for their management system. The recently introduced ISO quality standards are extra relative to the quality standards already applicable. The reason of performing this research is: the ISO standards which are used by Rijkswaterstaat give certain restrictions about how processes are set-up within a project organization. Restricting the private contractors in their set-up of the processes in their organization seems to contradict with the ‘Market, unless…’ policy which Rijkswaterstaat is expressing. There is an increasing concern that the introduction of extra standards is not leading to better performance.

Topic researched

This master thesis researches the influence of three quality standards in the infrastructure sector, ISO 9001, ISO 15288 and ISO 15504, on the performance of the verification process. In this research a project, which applied ISO 9001, ISO 15288 and ISO 15504 was compared to two projects that only applied the ISO 9001. Specifically the process performance of the verification process is investigated for the three projects. The objective of this research is to gain insight in how the different quality standards influence the verification process performance within large infrastructure projects in the Netherlands. The main research question is:

*What is the influence of the use of different quality standards applied in Dutch integrated contracts on the verification process performance within large infrastructure projects?*

Methodology

Case studies were used to answer the question. This research method was chosen because its ability to handle quantitative and qualitative data. The criteria for choosing the case study projects are given in Table 1.
Based on the criteria the projects in Table 2 are selected.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project where the ISO standards are used</td>
<td>A least one project where the ISO 15288 and ISO 15504 are used and a project where the standards are not used. Otherwise the influence of using more standards cannot be investigated.</td>
</tr>
<tr>
<td>The projects are procured with an integrated contract</td>
<td>A D&amp;C or DBFM contract</td>
</tr>
<tr>
<td>Volker Wessels projects</td>
<td>Because of the availability and accessibility of project documents. Exclude potential interfering factors which can be caused by for example another corporate culture.</td>
</tr>
<tr>
<td>Projects which are at least finished with the design phase</td>
<td>Because the verification process in the design phase is researched.</td>
</tr>
<tr>
<td>Transport infrastructures in the road and waterway sector</td>
<td>Delineation of the research.</td>
</tr>
<tr>
<td>Project budget over 100 million euro</td>
<td>Delineation of the research.</td>
</tr>
</tbody>
</table>

Table 1 Project selection criteria

The case study focused on three parts:

1) Verification process set-up
2) Verification process performance measurement
3) Verification process capability assessment

First the set-up of the verification process was investigated. For each project the similarities and differences of the verification processes were investigated. Second, a verification process performance measurement (quantitative) was executed. In this step performance indicators for the verification process were defined. In the last step the qualitative analysis was performed. Interviews were held on different levels in the project organizations. These interviews were used to make a verification process capability assessment. This analysis gave insight in the functioning of the verification processes as implemented on the projects.
Results and analysis

1) Verification process set-up

From the process flows of the verification processes it can be concluded that there are differences in the set-up of the verification processes. The design of the SAAone process is very much based on the requirements of ISO 15288, which results in a relatively complex process compared to the other processes. From the processes of A4all and WillemsUnie we can conclude that only guidance from ISO 9001 was not sufficient for establishing the verification process. The specific steps with respect to the verification plan, verification report and reviews are requested from the requirement specification (VS2) of RWS. It is also noticed that the verification process of A4all has some ISO 15288 characteristics more than WillemsUnie (more objective proof documents, higher review frequency, presence of working instructions).

2) Verification process performance measurement

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>A4all</th>
<th>SAAone</th>
<th>WillemsUnie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revisions</td>
<td>62 x 1.0</td>
<td>111 x 1.0</td>
<td>48 x 1.0</td>
</tr>
<tr>
<td></td>
<td>15 x 2.0</td>
<td>79 x 2.0</td>
<td>63 x 2.0</td>
</tr>
<tr>
<td></td>
<td>93 x 3.0</td>
<td></td>
<td>45 x 3.0</td>
</tr>
<tr>
<td></td>
<td>20 x 5.0</td>
<td></td>
<td>32 x 4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 x 7.0</td>
</tr>
<tr>
<td>Average amount of processing time verification report days</td>
<td>59.6 days average</td>
<td>9.4 days average</td>
<td>92.7 days average</td>
</tr>
<tr>
<td>Range of processing time verification report days</td>
<td>2 until 220 days</td>
<td>0 until 114 days</td>
<td>1 until 569 days</td>
</tr>
<tr>
<td>Deviations</td>
<td>0/190</td>
<td>6/190</td>
<td>11/190</td>
</tr>
</tbody>
</table>

Table 3 Performance indicators of case study projects overview

In the verification process performance measurement the influence is measured with performance indicators (quantitative analysis). The values of the performance indicators are given in Table 3. For each project, 190 requirements are investigated, for SAAone 111 times a 1.0 revision is found and for WillemsUnie a broader distribution of revisions is shown. SAAone shows an average of 9.4 processing time verification report days which is the lowest of the three projects. The range of processing time verification report days is 0 until 114 days on SAAone which is low compared to the WillemsUnie where the range is 1 until 569 days. For A4all zero deviations are found.
3) Verification process capability assessment

A self-designed capability assessment inspired by ISO 15504 was performed on the projects. For each project 4 interviews were performed. The verification processes was assessed on specific characteristics subdivided on 5 categories shown in Table 4.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>Gives insight if the verification process is able to produce the required outcome.</td>
</tr>
<tr>
<td>Category 2</td>
<td>Gives insight in the organization is able to control and maintain the verification process.</td>
</tr>
<tr>
<td>Category 3</td>
<td>Gives insight if the verification is well-known within the whole organization.</td>
</tr>
<tr>
<td>Category 4</td>
<td>Gives insight if the verification process is consequently executed and if quantitative steering is performed.</td>
</tr>
<tr>
<td>Category 5</td>
<td>Gives insight if continuous improvement is applied on the verification process.</td>
</tr>
</tbody>
</table>

The outcome gives a capability profile which is an indication of the achievement of the characteristics per category per project. The analysis gives insight in the influence of the used quality standards on the characteristics of the verification process and how well the verification process performs.

![Capability profile](image)

**Figure 1** Capability profile of verification process case study projects
Conclusions

The influence of the different quality standards is determined by two types of analysis. The results of the verification process performance measurement (quantitative) suggest that projects where the ISO 15288 and ISO 15504 are applied on the project, advantages for the verification process performance are found. The results show that fewer revisions are necessary: this suggest that the use of the ISO 15288 has a positive influence on the verification process performance because the objective demonstration is accomplished better. Also the average amount of days is lower on the project with the ISO 15288 and ISO 15504: this suggests that the use of the ISO 15504 has a positive influence on the verification process performance. The range of processing time days is smaller on a project with the ISO 15288 and ISO 15504 applied, this implies that the ISO 15504 indeed has a positive influence on the functioning of processes and therefore on verification process performance. However it is difficult to say that fewer deviations found means that less non-conformities are found.

From the verification process capability assessment (qualitative) the implementation and functioning of the verification process is determined. The results suggest that if an organization wants a full achievement of the categories 1 to 3, the choice for an ISO 15288 set-up of the management system is preferred. The verification process of SAAone is completely performed, managed and established (the verification process is able to produce the required outcome, the organization is able to control and maintain the verification process and the verification is well-known within the whole organization). The results suggest that a complete achievement of the established process characteristics (category 3) can also be achieved by using an ISO 9001 verification process set-up. With respect to the consequent execution and quantitative steering on the verification process (category 4), verification processes with ISO 15288 characteristics are achieving the related characteristics more. If an organization would like to focus on continuous improvement characteristics (category 5) of the process, the process set-up according to the ISO 15288 is not preferred. The results suggest that an ISO 9001 set-up scores the same or even better. A better result is achieved with an ISO 9001 set-up combined with some ISO 15288 aspects.

The results from the case study point in the direction those verification processes where ISO 15288 and ISO 15504 standards are demanded, perform better than just using an ISO 9001 set-up. However, there are reasons why these conclusions may not be stated so firmly. The values of the
performance indicators do not necessarily say something about the specific content of the verification procedure. There could be more certainty obtained about these indicative results by investigating more processes than only the registration part of the verification process, examine more projects, check the relations of verification process characteristics with the performance indicators, check the opinion of RWS and investigating the influence of human behavior.

With respect to the discrepancy between the ‘Market, unless…’ policy and the increasing amount of control by imposing more quality standards, this research is considered as an indication that imposing extra quality standards, in this case the ISO 15288 and ISO 15504, result in potential advantages for the verification process performance.

Recommendations
To build upon the current research and strengthen its conclusions, the following research could be performed:

- Investigating the relation between non-conformities and deviations in order to improve the reliability of the performance indicator deviations.
- A larger quantitative survey on the relations between ISO 15288 characteristics and the process performance indicators.
- Check the interpretation of the performance indicators with Rijkswaterstaat.
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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D&amp;C</td>
<td>Design and construct</td>
</tr>
<tr>
<td>DBFM</td>
<td>Design, Build, Finance and Maintain</td>
</tr>
<tr>
<td>DO</td>
<td>Definitive design (Definitief ontwerp)</td>
</tr>
<tr>
<td>PPC</td>
<td>Public-Private comparator</td>
</tr>
<tr>
<td>PSC</td>
<td>Public Sector comparator</td>
</tr>
<tr>
<td>QM</td>
<td>Quality management</td>
</tr>
<tr>
<td>RWS</td>
<td>Rijkswaterstaat</td>
</tr>
<tr>
<td>SBCC</td>
<td>System based contract control</td>
</tr>
<tr>
<td>SCB</td>
<td>Systeemgerichte contractbeheersing</td>
</tr>
<tr>
<td>UAV-GC</td>
<td>Uniform conditions for integrated contracts</td>
</tr>
<tr>
<td>VS2</td>
<td>Requirements specification 2 (Vraagspecificatie 2)</td>
</tr>
<tr>
<td>ISO 15288</td>
<td>NEN-ISO/IEC 15288:2088</td>
</tr>
<tr>
<td>ISO 15504</td>
<td>NEN/IEC 15504-6:2012</td>
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Chapter 1
1 Introduction

1.1 Introduction to the subject

In The Netherlands the government was traditionally responsible for the plan-making, construction and maintenance of infrastructure projects. The Directorate-General Public Works and Water Management (Rijkswaterstaat) is the executive department responsible for the management and development of the Dutch main road network, main waterway network and the main water system network. The goal of RWS is to manage and realize these networks from their national functionality in order to guarantee the safety of the Dutch citizens (Rijkswaterstaat, 2011a). In recent years, the Dutch politics have been striving for a more flexible and compact government in order to reduce costs. The corresponding task for RWS is to achieve a reduction of 185 million euro (17.5%) in execution costs for the year 2015. For RWS this means a modernization of the organization with respect to working methods, knowledge, attitude and behavior. A modernization of the organization implies an internal reorganization combined with market consultation (Rijkswaterstaat, 2011a). RWS is responsible for the tendering of ground and road and waterway construction projects in The Netherlands. In order to utilize the specific qualities of the private contractors and make optimal use of the market capacity, public-private cooperation and integrated contracts are becoming increasingly important. RWS strives for more uniformity and standardization in tenders. RWS would like to achieve this with the ‘Market, unless...’ policy, which implies that private market entities should be used for the execution of works, unless there is no added value doing this (Rijkswaterstaat, 2007). When there is a need for the construction of new infrastructure projects, RWS involves private contractors to execute this work. After the procurement, the responsibilities between RWS and the private contractors are written down in a building contract. Traditionally the building contracts were based upon the Uniform Administrative Conditions for the Execution of Works (UAV 1989). Nowadays RWS makes use of integrated contracts in order to make optimal use of private market qualities and capacity. For this type of contracts, Uniform Administrative Conditions for integrated contracts are defined. These conditions are called the UAV-GC 2005. An UAV-GC contract is a basic agreement which includes principal requirements, contract documents and the UAV-GC 2005 general terms and conditions (Bruggeman, Chao-Duivis, & Koning, 2010). In line with the decentralization plans of the of the Dutch government and the ‘Market, unless...’ policy of RWS, RWS wants to involve and give the private sector more responsibility in the life
cycle of projects (Rijkswaterstaat, 2011a). The integration of the projects life cycle can be achieved by pulling together the actors, scope and time dimensions. This means the assignment of responsibilities to other actors than the government. For example, assigning responsibilities to local stakeholders or consortia of private parties can lead to better balanced outcomes with a broader public support. By using market expertise various local and national interests can be served (Arts, 2007). Projects with an integration of different phases of the project life cycle show possible advantages compared to projects with traditional contracting methods. Efficiency gains, increased project control and projects delivered better in time and within budget are possible (Ministerie van Financien, 2010). In the current RWS working method integrated contracts are used in cooperation between RWS and the private sector. Integrated contracts in which the design and construction is performed by one contractor result in a more optimized process and product. A better optimized process and product leads to qualitative better and cheaper solutions. Since the private sector can compete on product, instead of production capacity, the construction sector will focus more on the client needs (Dorée, 2001).

![Diagram of integrated contracts]

*Figure 2 Development of integrated contracts from (Lenferink, Tillema, & Arts, 2013)*
DBFM (Design-Build-Finance-Maintain) contracts integrate the stages of design, construction and maintenance in a single arrangement. Financing is part of the contractual arrangement and taken care of by the contractor; it is used as project control during all the life-cycle stages. Through integrating the stages in one integrated contract, the government distributes responsibilities to other actors (local stakeholders, consortia of private parties) in order to make optimal use of the knowledge, creativity and innovative power of the market (Lenferink et al., 2013).

Figure 2 gives an overview of the development of integrated contracts in the infrastructure project life cycle. In the construction sector the most commonly used contracts by RWS are the Design & Construct (D&C) and the Design, Build, Finance & Maintain (DBFM) contracts. More about the specific characteristics of integrated contract can be found in the Context chapter.

1.2 Problem definition

Construction cost overruns and time delays of large infrastructure project are occurring on a frequent basis. One of the most well-known cost overrun projects is the Channel Tunnel. The final construction cost overrun of this project totaled 80 per cent more than the estimated costs (Flyvbjerg, Bruzelius, & Rothengatter, 2003). The Netherlands have a history of poor project performance. Examples of projects with cost overruns are the Betuweroute and the HSL-South. Attention for cost overruns increased because of the large budget increase of these projects (Cantarelli, 2011). The North-South line in Amsterdam is another infrastructure project which suffered from cost overruns and time delays. The estimated budget is already exceeded by two times and the time delay is estimated at 6 years (Soetenhorst, 2012). Cost overruns like this do not fit in the cost reduction ambition of RWS. RWS stimulates the efficiency and effectiveness of the contractor through the free-market system by the Market, unless...’ policy, but would like to keep track on the performance of the contractor. RWS uses system based contract control (systeemgerichte contractbeheersing) in the ground, road and waterway construction works to gain insight in the process of the contractor (Rijkswaterstaat, 2007). System based contract control tries to achieve that all activities which the contractor performs, in all different phases of the project, are executed according to the contract (Rijkswaterstaat, 2011b).

One of the main principles of system based contract control is verification. The definition of verification which Rijkswaterstaat (2009) uses, reads: ‘Confirmation by research and provision of objective evidence that the specified requirements are satisfied’. In practice this means that the
responsibility for complying with the contract requirements lies with the contractor. The contractor has to prove he complies with the requirements by registering the evidence in verification plans and verification reports. Verification is part of the quality management of the contractor and has as main goal the detection of deviations and non-conformities with respect to the contract requirements. A prerequisite for the contractor is to describe the verification process and how he controls this (Rijkswaterstaat, 2011b). To keep track of the performance of the contractor, RWS requires the contractors to work according to a set of quality standards. A better performance means lower failure costs and better customer satisfaction (Werkgroep Leidraad Systems Engineering, 2013). The quality standards prescribe how processes in organizations need to be organized. When the contractor complies with these standards a certification is awarded. This certification gives RWS a certain degree of certainty about the capability of the contractor to control the process in order to produce a product of satisfying quality (Steens, Boddeke, & Hertogh, 1998).

As a contractor in the private sector, VolkerInfra is one of the contractors with which RWS cooperates on infrastructure projects. VolkerInfra has to comply with the requirements that RWS has set regarding certification. During the last years VolkerInfra is experiencing a trend of more standards imposed by RWS. Figure 3 gives an overview of the trend of the required quality standards which contractors, including VolkerInfra are experiencing. A more precise elaboration of the content of the standards can be found in the Context chapter.

![Figure 3 Trend in quality standards](image)
In conclusion, at present there is a discrepancy between the policy which RWS expresses to the private contractor with the ‘Market, unless...’ policy and the increasing amount of control by imposing more quality standards. In addition, there is an increasing concern that the introduction of extra standards is not leading to better performance of the organizations processes. Another reason for concern is that complying with more standards leads to spending more time and money and is thus costly for the contractor.

There are reasons why it is relevant to perform research about the influence of quality standards on the process performance of infrastructure projects. The first reason is practical and social oriented; the second reason is scientific.

1.2.1 Practical and social relevance

Although RWS and private contractors have different goals and working methods, both parties benefit from efficient and effective execution of a project. The ‘Market, unless...’ policy of RWS aims to provide the method to achieve this. Imposing the quality standards with the accompanying certification should give RWS a certain degree of certainty about the final result of the project. However, the contractor is not sure if the implementation of extra standards actually is leading to better process performance. On the one hand RWS is promoting the “Market, unless...” policy for infrastructure projects. On the other hand RWS is imposing more standards to have control over the project, restricting the freedom of the contractor. For VolkerInfra, the gathered information contributes to the knowledge they have about the effect of quality standards on process performance. After discussions with experts from VolkerInfra it became clear that there is a lack of knowledge about the relevance and the future use of the NEN-ISO/IEC standards. Related to the social relevance, more knowledge about the standards should result in an improvement of the process performance of infrastructure projects in the Netherlands. In order to reduce overruns in costs and time on infrastructure projects in the Netherlands it is useful to achieve more understanding about the influence of quality standards on process performance. A better process performance results in reduction of costs and time overruns. This means lower costs for the government and therefore for the Dutch citizens.
1.2.2 Scientific relevance

The topic of quality management is broadly discussed in literature. Also research on the use of quality management in the infrastructure sector can be found (Arditi & Gunaydin, 1997; Hoonakker, 2006). Nevertheless, research with respect to the influence of quality standards on process performance in the infrastructure sector is scarce. Landin (2000) discusses the acceptance of the use of the ISO 9001 standards in the construction sector and concluded that the acceptance of the standard is increasing. The effects of the ISO 9001 standard is only investigated for other sectors (Psomas, 2013; Tari, Molina-Azorin, & Heras, 2012). Also the effects of the ISO/IEC 15288 and ISO/IEC 15504 are discussed for other sectors than construction, mainly in sectors where they originate from (Elm, Goldenson, Eman, Donatelli, & Neisa, 2007; Fabbrini, Fusani, & Lami, 2009). This research contributes to these existing researches, specifically for the effects of the quality standards concentrated on the construction sector.
1.3 Research objective and research questions

1.3.1 Research objective
The objective of this research is to gain insight in how quality standards influence the verification process performance within large infrastructure projects in the Netherlands. This thesis is intended to provide insights in the usefulness and influence of the different quality standards on the verification process performance within large infrastructure projects. The knowledge gap which is investigated in this research is based on the fact that it is unknown what the influence of the ISO 15288 standard is on process performance compared to the more traditional ISO 9001 standard.

1.3.2 Research questions
In order to reach the research objective the following main research question is formulated:

*What is the influence of the use of different quality standards applied in Dutch integrated contracts on the verification process performance within large infrastructure projects?*

The main research question is investigated on the basis of the following sub-questions:

a) How is contracting and procurement organized for large public-private infrastructure projects in the Netherlands?

b) What types of quality management are imposed for the control of large infrastructure projects?

c) How is the verification process set-up within large infrastructure projects?

d) What is the performance of the verification process within large infrastructure projects?

The sub-questions serve as a basis for the structure of the thesis research. The research activities are performed in line with these questions and are aimed at giving the answers to these questions. Sub questions a and b are aimed to establish a research context for the eventual research. Sub questions c and d focusses specifically on the verification process. The research methodology for answering the questions is elaborated in the Methodology chapter.
1.4 Reader’s guide

This report comprises the graduation research about the influence of quality standards on the verification process performance of large infrastructure projects. The structure of the report is shown in Figure 4. This report begins by introducing the topic of quality standards with respect to process performance in chapter 1. Next, in the methodology a detailed explanation of research methods is given. After the methodology the research context which serves as a basis for the research is defined. Chapter 4 comprises the case study results; it is the part of the research where the results of the case study research on the influence of quality standards on the verification process performance are displayed. The findings from the case study are analyzed in chapter 5. In chapter 6 broader applicability of the research is discussed and the assumptions in research are mentioned. The knowledge vested from theory and practice will lead to the conclusions in chapter 7. Based on the results and conclusion, recommendations to the managerial approach and recommendations for further research are given in the final chapter.
Chapter 2
2 Methodology

In order to answer the research questions and reach the research objective, it is necessary to develop a research methodology. In this thesis a case study research is chosen. An overview of the phases of the research is given with an accompanying elaboration of every phase. The second section comprises the set-up of the case study.

2.1 Research methodology

According to Verschuren and Doorewaard (2010); ‘The most significant decision the researcher has to make when constructing a technical research is what kind of approach will be taken’. A case study research is chosen since in this research the types of information gathered are from different kind. The unique strength of the case study research is its ability to deal with a full variety of evidence-documents, artifacts, interviews, and observation. Also events are directly observed and people involved in the events are interviewed (Yin, 2009).

2.1.1 Phases in the research

Figure 5 Research framework

Figure 5 gives the research framework. Based on this framework a more extensive explanation of the phases is given below.
**Phase 1: Context**

In the first phase of the research the focus lies on establishing a research context and gain better understanding of the subject matter. The first phase is performed in chapter 3. The context is used as basis for the thesis research.

**Literature research**
A literature study is performed. The following relevant topics are investigated thoroughly:

- Procurement
- Building contracts
- Contract control methods
- History of quality
- Quality management

**Practical research**
In the exploratory research the subject of *quality standards in infrastructure projects* is investigated. In order to obtain a better feeling and understanding of the subject, desk research in practical project documents (contracts, ISO-standards, reports, instruction manuals) and theoretical documents (books, scientific literature) was performed. Also conversations with employees on project locations and participation in two workshops on the ‘PPP works conference’ of RWS contributed to the conceptualization of the research. 7 Semi-structured interviews were held with representatives from various organizations. The exploratory interviews were performed according to the *interview protocol round 1*, which can be found in Appendix 2 Interview protocol Round 1. Also a list of the people interviewed can be found in that Appendix. The exploratory research was the trigger for the (first) research questions and the relevant topics to be researched. Also the necessary link from theory to practice was made. This chapter is used as an introduction to the case study. The topics which are important in the case study are introduced in a theoretical way and then linked to project practice.

**Phase 2: Case studies and interviews**
The information from the previous phase is used as input for the case studies and interviews. The goal is to analyze three cases. The case study follows three steps. First, the set-up of the verification process is elaborated. The second step comprises the verification process performance measurement. The third step is the verification process capability assessment.
The case studies in this research are aimed at providing the information needed for describing the influence of quality standards. The essence of this case study research is to make a comparison between the process performances of infrastructure projects. Three projects were investigated; one that works according to the ISO 9001, ISO 15288 and ISO 15504 standard and the other two that work with ISO 9001.

In order to define the process performance of the case study projects, three research steps were performed:

1. Verification process set-up
   As a part of the case study the influence of the quality standards on the set-up of the verification processes is examined. Based on the management systems and project documents process flows are defined. A further elaboration of the working method can be found in the case-study set-up.

2. Verification process performance measurement
   Research on project documents of the three case study projects is performed. Performance indicators, specific project characteristics and their relation with the verification process performance are explored. A further elaboration of the working method can be found in the case-study set-up.

3. Verification process capability assessment
   Semi-structured interviews were held according to the interview protocol round 2. Inspired by the ISO 15504 generic capability assessment tool and supporting information from a professional from the SQS independent assessment company, an assessment framework is established. The 12 interviews which were held are transcribed. Next, the statements from these interviews are structured into tables in order to obtain insight in patterns. The goal of the assessment is to gain insight in the functioning of the verification processes of the case study projects. The interview protocol can be found in Appendix 3 Interview protocol Round 2.
Phase 3: Analysis, conclusions & recommendations

The results from the case study are used to make comparisons between the cases. The goal is to find explanations for the similarities and differences between the various cases (Verschuren & Doorewaard, 2010). The information from the interviews and data gathered from the project documents is analyzed and categorized by means of categorization in tables. Conclusions are drawn on basis of the analysis and recommendations are made in order to answer the research questions.

2.1.2 Scope

In order to give a clear answer on the main research question the research topic needs to be framed. Although on basis of the context explored in Chapter 2 the research setting is already defined some specific remarks with regard to the delineation of the research are necessary. This research focuses on large infrastructure projects in the Netherlands where quality standards are involved.

The definition of infrastructure projects is broader than the projects for which RWS is responsible. Infrastructure projects include: energy (power generation and supply), transport (toll roads, bridges and tunnels), water (sewerage, water supply), telecommunications (telephones) and social infrastructure (hospitals, prisons, government accommodation) (Grimsey & Lewis, 2002). In this research the focus lies on transport infrastructures in the road and waterway sector which are executed under an integrated contract in the Netherlands. In this research the two most common contract types, D&C and DBFM, are analyzed. With ‘large infrastructure projects’, the definition from Flyvbjerg (2005) is used: ‘the most expensive infrastructure projects that are built today, typically at costs per project from around a hundred million to several billion dollars’.

The case study projects under investigation are VolkerWessels projects. Doing a VolkerWessels specific case study limits the interference of deviating external factors. The influence of the standards NEN/ISO 9001:2008, NEN-ISO/IEC 15288:2008 and NEN/IEC 15504-6: 2012 is investigated. Throughout this thesis the term ISO 9001, ISO 15288 and ISO 15504 are used to refer to these standards. With regard to the verification process this research is very strictly delineated to the verification process as defined in the quality standards. The verification process in the design phase is investigated, which implies that interfaces with other processes are excluded. An overview of the definition of the terms can be found in Table 5.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quality standards</strong></td>
<td>In this research limited to the ISO 9001, ISO 15288 and ISO 15504</td>
</tr>
<tr>
<td><strong>Integrated contracts</strong></td>
<td>D&amp;C and DBFM contracts</td>
</tr>
<tr>
<td><strong>Large infrastructure projects</strong></td>
<td>Projects in the road or waterway transport sector with a project value of at least 100 million euro performed in the Netherlands</td>
</tr>
<tr>
<td><strong>Verification process</strong></td>
<td>The process as defined in the quality standards</td>
</tr>
</tbody>
</table>

Table 5 Delineation of terms
2.2 Case study set-up

In this section the method and assumptions which apply to this case study specifically are introduced. First importance of a case study protocol is mentioned. Next, the case study projects and their characteristics are introduced; then the case study approach for researching the verification process is explained. The case study set-up is based upon the experience acquired during the practical context definition phase.

2.2.1 Case study- and interview protocols

According to Yin (2009); ‘Having a case study protocol is essential if you are doing a multiple-case study. The protocol is increasing the reliability of case study research and is intended to guide the investigator in carrying out the data collection.’ The information regarding the verification process performance measurement can be found in the case study set-up. For the verification process capability assessment semi-structured interviews were held with four persons per project. The first person is involved in the set-up of the management system and the processes, the second person is the Head of Design, the third person is involved in the design but has supervising tasks related to the verification process and the fourth person experiences the verification process from a more practical viewpoint. In this way the complete picture of the current situation can be established. The information gathered from these interviews is structured according to a capability assessment framework. Performing a case study desires skills from the researcher. The quality of the outcome of the research depends for a great part on the quality of the skills of the researcher. The basic commonly required skills according to Yin (2009) are: ‘be a good listener’, ‘be adaptive and flexible’, ‘have a firm grasp of the issues being studied’ and ‘be unbiased by preconceived notions’. In this research it is tried as much as possible to use these skills. The protocol for the interview and a list of people interviewed can be found back in Appendix 3 Interview protocol Round 2.

2.2.2 Case study projects

The projects are chosen based on the characteristics of the project and accompanying contract specifications. Based on the criteria in Table 6 three projects are chosen. The projects and their basic characteristics can be found in Table 10. In the case study the project are named to the names of the building consortiums, because this is in practice the most common way of referring to projects.
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project where the ISO standards are used</td>
<td>A least one project where the ISO 15288 and ISO 15504 are used and a project where the standards are not used. Otherwise the influence of using more standards cannot be investigated.</td>
</tr>
<tr>
<td>The projects are procured with an integrated contract</td>
<td>A D&amp;C or DBFM contract</td>
</tr>
<tr>
<td>Volker Wessels projects</td>
<td>Because of the availability and accessibility of project documents. Exclude potential interfering factors which can be caused by for example another corporate culture</td>
</tr>
<tr>
<td>Projects which are at least finished with the design phase</td>
<td>Because the verification process in the design phase is researched</td>
</tr>
<tr>
<td>Transport infrastructures in the road and waterway sector</td>
<td>Delineation of the research.</td>
</tr>
<tr>
<td>Project budget over 100 million euro</td>
<td>Delineation of the research.</td>
</tr>
</tbody>
</table>

Table 6 Project selection criteria
2.2.3 Defining verification process performance

The case study focuses on defining the verification process performance. The choice of investigating the verification process in this research is based on the following considerations:

- Investigating all processes is not possible within the given scope of time.
- Verification is the basis of the system based contract control method used by RWS.
- The importance of the verification of contract requirements is underpinned by RWS. Based on the verification proof, payments are done by RWS.
- The need for verification is defined in the ISO 9001 and the ISO 15288, and therefore present in all the case study projects.
- The choice for investigating the verification process of the design phase is based upon the fact that this phase is finished and the related information is available for all three case study projects.

A random sample of 190 requirements from the definitive design (DO) is taken, because:

- In the definitive design all the elementary requirements are defined and also the interfaces with other disciplines are already coordinated.
- The amount of 190 requirements is restricted by the limited provision of verification reports from the WillemsUnie.

The case study research on the verification process consists of three parts.

1. **Verification process set-up**

To give a more profound idea about the influence of quality standards on the process set-up the differences and similarities in the projects are investigated on basis of the requirements from the quality standards. Thus it becomes more tangible what the actual influence of the quality standards is on the set-up of the verification process. This step of the case study provides insight whether the set-up of the verification process is influenced by the use of different process set-up standards.

**Result:** Verification process flows and overview of specific verification process characteristics with reference to applicable parts of the quality standards.
2. Verification process performance measurement

This section of the case study comprises the steps that explain how the performance of the verification process is defined. The potential gains of using quality standards are the reduction of failure costs and to improve customer satisfaction (Werkgroep Leidraad Systems Engineering, 2013). Four performance indicators are defined. All the four performance indicators can be determined with data from the verification reports and are assumed to give insight in customer satisfaction and failure costs. The verification report is the output of the verification process and contains the information with respect to the verification process. It gives insight in the fact whether the projects are complying with the contract requirements. A random sample of 190 requirements from the definitive design (DO) phase is taken. The performance indicators and their descriptions can be found in Table 7.

Result: A comparison between the case study projects and how they score on the performance indicators.

3. Verification process capability assessment

12 semi-structured interviews are held on the three case study projects. With the information from these interviews a capability assessment of the verification process is performed. The interview questions can be found in the interview protocol round 2. The interview is not only focused on the capability assessment but leaves room for comments with respect to the implementation of the verification process as interpreted by the different professionals. The capability assessment gives an indication of the verification process capability categories. A better score on the capability assessment implies a better verification process performance. Capability profiles of the projects are established based on the categories of Figure 12. To which extent the categories of the projects are achieved is determined by interpretation.

Result: Framework with statements from interviews and accompanying capability profiles of the projects.
<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Description</th>
<th>Contribution to verification process performance</th>
<th>Insight in process performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of revisions</td>
<td>The number of revisions tells something about the output of the process. When the output of the process complies with the requirements, no revisions are necessary.</td>
<td>The verification process performance is better when fewer revisions at the end of the process are necessary. A revision is an indication that the current results of the process do not comply with the demands of RWS and needs to be improved.</td>
<td>Customer satisfaction &amp; failure costs</td>
</tr>
<tr>
<td>Average amount of processing time verification report days</td>
<td>Average number of days between submitting the first version of verification report and finishing the requirement by authorization of the work package responsible.</td>
<td>The lower the average amount of processing time days, the more efficient the verification process works. Process performance is better with a lower average number of days.</td>
<td>Failure costs</td>
</tr>
<tr>
<td>Range of processing time verification report days</td>
<td>Range of days between submitting the first version verification report and finishing the requirement by authorization of the work package responsible.</td>
<td>The smaller the range of the processing time days is, the more predictable the duration of the process. Delivering within a smaller range of days leads to better process performance.</td>
<td>Customer satisfaction &amp; failure costs</td>
</tr>
</tbody>
</table>

**Possible extra performance indicator**

| Number of deviations | The goal of reporting deviations is isolating the part of the system which causes non-conformity with the requirements. The reporting of a deviation is accompanied by a control measure. | Non-conformities are isolated and removed. A deviation needs to be written when the contractor deviates from the requirements as set by RWS which he could have met. When deviations are found this means that the process performance could have been better. | Customer satisfaction |

Table 7 Performance indicators
2.3 Conclusion

The result of the case study gives the information needed to answer the main research question. The first step provides insight in the set-up of the verification process. The differences and similarities between the verification processes and their respective links to the quality standards are shown. Based on this information specific verification process characteristics are known. The second step gives information, based on the known specific verification process characteristics of step one, about how the projects scores on the process performance indicators. The outcome of these two steps combined gives an indication how the verification process performance is influenced by the quality standards. The third step, the capability assessment, gives an evaluation of the functioning and implementation of the verification process. This information, combined with the specific verification process characteristics, gives an indication of the influence of the quality standards on the verification process performance. For the first two steps of the case study the projects database ViSe (VolkerInfa Systems Engineering) is used. All three projects are using this system for verification purposes. In this way data gathered on the projects can be compared without potential interference caused by using different data from different databases. Table 8 summarizes what the performance indicators imply with respects to verification process performance.

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revisions</td>
<td>It is assumed that this indicator measures that the performance of the verification process is better when the amount of revisions is low.</td>
</tr>
<tr>
<td>Average time of processing time days</td>
<td>It is assumed that this indicator measures that the performance of the verification process is better when the average amount of processing time days is low.</td>
</tr>
<tr>
<td>Range of processing time days</td>
<td>It is assumed that this indicator measures that the performance of the verification process is better when the range of the processing time days is smaller.</td>
</tr>
<tr>
<td>Deviations</td>
<td>It is assumed that this indicator measures that the performance of the verification process is better when the amount of deviations is low.</td>
</tr>
</tbody>
</table>

Table 8 Assumptions relation performance indicator and process performance
Chapter 3
3 Context

In order to be able to perform a thorough study on the subject of verification process performance, the context of the research is set. The information gathered in this chapter is used as background for the case studies later in the research. This chapter provides the theoretical and practical background to the topic of research. With the information in this chapter, sub-questions a and b are answered.

3.1 Working method Rijkswaterstaat

In the introduction the system based contract control method of RWS was mentioned. This is the control method which RWS uses on integrated contracts. A characteristic of integrated contracts is that the contractor is responsible for the quality of the product he produces. This is the so called external quality assurance. When RWS makes use of the quality management of the contractor for controlling the contract, the method is called system based contract control (Rijkswaterstaat, 2007). RWS intends to make use of the advantages of integrated contracts and wants to double the amount of DBFM-contracts till the year 2020 (Rijkswaterstaat, 2011a). The two most common used integrated contracts in the infrastructure sector are the D&C and DBFM contracts.

3.1.1 Design and Construct (D&C)

A D&C contract is an integrated contract where the design and execution are in the hands of one single party. The party in control may be a contractor, but also the designer party or another party. Figure 6 shows an overview of the (contractual) relationships. The design and construction are united in a single contract and the result is a turnkey project which is delivered. Integrated contracting according to the D&C method does not necessarily mean that the contractor takes care of both design and construction of the project. It is still possible to outsource parts of the work to subcontractors (Bruggeman et al., 2010).
3.1.2 Design, Build, Finance and Maintain (DBFM)

In the DBFM contract the different elements related to the design, realization and exploitation of a building contract are integrated in one contract and commissioned to one party. One of the main characteristics of the DBFM contract is that the financing is realized by the contractor; in return he receives a periodical fee during the entire term of the contract. The term of the contract is related to the economic life of the object. Terms from 20 to 25 years are normal. The other main characteristic is that the client does not steer the contractor on the basis of detailed instructions but on the basis of performance criteria. The process is steered on output, a payment mechanism encourages the contractor to perform well (Bruggeman et al., 2010).

Figure 6 Overview contract design and execution from (Bruggeman et al., 2010)

Figure 7 Schematic representation of DBFM contract (Bruggeman et al., 2010)
Figure 7 shows an overview of the (contractual) relationships in a DBFM contract. The most important relationship is the agreement between the client and the consortium which will realize the contract. The client may demand procedures regarding the execution of the work. The main tool of the client to influence the work performed, is the use of financial incentives (Bruggeman et al., 2010).

In order to make a well-founded decision between the contract variants, RWS uses the Public-Private comparator (PPC). The goal of the PPC is to find the most attractive variant. It is a qualitative and quantitative instrument which makes a comparison between a D&C and a DBFM contract. The added value when using a DBFM contract is expressed in time and money. For RWS it is obliged to use the PPC in case of the procurement of MIRT-projects (Meerjarenplan Infrastructuur, Ruimte en Transport) with a budget of more than 60 million euros. The public sector comparator (PSC) is a test which is done when a DBFM contract is chosen. It is a comparison method which gives insight in the total costs of a project over the life-cycle of a project. The outcome is used to assess if a public-private partnership set-up is favorable in comparison with a public variant (Wijsman, Prins, Gorgels-Timmersmans, Van Gulpen, & Blanken, 2011).

3.1.3 External tests
A characteristic of integrated contracts is the increased distance of RWS towards the execution of works. The integration of the various aspects of an infrastructure project in one contract results in an optimization of life-cycle thinking. In an integrated contract, the private contractor is forced to align the various phases in the life-cycle of the project. The integral approach of a project can result in financial and quality advantages for the project. The integration of the various aspects in one contract results also in a different distribution of risks between RWS and contractor. In an integrated contract the risks are allocated to the party who can control the risks the best (VROM, 2008). The risks for RWS should be controlled provably by the contractor. The primary goal for RWS of the contract control is: efficiency (distance contract control with as little as possible effort). Secondary the method should be effective, so focussed on the biggest risks of the client. (Rijkswaterstaat, 2011b).

RWS uses a mixture of tests to perform risk based contract control (Figure 8). The mixture of tests follows the risk profile during the realization of the project and is testing the contractual obligations of the contractor. The tests provide a judgment about the performance of the project and the quality
management of the contractor. There are three tests: System test, process test, product test. The system test is a test on the functioning of the integral project management system. The emphasis lies on the compliance of the system and quality assurance. The process test is a test on the functioning of the described processes during the design- and execution process. The product test is a test in the execution phase. It tests the reliability of the verification- and inspection results of the contractor (Rijkswaterstaat, 2011b).

Figure 8 Theoretical ideal mix of tests over the duration of the project based on (Rijkswaterstaat, 2007)

The responsibility of complying with the contract requirements lies with the contractor. The contractor manages his own project and proves that the (sub) products comply with the requirements from the contract. In order to prove it registrations should be included in the verification- and inspection plan. The most important element of quality management by the contractor is: process description, risk control, detecting deviations, taking appropriate measures and regularly evaluate this process.
3.2 Quality management

The previous section gave a brief introduction to quality management. To be able to perform well on quality management of the project it is necessary to know what exactly quality is. For mature organizations it is difficult to give a definition of quality because quality is defined by the customer. These organizations view quality more as a process than as a product. It is viewed as a continuously improving process where lessons learned are used for enhancing future products and services in order to: retain existing customers, win back lost customers and win new customers (Kerzner, 2009). Different points of view with respect to content can be found. The Project Management Institute (2000) states: ‘the quality management processes includes all the activities of the overall management of the performing organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken’. To define what quality management means in this study the history of quality management is summarized and a link with current practices is made.

3.2.1 History of quality management

In the course of time views on quality management have changed considerably. Three quality pioneers have set the scene with their own theories. The first one, Deming believes that quality is reached by ‘continuous improvement’. Another pioneer in quality management is Juran, who believes that 80% of a problem is caused by 20% of the causes; ‘sporadic’ and ‘chronic’ problems can be solved by existing techniques or scientific breakthroughs. The third pioneer, Crosby, argues that quality is about doing it right the first time, the only costs of quality should be those of nonconformance (Kerzner, 2009). Based on the theories of these three quality pioneers several types of quality management are used in practice. In the following section a historical overview of the changes in the last century is given.
Based on Figure 9 the changes are described from a time perspective. From this figure appears that every successive phase is containing characteristics and elements from the previous phase.

**Traditional quality**

Before the industrial revolution quality was viewed from a traditional standpoint. The basis was ‘face-to-face’ contact between supplier and customer. The demand of the customer with respect to the product was clear and the craftsman was responsible for the realization of the product. The quality of the product was controlled by the fact that the customer was not obliged to buy the product when this not matched his requirements (Van der Bij et al., 1999).

**Quality inspection (1930)**

The industrial revolution was the cause of the introduction of quality inspection. Mass production for anonymous customers became possible. Quality management became a separate function performing inspections, sorting out the good items from the bad. The emphasis was on problem identification. However, the system of 100 percent inspection turned out not to be so effective (Kerzner, 2009; Van der Bij et al., 1999).
Quality engineering (1950)
After the further development of quality inspection, people realized that the quality of a product largely depends on the quality of the design. A complicated design leads to a bigger chance on errors. Focus shifted to the prevention of errors in the design process. A new quality discipline was started with the focus on the functions of a product (Van der Bij et al., 1999).

The next phase in the evolution is the change from a product focus towards a focus on process control. The main question became how a good quality management system can be introduced in organizations. In this phase quality instruction manuals, quality standards and audits were introduced. Quality was guaranteed with rules, procedures and instructions. In the civil sector the NEN-standards were introduced (Van der Bij et al., 1999). The best-known quality standards are the NEN-ISO 9000 series. In the Dutch construction sector specifically the ISO 9001 standard is asked by RWS. In practice this standard is called ‘the hat rack’ (‘kapstok’) standard. The standard does not describe how an organization can guarantee quality, but only that an organization needs to arrange certain matters concerning quality. Focus lies on the control of certain steps in the process (Steens et al., 1998; Van der Bij et al., 1999).

Total quality management (1990)
Today the emphasis is more on quality management in a strategic way. The addition to quality assurance is the more dynamic and integral approach towards quality management. The organizations need to be more effective, every possibility of improvement is utilized. Customer satisfaction, continuous improvement combined with teamwork and participation is the concept (Kerzner, 2009; Van der Bij et al., 1999).

Quality management in the future
Because of the smaller role of the government in the future, quality management in the construction sector will be more and more focused on the control of quality by imposing a quality management system by the contractor. The quality management system must be certified based on the ISO quality standards. More about these quality management systems can be found in the next section.
3.2.2 Quality management systems

For management systems or quality management systems a broad range of definitions can be found. The following definition of Van der Bij and Broekhuis (1998), comprises most of the important aspects of a management system:

‘The whole of management and control, monitoring and improvement activities dealing with the aspects or characteristics of quality, as well as the organization of those activities’

In practice a management system is a digital or analog system, where the contractor demonstrates and registers that he controls the project and complies with the requirements for the (sub) products set by the client. In the management system the contractor describes the process, controls risks, signals deviations and takes measures to correct these deviations itself. The whole process also needs to be evaluated on a regular basis (Rijkswaterstaat, 2011b). The requirements from the contract are translated into processes in the management system. The private contractor is relatively free in the design and interpretation of the requirements when translating them to the management system. He only has to comply with certain quality standards which are applicable to the management system (Rijkswaterstaat, 2011b). In practice the quality management system is part of the broader generic management system of the organization. For example, the management systems from the case study projects are based on diverse requirements varying from the quality standards, safety, health and environment requirements up to the more general process organizations standards. The requirements have influence on the set-up of the processes in the management system. Appendix 4 provides an indication of how management systems are set-up on the projects and gives three overview figures of the management systems with corresponding requirements. More about the quality standards which are used in current practice and on which this research is focused can be found in section 3.3.
3.3 Quality standards

A management system can be assessed on the basis of quality standards. In literature a broad range of standards can be found, which vary from general standards to standards for a specific branch (Van der Bij et al., 1999). An important goal of quality standards or management system standards is to describe processes and control or eliminate risks. Another goal is improving products, processes and services. Both the goals lead to better customer satisfaction. Several standards were introduced over the years. Internationally the ISO 9001 was developed. Companies could get an ISO 9001 certification, assessed by an independent assessor, when they complied with the demands from the standard. Based on this standard, other standards like the ISO 14001 for the environment, OHSAS 18001 for working conditions and HKZ-standards for social services were introduced (De Vaal, Pijl, & Van Schijndel, 2013).

This research is delineated to the ISO 9001, 15288 and 15504 standards, since these are in general use in the current integrated contracts of RWS. The main reason for RWS to demand the ISO-certificate is because it gives the client a certain degree of certainty about the ability of the contractor to control the process. In the tender procedure more often an ISO-certificate is demanded as minimum requirement for selection (Steens et al., 1998). ISO standards are also a good indicator of well-weighted spending of public money. From the introduction section it became clear that RWS demands contractors to have a management system set-up based on the ISO 9001 standard, sometimes in combination with the ISO 15288 standard. The two standards combined are required when performing a first or second generation DBFM construction project. In combination, the standards provide a foundation for the development, implementation and support of complex systems. They are the basis of the quality requirements and providing the guidance for measuring and improving process performance.

The ISO 9001 and ISO 15288 are standards that promote a process approach for management system set-up. The ISO 15504 is a standard which assesses the processes. A division between process set-up standards and process assessment standards is made.
3.3.1 Process set-up standards

In this thesis process set-up standards, mean the quality standards which require a certain approach towards the set-up of processes in the management system. This research is delineated to the ISO 9001 and ISO 15288, therefore these two standards are discussed in the following section. More about processes can be found in section 3.4.

ISO 9001: 2008 (quality management system - requirements)

This standard stimulates the implementation of a process approach when building up, implementing and upgrade the effectiveness of a quality management system. "The application of a system of processes within an organization, together with the identification and interactions of these processes, and their management to produce the desired outcome, can be referred to as the "process approach" (ISO, 2008a). The standard is intended to increase the organizations responsibility towards customer satisfaction. The responsibility is to meet the demands and wishes of the customer and comply with the legal requirements which are applicable to their product. The organization must manage their business processes and should be able to show this. When the organization complies with the ISO 9001 standard this means that the organization works with a predefined and structured way of quality management. The standard gives a good starting point for setting up a quality management system (ISO, 2008a).

Figure 10 Quality management of contractor, including PDCA-circle and test moments RWS from (Rijkswaterstaat, 2011b)
This mechanism is shown in Figure 10 and is used to control the process- and product quality. The contractor must demonstrate the use of the Deming circle (plan-do-check-act) in their project. The Deming circle principle is based on continuous improvement: the contractor is forced to improve its own process continuously (Rijkswaterstaat, 2011b). When the system based contract control method is applied correctly it should ensure the legitimacy of the payments for the delivered performance. The test process and the paying process are inseparably connected with each other. With the results of the tests the actual performance can be underpinned and according to this the correct payment can be done. When RWS detects a shortcoming (a negative finding in the opinion of the client) during the test process, they can postpone the payment or even sanction the contractor till the shortcoming is repaired or improved (Rijkswaterstaat, 2011b).

The first principle of quality control is: ‘task executor is task responsible’. The thought behind this idea is that the executor of the task is best able to control whether the result complies with the requirements. The second principle is ‘continuous improvement’, with the goal to constantly improve the product- and process quality by continuous evaluation of the working methods (Steens et al., 1998).

**ISO/IEC 15288:2008 (Systems engineering, system life cycle processes)**

The systems engineering standard delivers a clear-cut set of processes, in order to facilitate the communication between clients, contractors and other stakeholders during the system life-cycle. It provides a common framework which ensures an integrated and understandable working method. The standard defines the processes and terminology for the full life cycle. These processes can be applied to every level of a system structure. The standard defines the processes that meet the definition, control and improvement of the life cycle processes used within an organization or project. The organizations and projects can use these life cycle processes when delivering and acquiring systems (ISO, 2008b). An overview of the processes according to the system life cycle can be found in Figure 11. In the ground, road and waterway construction sector the system engineering approach is promoted since 2007. The method was implemented as a joint initiative of RWS, ProRail, Bouwend Nederland, NLIngenieurs and the association of Water builders.
The goal of implementing the method according to the Werkgroep Leidraad Systems Engineering (2013) is threefold:

- Efficiency: The ability to meet customers’ demands within socially well-considered costs.
- Effectiveness: Bringing back fail costs and better use of available resources.
- Transparency: Provable and controlled delivery of what is agreed with the customer.

![Diagram of processes of a system life cycle](image-url)

*Figure 11 Processes of a system life cycle according to (ISO, 2008b)*
Management specifications

In case of a project which is subject to the ISO 15288, the standard does not entail the organization to exactly implement all the defined life cycle system processes. There is the possibility to tailor the processes in a certain extent by adding, deleting or expanding processes. The extent to which a contractor must fully conform to the ISO 15288 is stated in the management specifications enclosed with the standard. The management specifications stipulate the parts of the ISO 15288 which the contractor must detail in full conformance. For some of the processes customized conformance is permitted. The management specifications entail a restriction, detailing and possibly a supplementation to the requirements from the ISO 15288. In the case of SAAone for the verification process full conformance with the provisions of the ISO 15288 is demanded. For A4all and WillemsUnie also management specifications are demanded. For these projects the specifications are named requirement specifications (Vraag specificatie 2). With respect to the verification process supplements on the provisions from the ISO 9001 are made. The specification requires the making of a verification plan and verification report, also a review activity is requested. When there is a contradiction between the provisions from the quality standards and the requirements from the specifications, the requirements from the management and/or requirement specifications are leading.
3.3.2 Process assessment standards

In practice the *process assessment standard* which is requested from RWS is the ISO 15504. The functioning of the management system and its processes is assessed by this standard.


The ISO 15504 is standard which assesses the functioning of the processes within an organization. It contains a reference model by which capability categories can be determined. The extent in which an organization complies with the specific capability level is determined by process attributes. It gives an overall determination of the organizations capability. The ISO 15504 contains a process reference model (PRM), a measurement framework (5 categories of capability) and a process assessment model (PAM). In Figure 12 an overview of the capability categories with corresponding short description is given.

---

**Figure 12** Capability levels and process attributes based on (ISO, 2008c)
The PRM provides the standard requirements on which the processes are assessed. For example, on the SAAone project the reference model is the ISO 15288 standard. It contains the purposes and goals of the standard. The PAM is a combination of the PRM and the measurement framework. In Figure 13 an example of a PAM is given.

A process dimension and a capability dimension are defined. ISO 15504 provides a framework for the assessment of process capability. The PAM consists for example of assessment indicators, which prove that actions are performed. This framework can be used by organizations involved in planning, managing, monitoring, controlling and improving the acquisition, supply, development, operation, evolution and support of products and services (ISO, 2008c).

![Process assessment model (PAM) from (ISO, 2008c)](image)
3.4 Processes

From the previous sections we know that management systems consist of processes. The processes in the management systems can be designed and assessed based on the prerequisites of quality standards. Also the mode of thought regarding the ‘process approach’ was introduced. The exact definition of a process is not yet given. Based upon two definitions from Wealleans (2001) and De Vaal et al. (2013) the following definition of process is composed:

‘A coordinated set of coherent and returning activities that achieve something (a goal)’

Figure 14 Example process with its boundary based upon (Wealleans, 2001)

As Figure 14 indicates, a process is a set of activities within a certain boundary. Inputs are used for the activities in order to achieve something, for a customer or stakeholder, in the form of an output. That is also the reason why processes are important for quality management. Other advantages of working according to processes are: efficient use of professionals, clear responsibilities and a good coordination of mutual tasks. Disadvantages of working according to processes is that you always have to look for a good balance between the standardization and establishment of processes and the professional freedom of the employees (De Vaal et al., 2013).

In practice there are different layers of processes in organizations. When you are working with processes you have to be able to think vertically and horizontally. In Figure 15 an example from the
process structure of SAAone is given. In fact it shows how you need several steps to zoom in on a lower layer of processes. In this example we zoom in on the layer of the processes (PRO’s) 10-5 c and e.

**Figure 15** Example of a vertical process structure

Figure 16 and Figure 17 show an elaboration of the sub-processes 10-5c and 10-5e. They give an indication of the level of detail: the processes exist of input, activities and outputs. The outputs of the processes are used as inputs for other processes. Not all organizations are working with illustrated versions of processes; the system can also be based on written process descriptions.
Figure 16 PRO 10-5c Sub process Opstellen verificatieplan DO SAAone

Figure 17 PRO 10-5e Sub process Opstellen verificatierapport DO SAAone
2.4.1 Verification process

From the introduction it became clear that verification is an essential part of the current working method of RWS. The reason why specifically the verification process is researched can be found in the chapter 2. The definition of verification which Rijkswaterstaat (2009) uses, reads:

‘Confirmation by research and provision of objective evidence that the specified requirements are satisfied’

The specified requirements are the requirements which are derived from the contract between RWS and the contractor. The contractor needs to prove he complies with the requirements by proving this with objective evidence. As can be seen in Figure 15 the verification is a sub process in the organizations management system and is a process which has interfaces with different other processes in the management system. For example, Table 9 indicates on the SAAone project verification is presence on a limited set of processes.

<table>
<thead>
<tr>
<th>Sub-process Systems Engineering PRO-09-2 as part of PRO-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-processes Managing Main work package Environment Management</td>
</tr>
<tr>
<td>Sub-processes of the primary processes PRO-010 Design, PRO-011 Realization, PRO-012 Maintenance</td>
</tr>
</tbody>
</table>

Table 9 Processes where verification is presence on SAAone
3.5 Process performance measurement

The main topic of this thesis is the performance measurement of the verification process. The reason why specifically the verification process is chosen can be found in the methodology chapter. Measuring the performance of a process is monitoring how well the activities in the process behave. In order to be able to measure the process, quantitative performance indicators need to be defined. The indicators tell us something about the product, services and the processes that produce them. (Oak Ridge Institute for Science and Education, 2005; Wealleans, 2001).

Summarized, according to Oak Ridge Institute for Science and Education (2005) performance indicators give us insight in:

- How well the organization is doing
- Goal achievement
- Customer satisfaction
- Process control
- Possibilities to improve

In order to get these insights about the verification processes of the case study projects it is necessary to define performance indicators for the verification process. Based on these performance indicators, process performance can be compared between the projects. The most important indicators can be categorized in the following six types: effectiveness, efficiency, quality, timeliness, productivity and safety (Oak Ridge Institute for Science and Education, 2005). How the performance of the verification process is measured can be found in the methodology chapter. It takes the customer requirements of the verification process in consideration. The specific characteristics of a process are turned into elements that we can measure, so called metrics or operational performance indicators (OPI's).
3.6 Conclusion

In the previous section the context of this research was set. From the combination of theoretical and practical research, the following can be concluded: Quality management in the current infrastructure sector is based upon the concept of total quality management combined with the quality assurance characteristics that quality standards entail to the quality management. RWS uses the system based contract control method for controlling their integrated contracts. The method involves an increased distance between public and private parties, risk based testing and furthermore the contractor needs to prove the conformance with the contract requirements by verification. The contracts which are currently used most are the D&C and DBFM contracts. RWS uses the public private comparator to make a decision about which contract form to use. In these contracts RWS enforces the contractor to set-up their quality management system based upon the ISO 9001 or the combination of the ISO 9001 and ISO 15228 standard. For some of the processes customized conformance is permitted. The management specifications and/ or requirements specifications entail a restriction, detailing and possibly a supplementation to the requirements from the quality standards demanded. The ISO 15504 is used to determine the process capability and is in fact assessing the functioning of the processes in the quality management system. Imposing the use of these quality standards gives the client a certain degree of certainty about the ability of the contractor to control its processes. It gives RWS proof about the degree of compliance with the requirements. Because of the reorganization of RWS and the accompanying system based contract control method used, RWS is forced to keep using the quality standards in the future.
Chapter 4
4 Case Study results

This chapter comprises the results of the case study research. First the verification process set-up is explored. Secondly, the verification process performance is defined based on process performance indicators. In the last section a verification process capability assessment is performed. In the case study a comparison between the case projects is made. The purpose of the case study research is to find a difference between the projects where the ISO 9001 influenced the set-up of the management system and projects where a combination of the ISO 9001 and ISO 15288 is applicable. The outcome of this chapter gives the results by which sub questions c and d can be answered.

4.1 Case study projects

Based on the project selection criteria of Table 6, three projects are chosen. The three projects are A4all, SAAone and WillemsUnie. An overview of the project characteristics can be found in Table 10.

<table>
<thead>
<tr>
<th></th>
<th>A4all</th>
<th>SAAone</th>
<th>WillemsUnie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>A4</td>
<td>A1/A6</td>
<td>Zuid-Willemsvaart</td>
</tr>
<tr>
<td>Client</td>
<td>Rijkswaterstaat</td>
<td>Rijkswaterstaat</td>
<td>Rijkswaterstaat</td>
</tr>
<tr>
<td>Location</td>
<td>Delft-Schiedam</td>
<td>Diemen-Almere Havendreef</td>
<td>'s-Hertogenbosch</td>
</tr>
<tr>
<td>Start realization</td>
<td>2012</td>
<td>2014</td>
<td>2010</td>
</tr>
<tr>
<td>Complete realization</td>
<td>2015</td>
<td>2020</td>
<td>2015</td>
</tr>
<tr>
<td>Project status</td>
<td>Realization</td>
<td>Preparation</td>
<td>Realization</td>
</tr>
<tr>
<td>Contract type</td>
<td>D&amp;C</td>
<td>DBFM</td>
<td>D&amp;C</td>
</tr>
<tr>
<td>Assessment standard</td>
<td>ISO 9001</td>
<td>ISO 9001 &amp; ISO 15504</td>
<td>ISO 9001</td>
</tr>
<tr>
<td>Contract value</td>
<td>±€860 million</td>
<td>±€1 billion</td>
<td>±€150 million</td>
</tr>
</tbody>
</table>

Table 10 Overview of project chosen and their characteristics
4.2 Results A4all (motorway A4 Delft-Schiedam)

The A4 Delft-Schiedam project encompasses the construction of 7 kilometres of motorway from Delft to the Kethelplein. The route concerns 2.6 kilometres of half deepened motorway and 1.4 kilometres of deepened motorway. Also a tunnel of 2 kilometres starts at Vlaardingen and Schiedam. After the crossing with the Kethelplein the new part of the A4 connects with the existing part of the A4 in the direction of the Beneluxtunnel and the A20 (VolkerWessels, 2013). The reasons for this project are the capacity problems of the A13, which cause accessibility problems of Rotterdam and The Hague. Cut-through traffic causes problems at the underlying road system and also livability problems at Overschie (Ministerie van Infrastructuur en Milieu, 2013). The contractor who is responsible for the execution of the project is A4all, a consortium of Boskalis, Heijmans and VolkerWessels. The project is executed under a Design & Construct contract which includes the design and realization. After the realization a maintenance period of 8 years is included for technical installations and structural works.

4.2.1 Verification process set-up

In Figure 19 an overview of the verification steps in the design process of A4all is given. The verification process consists of two activities: making a verification plan, followed by making a verification report. The verification plan is used to define how and when the requirements are met. The verification plan is confirmed with RWS. On the basis of this verification plan, the verification is performed. The compliance with the requirements is proved on basis of proof documents and can be found back in the verification report. Also a review activity is present in the verification process. The drawing up of a verification plan and report and performing a review is requested by the
requirement specification part 2 (VS2). The verification note contains the information necessary to perform the verification. The specific verification process characteristics can be extracted from the activities performed during this process. The balloons are indicating the activities which are related to verification.

![Figure 19 The verification process set-up A4all](image)

Based on the verification process the specific verification process characteristics from A4all can be defined. An overview of these characteristics is shown in Table 11. The table shows that persons which are responsible for the verification have correctly used proof documents as the basis of their verification. However the specific reference to a standard or guideline in verification reports is not always performed consequently. On A4all four review moments and working instructions are formally present in the process. The process does not contain a verification & validation action plan. When the process characteristics are linked to the quality standards, none of the process characteristics is explicitly demanded from the ISO 9001 for the set-up of the verification process.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>A4all</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of proof documents</td>
<td>190/190</td>
</tr>
<tr>
<td>Number of objective proof documents</td>
<td>29/190</td>
</tr>
<tr>
<td>Review frequency</td>
<td>4</td>
</tr>
<tr>
<td>Presence of working instructions</td>
<td>+</td>
</tr>
<tr>
<td>Presence of verification &amp; validation action plan</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 11 Verification process characteristics A4all
4.2.2 Verification process performance measurement

Based on the performance indicators defined in chapter 2 the verification process of A4all is investigated. Table 12 gives an overview of the specific performance indicators. Various verification reports are examined in order to gather the data of 190 requirements. The amount of deviations found is 0. The amount of revisions varies from 1.0 until 3.0, also 5.0 revisions are present. The average amount of processing time verification report days is 59.6 days. The range of these processing time verification report days amounts 2 until 220 days. What this information means in relation to the verification process performance can be found in the case study analysis.

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>A4all</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>62 x 1.0</td>
</tr>
<tr>
<td></td>
<td>15 x 2.0</td>
</tr>
<tr>
<td></td>
<td>93 x 3.0</td>
</tr>
<tr>
<td></td>
<td>20 x 5.0</td>
</tr>
<tr>
<td>Revisions</td>
<td></td>
</tr>
<tr>
<td>Average amount of processing time verification report days</td>
<td>59.6 days average</td>
</tr>
<tr>
<td>Range of processing time verification report days</td>
<td>2 until 220 days</td>
</tr>
<tr>
<td>Deviations</td>
<td>0/190</td>
</tr>
</tbody>
</table>

Table 12 Performance indicators A4all

4.2.3 Verification process capability assessment

Four interviews were held with professionals on A4all. Based on these interviews a capability assessment of the verification process of A4all is made. Based on the statements from the interviews an indication of the capability category is made. The interview questions of the capability assessment can be found in Appendix 3 Interview protocol Round 2. In Table 13 until Table 17 statements of the different roles in A4all (numbers 1 until 4), with accompanying capability indicators are shown. The questions are asked in order to form an image of the extent to what the capability categories are reached throughout the different levels of the organization. You could say that roles 1 and 2 are more ‘process oriented people’ (people which are used to thinking in abstract processes and were involved in the set-up of the processes in the management system), while roles 3 and 4 are more practical. Per capability category a comparison between these two types of roles is made. The comparisons can be found underneath the respective tables.
The experience during the interviews was that both the process persons and practical persons shared the same opinion about the achievement of the outcomes of the process. You could say they were both realistic about the outcome. When talking about supporting the requirements with evidence, a distinction between the roles could be found. The practical persons said they are delivering the right evidence to support the requirements, where the process persons stated this could be improved.

With respect to the systematical implementation of the verification process the opinions differ. The practical persons sometimes feel themselves excluded from the implementation of the verification process. The opinions are equally positive about the availability of resources.
In relation to the implementation of standardized processes throughout the organization no real conflicting opinions between the process- and practical person were discovered. The answers during the interviews were quite similar.

Table 15 Statements established process A4all

Table 16 Statements predictable process A4all

Again during the interviews the persons on the project shared the same opinion with respect to quantitative steering and the collection of data. Quantitative steering is to some extent present in the organization. According to all persons interviewed processes are analyzed based on the collection of data.
Referring to the capability indicators which give an indication to which extent improvement options are used, the opinions are almost all positive. No conflicting opinions between the process- and practical persons are found.
4.3 Results SAAone (motorway A1/A6 Diemen-Almere Havendreef)

The motorway extension of the A1/A6 concerns construction activities over 20 kilometres. It encompasses an expansion of 2x5 traffic lanes of the motorways A1 and A6 between the interchange of Diemen and the Hollandse Brug. From the Hollandse Brug towards the Hoge Ring near the city of Almere, the A6 is expanded to 4x2 traffic lanes. The whole route A1/A6 has two lanes of which the traffic direction can be changed. The extension is also providing a range of structural works. For instance a new bridge across the Amsterdam Rijnkanaal, an aqueduct underneath the Vecht river and extension of the Hollandse Brug (VolkerWessels, 2013).

![Figure 20 Overview A1/A6](image)

The reason for the extension of the A1/A6 route is the poor road accessibility in the Schiphol-Amsterdam-Almere area. The developments in the future, for instance the expansion of Almere with 60,000 houses between the year 2010 and 2030, are influencing the accessibility even more on the longer term (Ministerie van Infrastructuur en Milieu, 2013). The contractor who is responsible for the execution of the project is SAAone, a consortium of VolkerWessels, Boskalis, HOCHTIEF and DIF. The project is executed under a DBFM contract which includes the design, realization, finance and maintenance. The total contract period is 30 years of which 25 years comprise the maintenance of the project.
4.3.1 Verification process set-up

Figure 21 gives the verification process of SAAone. The verification process of SAAone consists also of two verification steps: making a verification plan followed by the making of a verification report. The verification report is exchanged with RWS and serves as evidence for complying with the requirements. The balloons are indicating the links with the specific parts from ISO 15288 with respect to the verification process. Notable is the presence of a review activity explicitly mentioned in the process. The set-up of the process is very much based upon the conditions of ISO 15288.

Figure 21 The verification process set-up SAAone

Based on the verification process the specific verification process characteristics of SAAone can be defined. Table 18 gives an overview of the SAAone specific verification process characteristics. The information is gathered from several verification reports. The data show that underpinning of the requirement compliance by using proof documents is good. Also the reference to objective proof documents is present. The formal review frequency on SAAone is four. Working instructions and a verification & validation action plan are present. All these characteristics are explicitly demanded for the verification process by ISO 15288. The link with what these specific characteristics mean with respect to the verification process performance can be found in Chapter 5.
4.3.2 Verification process performance measurement

Also on SAAone 190 requirements from verification reports are investigated on basis of the defined performance indicators. The amount of deviations found on SAAone is higher than the amount found on A4all. The total amounts 6 out of 190. The range with respect to revisions is less wide. 111 times a 1.0 revision and 79 a 2.0 revision is counted. The average amount of processing time days amounts 9.4 days. The range of processing time verification report days is also less wide: 0 until 114 days.

<table>
<thead>
<tr>
<th>Performance indicators</th>
<th>SAAone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revisions</td>
<td>111 x 1.0</td>
</tr>
<tr>
<td></td>
<td>79 x 2.0</td>
</tr>
<tr>
<td>Average amount of processing time days</td>
<td>9.4 days average</td>
</tr>
<tr>
<td>Range of processing time days</td>
<td>0 until 114 days</td>
</tr>
<tr>
<td>Deviations</td>
<td>6/190</td>
</tr>
</tbody>
</table>

Table 19 Performance indicators SAAone

4.3.3 Verification process capability assessment

On SAAone also four interviews with professionals with different roles in the project organization were held. In Table 20 until Table 24 the statements per capability category are evaluated. Again a comparison between process- and practical persons is made for all the capability categories. The comparisons and the notable statements are mentioned underneath the tables. From these results an analysis of the capability categories, with corresponding capability profile is made which can be found in the analysis chapter. The statements from the interviews performed on SAAone suggest that the persons on the project share the same opinion over the different layers in organization.
Table 20 Statements performed process SAAone

For capability category one for instance, all the opinions are underpinning that the outcome of the process is achieved with the current working method and requirements are supported with evidence.

Table 21 Statements managed process SAAone

The same holds for capability category 2: the opinion is positive for most of the interviewees. No contradiction between the opinions of the process- and practical persons was found. In general the viewpoints regarding the achievement of a systematical implementation of the verification process and the availability of sufficient resources are positive.
Table 22 Statements established process SAAone

Again, also for capability category 3 the statements from the interviewees are almost unanimous. They are positive about the implementation of standardized processes in the organization and the information available for performing the implementation.

Table 23 Statements predictable process SAAone

With respect to quantitative steering on the processes the opinions were not so positive. People are seeking for the right implementation of this method. The opinion with respect to the achievement of data collection for analyzing processes is mostly positive.
Table 24 Statements optimizing process SAAone

Again no real conflicting statements towards the achievement of the capability indicators of capability category 5 are seen. In general the interviewees were moderately positive about how improvement options are examined and performed.
4.4 Results WillemsUnie (Zuid-Willemsvaart ‘s-Hertogenbosch)

The project Zuid-Willemsvaart encompasses the construction of a new canal of 9 kilometres long. It concerns a branch of the Zuid-Willemsvaart, between the Maas River and Den Dungen. After the diversion of the canal, bigger ships (class IV) are able to navigate towards the container terminal in the city of Veghel. The project also realizes 8 new bridges from which the biggest span amounts 100 metres (VolkerWessels, 2013). The goal of the project is to solve the transport- and accessibility problems on the water between ‘s-Hertogenbosch and Veghel. Bigger ships are not forced anymore to navigate through the city center of ‘s-Hertogenbosch, which reduces the amount of cars waiting for open bridges (Ministerie van Infrastructuur en Milieu, 2013). The contractor of the project is WillemsUnie, which is a cooperation between VolkerWessels, GMB Civiel and Van den Herik Kust- en oeverwerken. The project is executed under a Design & Construct contract which includes the design and realization of the project. No maintenance activities are defined.

4.4.1 Verification process set-up

The verification process set-up of the WillemsUnie is the simplest version compared to the verification processes of the other case studies. Figure 23 gives an overview of the verification process and shows the two verification steps: the making of a verification plan followed by the making of a verification report. Also a review activity is included. The drawing up of a verification plan and –report and performing a review is requested by the requirement specification part 2.

Figure 22 Overview Zuid-Willemsvaart from (Ministerie van Infrastructuur en Milieu, 2013)
(VS2). The balloons highlight the activities in relation to performing verification. The output of the process is again a verification report, in which compliance with the requirements is demonstrated with proof documents. Based on the set-up of the verification process, information about the specific verification process characteristics was gathered.

For WillemsUnie again several verification reports were investigated to gather the information from 190 requirements. Proof documents are enclosed with the verification of requirements. A reference to an objective proof document is supplied for two requirements. The formal review frequency of three is lower than on A4all and SAAone. Also working instructions and a verification & validation action plan are not formally present in the verification process of WillemsUnie. All of these characteristics are not explicitly demanded for the verification process from the ISO 9001 quality standard. An overview of the process characteristics can be found in Table 25.
4.4.2 Verification process performance measurement

Various verification reports were investigated in order to obtain the information about the verification of 190 requirements. Table 26 gives an overview of the performance indicators of the WillemsUnie. The amount of deviations on the WillemsUnie is the highest compared to the other two case study projects; in total 11 deviations occur. The amount of revisions ranges from 1.0 until 4.0 with the exception of two times 7.0 revisions. The average amount of processing time verification report days and the accompanying range is also the highest of the three projects. A 92.7 days average with a range of 1 until 569 days was found.

<table>
<thead>
<tr>
<th>Performance indicators</th>
<th>WillemsUnie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revisions</td>
<td></td>
</tr>
<tr>
<td>48 x 1.0</td>
<td></td>
</tr>
<tr>
<td>63 x 2.0</td>
<td></td>
</tr>
<tr>
<td>45 x 3.0</td>
<td></td>
</tr>
<tr>
<td>32 x 4.0</td>
<td></td>
</tr>
<tr>
<td>2 x 7.0</td>
<td></td>
</tr>
<tr>
<td>Average amount of processing time days</td>
<td>92.7 days average</td>
</tr>
<tr>
<td>Range of processing time days</td>
<td>1 until 569 days</td>
</tr>
<tr>
<td>Deviations</td>
<td>11/190</td>
</tr>
</tbody>
</table>

Table 26 Verification process performance indicators

4.4.3 Verification process capability assessment

Just like on the other two case projects four interviews with professionals were held. In Table 27 until Table 31 the statements with respect to the achievement of the capability indicators can be found. Also for WillemsUnie a comparison between the process- and practical persons was made. The descriptions per capability category can be found underneath the corresponding tables. The first impression of the interviews on WillemsUnie is that persons on the project were seeking for the right approach to the subject of verification. Most of the people were uncertain about the topic.
The people interviewed on the project were quite positive about the achievement of the intended outcome of the process. However confusion about the approach with respect to the supporting of requirements with proof documents was present. The total achievement of capability category one is therefore weak.

The opinions about the implementation of the verification process are similar, but not positive. About the availability of sufficient resources, a contradiction in opinion is present. The design leader is thinking sufficient resources are available; however the designer is thinking the opposite.
Concerning the implementation of standardized processes and the implementation of these processes no contradictions between opinions are present. They agree on the way the standardized processes are implemented and information is supplied. The total achievement of capability category three is positive.

Table 29 Statements established process WillemsUnie

With respect to qualitative steering the opinions are the same. No or little quantitative steering is performed on the processes. There is difference however in the opinions regarding the data collection for analyzing processes. The process people think it happens, but the practical people say it is not happening.

Table 30 Statements predictable process WillemsUnie
With respect to continuous improvement the opinions are in general the same about the approach. Most of the interviewees are positive about how improvement options are investigated and executed. However some of the process persons interviewed are a bit stoical about the real added value of examining and communicating the improvement options.
4.5 Conclusion

From the previous sections it can be concluded that the set-up of the verification processes on the different case study projects are quite similar. A cut down version of the verification processes in the definitive design phase is drawn up, based on the management plans and management systems. On all three of the projects the verification steps are 1) the making of a verification plan followed by 2) the making of a verification report. For these two steps the verification processes are the same. The differences in processes can be found in the subtle distinctions, like the presence of working instructions and verification and validation action plans and the amount of review rounds. Also the amount of references to objective proof documents differs per projects. With respect to the verification performance measurement, the results of the verification of 190 requirements per case study project are given. An overview of the values of these performance indicators can be found in Table 34 on page 89. On all the three projects differences in the values are found. None of the projects scores the same on the performance indicators. The results of the verification process performance capability assessment, gives the impression that the opinions of the interviewees are divided between the projects but also between the persons on the projects self. The further analysis of the results can be found in the next chapter.
Chapter 5
5 Case study analysis

In this chapter the results from the case study are analyzed. The three case study projects are compared with each other. The analysis follows the three steps as defined in the methodology. In every step the case study projects are compared on a quantitative and qualitative basis. The outcome of this chapter shows what the results of the case study contribute to answering the main research question.

5.1 Verification process set-up

In this section the verification processes of the case study projects are investigated. Figure 19 on page 67, Figure 21 on page 73 and Figure 23 on page 79 provide overviews of the verification process flows. The process flows are based upon the project information as supplied by the project organizations. With this information the verification processes can be compared. All three processes have the same goal regarding the outcome. The process should result in a proof (verification) that the design requirements are fulfilled. The processes run through quite similar processes to achieve this. In all projects the first step is to make a verification plan, followed by making a verification report. The processes are compared on content and in- and output. The process characteristics can directly be linked to prescriptions from ISO 9001 and ISO 15288. Table 32 gives an overview of the characteristics and the (theoretical) relation with the process performance indicators. Also a clear distinction between the characteristics demanded by ISO 9001 and ISO 15288 for the verification process can be found. This provides insight in the specific characteristics which are explicitly demanded by the quality standards for the verification process.

From the process flows of the verification processes you can conclude that there are differences in the set-up of the verification processes. The design of the SAAone process is clearly based on the requirements of ISO 15288, resulting in a relatively complex process compared to the other processes. From the processes of A4all and the WillemsUnie we can conclude that only guidance from the ISO 9001 was not sufficient to establish the verification process. On A4all and WillemsUnie, RWS made the verification process requirements more specific by demanding extra requirement specifications (VS2) for the verification process.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
<th>Goal/relation</th>
<th>Explicitly in verification process</th>
<th>Explicitly in verification process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of proof document</td>
<td>When requirements are supported with proof documents, it gives confidence about the fact that the requirements which are completed are legitimate.</td>
<td>Reducing number of revisions necessary</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of objective proof documents</td>
<td>When completed requirements are supported with objective proof document (explicit reference to a standard and/or guideline in the verification report) it gives confidence about the requirements which are completed are legitimate and based on a known method.</td>
<td>Reducing number of revisions necessary</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Review frequency</td>
<td>Reviews during the process are used the check the status of the process. It indicates the current status and also gives an indication of where the process will end up when hold on to this approach (Kerzner, 2009). Reviews are used for checking and maintaining the level of quality and improving this.</td>
<td>Increase the amount of non-conformities discovered; decrease the amount of deviations and revisions at the end of the process.</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Presence of working instructions</td>
<td>The presence of working instructions provides certain degree of standardization in the method of working. The standardization of how the tasks are performed by different employees stimulates the effective and timely decision making. An unambiguous approach with respect to the goals and objectives makes it easier for the involved employees to achieve these (Kerzner, 2009).</td>
<td>Reduces the amount and range of processing time verification report days</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Presence of verification &amp; validation plan</td>
<td>A systematic approach with as input a functional plan like a verification &amp; validation plan will give the involved employees the information about what is involved with the process. It gives an overview of the structure, responsibilities and with what action the process is started. It should provide in a consistent and economical approach (Kerzner, 2009).</td>
<td>Reduces the amount and range of processing time verification report days</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 32 Process characteristics and their theoretical relation towards the process performance indicators
5.1.1 Verification process characteristics

Table 33 provides an overview of the verification process characteristics. For 190 requirements information with respect to the reference to (objective) proof documents is demonstrated. The review frequency, the presence of the working instructions and the presence of a verification and validation plan are based on the formal presence (explicitly mentioned in management plans or on the process). When comparing the characteristics of the three projects it can be identified that on all three the projects the number of proof documents amounts 190 out of 190. This suggests that all the requirements are founded with evidence. When a look further is taken a difference between the amounts of objective proof documents is found. This suggest that the projects with the lowest amount of objective proof documents, like A4all, do give the least confidence about that the requirements which are completed are legitimate and based on a known method. Compared to A4all and SAAone, WillemsUnie have a lower review frequency and no formal presence of working instructions. The review frequency gives an indication about how many times a review is formally done and working instructions provides a certain degree of standardization in the method of working. SAAone distinguish itself by the presence of verification and validation action plan, the plan gives an overview of the structure, responsibilities and with what action the process is started. The characteristics and their influence on the verification process performance are evaluated in section 5.2.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>A4all</th>
<th>SAAone</th>
<th>WillemsUnie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of proof documents</td>
<td>190/190</td>
<td>190/190</td>
<td>190/190</td>
</tr>
<tr>
<td>Number of objective proof documents</td>
<td>29/100</td>
<td>155/100</td>
<td>2/100</td>
</tr>
<tr>
<td>Review frequency</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Presence of working instructions</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Presence of verification &amp; validation action plan</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 33 Overview verification process characteristics
5.2 Verification process performance measurement

This section is continuing on the verification process set-up. First the projects are compared on basis of their scores on the performance indicators. Next, the specific characteristics from the verification processes are linked to the performance indicators of the projects. The information from Table 32 and Table 34 are together used to state conclusions with respects to the influence of quality standards on the verification process performance.

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>A4all</th>
<th>SAAone</th>
<th>WillemsUnie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revisions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>62 x 1.0</td>
<td>111 x 1.0</td>
<td>48 x 1.0</td>
<td></td>
</tr>
<tr>
<td>15 x 2.0</td>
<td>79 x 2.0</td>
<td>63 x 2.0</td>
<td></td>
</tr>
<tr>
<td>93 x 3.0</td>
<td></td>
<td>45 x 3.0</td>
<td></td>
</tr>
<tr>
<td>20 x 5.0</td>
<td></td>
<td>32 x 4.0</td>
<td></td>
</tr>
<tr>
<td>48 x 1.0</td>
<td></td>
<td>2 x 7.0</td>
<td></td>
</tr>
<tr>
<td>Average amount of processing time verification report days</td>
<td>59.6 days average</td>
<td>9.4 days average</td>
<td>92.7 days average</td>
</tr>
<tr>
<td>Range of processing time verification report days</td>
<td>2 until 220 days</td>
<td>0 until 114 days</td>
<td>1 until 569 days</td>
</tr>
<tr>
<td>Deviations</td>
<td>0/190</td>
<td>6/190</td>
<td>11/190</td>
</tr>
</tbody>
</table>

Table 34 Performance indicators of case study projects overview

5.2.1 Analyzing the performance indicators

The values of the performance indicators in Table 34 are elaborated. Per performance indicator the value and the respective influence on the process performance is explained. The basis of this analysis is the assumptions made in the Methodology chapter. An overview can be found in Table 8 on page 41. A 1.0 revision implies that the working package responsible is directly satisfied with the way the registration of the requirements is objectively demonstrated (aangetoond). It is assumed that the working package responsible is well-known with the requirements which RWS demands for the objective demonstration of fulfilling requirements. For instance, when a 2.0 revision is necessary this means the requirement is not satisfied directly and needs to be revised. When the amount of revisions is lower on a project with the ISO 15288 this suggest that the use of the ISO 15288 has a positive influence on the verification process performance because the objective demonstration is accomplished better. SAAone has the most 1.0 revisions and therefore scores best on this performance indicator. The average amount of processing time verification report days says something about the functioning of the verification process. Because a
combination of the ISO 15288 and the ISO 15504 (which assesses the functioning of processes) is applied the functioning needs to be tested. The average amount days of processing time verification report days gives an indication of the influence of the ISO 15504 on the functioning of the verification process. When the average amount of days is lower on the project with the ISO 15288+15504 this suggests that the use of the ISO 15504 has a positive influence on the verification process performance. The results show that this is the case with SAAOne. The range of processing time verification report days gives insight if a combination of the ISO 15288 and ISO 15504 has a positive influence on the functioning of the verification process. When the range of processing time verification report days is smaller on a project with the ISO 15288+15504 this implies that the ISO 15504 indeed has a positive influence on the functioning of processes and therefore on verification process performance. The results show that also SAAOne scores the best on this indicator. The *review* characteristic of the verification process, which is demanded by the ISO 15288 has the goal of finding non-conformities. In an ideal situation a *deviation* should possibly result in a non-conformity found. In this case a deviation found, is an indication for the amount of non-conformities. This is the reason why the deviations are a possible extra performance indicator. The weakness of this performance indicator is that the relation between non-conformities and *deviations* is not measurable. It is difficult to say if the amount of deviations says something about the amount of requirements met and therefore about the influence of the review characteristic on the verification process performance. If you assume that the amount of deviations says something about the amount of requirements met, A4All scores the best on this performance indicator.

5.2.2 Linking the process characteristics

In theory, certain process characteristics relations are assumed to be relating to performance indicators. From these relations the influence of the quality standards can be defined. For this step it is important to keep in mind that the characteristics are related only to the verification process specifically. No distinction can be made between the influences of the amount of *proof documents* available on the projects. This is because the amount of proof documents is equal for all projects. In the project there can be a difference found in the amount of *objective proof documents* per project. From theory it can be stated that a larger amount of references to objective proof documents should result in a reduction of the amount of revisions necessary. For SAAOne this is the case, for A4All there is also a better score on *revisions* compared to WillemsUnie, where the least references to objective proof documents are made. From theory a higher *review frequency*
implies a reduction of the amount of revisions and deviations. The review frequency of A4all and SAAone is higher than on WillemsUnie. Also fewer deviations are found on A4all and SAAone compared to the WillemsUnie. It is not possible to make a distinction between A4all and SAAone on this topic because the characteristics are the same. The review frequency has a positive impact on the revisions necessary for SAAone, also A4all scores better on the revisions performance indicator compared to WillemsUnie where a lower review frequency is applied. In theory the presence of working instructions should reduce the average and range of processing time verification report days. On A4all and SAAone where working instructions are implicitly part of the verification process the average and range of processing time verification report days are lower than on the WillemsUnie. The presence of also a verification and validation action plan explicitly in the process provides lower scores on the average and range of processing time verification report days, compared to A4all and WillemsUnie where this is not present.

5.2.3 Relationship between performance indicators

Not only relations between process characteristics and performance indicators can be assumed. Although it does not serve the main goal of the research, the potential relationships are still worth mentioning. A relationship between the performance indicators deviations and revisions in relation to the average and range of processing time verification report days could be assumed. It is important to realize that writing a control measure or revising a verification report involves time. When evaluating SAAone, reporting deviations does not involve more processing time verification report days or a wider range of processing time verification report days compared to A4all where no deviations are found. No unambiguous relation can be found for this because on WillemsUnie more deviations are found and the average and range are higher. For the relation between the amount of revisions necessary and the average and range of processing time verification report days it can be stated that for SAAone less revisions necessary means a lower range and average on processing time verification report days. The same applies for A4all and the. An overview of the relationships between the process characteristics and the performance indicators can be found in Figure 26.
5.3 Verification process capability assessment

In this section the results from the capability assessment are analyzed. Based on the 12 semi-structured interviews which were held on the three projects, a capability assessment is performed which give an indication about the functioning of the verification processes on the projects. The capability of the verification process is an indicator if the verification process is implemented correctly and tests how the processes are working within the organization. The statements from the interviewees are interpreted by the researcher according to the scale in Figure 24. The following rating is used: Not achieved (0 to 15% achievement), to some extent achieved (15% to 50% achievement), to large extent achieved (50% to 85% achievement) and completely achieved (85% to 100% achievement). Since the results of the process capability indicators can be different and potentially conflicting per person interviewed, the total achievement is determined by middling the scores of the outcomes of the sub achievements. The outcomes of the sub achievements are based on the statements from the persons interviewed. The elaboration per category is done after Figure 25. The results of this analysis can be found in Figure 25. Based on this, capability profiles are made. An overview of the capability profile can be found in Figure 27.

5.3.1 Interpretation of the capability assessment

The capability assessment analysis is based upon the capability categories and the process assessment model principle of which an overview can be found in Figure 13. Compared with a genuine capability assessment this specific capability assessment for the verification process is more in-depth. The verification process as currently implemented on the projects is investigated. The depth is created by interviewing not only the process responsible persons, but also the lower layers in the organization by interviewing persons who in practice are confronted with the verification process. In this way a clear overall picture of the organization is obtained. In the previous chapter the results of the analysis are already introduced, in the following section the different capability categories are compared per project.
Figure 25 Capability assessment analysis results
**Category 1 Performed process**

Category one can be seen as the basis of the capability assessment; it gives an indication about how the verification processes of the projects are able to produce the required outcomes. The assessment shows to which extent the verification process achieves its purpose. The information from the interviews shows that the outcomes of the verification process of SAAone completely achieve its purposes. The outcome of the verification process of A4all is achieving its purpose to a large extent. WillemsUnie is achieving its process outcome to some extent. These results suggest that the verification process where ISO 15288 is demanded completely achieves its purposes. For the projects with less ISO 15288 characteristics it suggests that the purpose of the outcome is achieved less. On SAAone and WillemsUnie the interviewees are unanimous with regard to their statements. On A4all lower achievement seems to be caused by internal (communication) problems between the process people and the practical people. On the one hand the practical people are thinking they are performing the verification of the requirements in the right way, on the other hand it is stated that RWS is not accepting this way of verification.

**Category 2 Managed process**

Category two is the first category which gives an indication of how the organizations are able to manage the verification processes. For category two specific, the emphasis lies on the ability of the organizations to control and maintain the process. When you look at the outcome of the assessment the results suggest that SAAone, the project with the most ISO 15288 characteristics, completely is able to manage the verification process. This implies that SAAone is fully able to control and maintain the process. The other two projects are achieving this to a large extent. It can be concluded that on both A4all and WillemsUnie, which are achieving to a lower extent than SAAone, conflicting statements between the process persons and practical persons can be detected. At A4all the designers state that they are not involved in the implementation of processes and therefore are not able to control the process. The usefulness and necessity of verification is unknown. For WillemsUnie something similar is happening: the designers are complaining that the design leaders are not providing the right resources to perform verification.

**Category 3 Established process**

Category 3 gives an indication about how the process is defined and used throughout the organization. The results suggest that all three the project completely achieve that the process is defined and used throughout the organization. The verification processes on all three the projects
are considered established. This implies that the verification process is known for everybody in the organization. This fact is underpinned by the interviews. The interviewees state that the verification process is known and defined well throughout the whole organization. There are no conflicting statements found between the statements from the interviews. The results suggest that for completely achieving an established process it does not matter which ISO standard is used.

**Category 4 Predictable process**

Category four gives insight whether the process is executed consistently within its defined limits. Checks on quantitative steering and data collection are performed. The results suggest that WillemsUnie, the project with the least ISO 15288 characteristics to some extent achieves that the verification process is executed within its defined limits. It also suggests that the projects with more ISO 15288 to a large extent achieve this. There can be made no difference between SAAone and A4all. A lower achievement is accompanied with conflicting statements between design leaders and the designers. In this case design leaders state that designers are audited in order to collect data. The designers, however, say that in practice this does not happen.

**Category 5 Optimizing process**

Category five checks to which extent continuous improvement is performed in order to reach the current business goals. Results suggest that A4all, the project with some ISO 15288 characteristics, completely achieves on continuously improving itself in order to be sure of reaching its goals. SAAone and WillemsUnie are achieving this to a large extent, for WillemsUnie it involves conflicting statements. This time the conflict is about the usefulness of the outcomes from the continuous improvement approach.
5.4 Conclusion

From the analysis some conclusions can be drawn. In the case study three steps are followed and on the basis of these three steps the conclusions are presented.

5.4.1 Conclusion verification process set-up

From the process flows of the verification processes you can conclude that there are differences in the set-up of the verification processes. The design of the SAAnone process is very much based on the requirements of ISO 15288, which results in a relatively complex process compared to the other processes. From the processes of A4all and WillemsUnie we can conclude that only guidance from ISO 9001 was not sufficient for establishing the verification process. The specific steps with respect to the verification plan, verification report and review are requested from the requirement specification (VS2) of RWS. It is also noticed that the verification process of A4all has some ISO 15288 characteristics more than WillemsUnie (more objective proof documents, higher review frequency, presence of working instructions).

5.4.2 Conclusion verification process performance measurement

Since the amount of revisions is lower on a project with the ISO 15288 this suggest that the use of the ISO 15288 has a positive influence on the verification process performance because the objective demonstration is accomplished better. Also the average amount of days is lower on the project with the ISO 15288 and ISO 15504, this suggests that the use of the ISO 15504 has a positive influence on the verification process performance. The range of processing time days is smaller on a project with the ISO 15288 and ISO 15504 this implies that the ISO 15504 indeed has a positive influence on the functioning of processes and therefore on verification process performance. However it is difficult to say that fewer deviations found means that less non-conformities are found and therefore more requirements are met, this result can be seen as an indication that the review characteristic has a positive influence on the satisfaction of requirements.

The causal relationship diagram in Figure 26 provides an indication of the potential relations found between the factors which are relevant for the process performance measurement.
In Figure 26 the green circles are the process characteristics following from the quality standards. The blue circles are the verification process performance indicators. A plus symbol indicates a positive causal relation; a minus sign indicates a negative causal relation. In this case a combination of a plus- and minus sign means an unknown causal relation. The relations found in practice are underpinning the relations as indicated in theory and therefore are considered as plausible.

5.4.3 Conclusion verification process capability assessment

With the outcome of this analysis it is independently decided on which case project the verification process is implemented the most correct. Figure 27 gives an overview of the capability profile of the verification processes of the projects. For every organization a difference between the extent to which a category needs to be achieved can be defined. The results suggest that if an organization wants a full achievement of the categories 1 to 3, the choice for an ISO 15288 set-up of the management system is preferred. The verification process of SAAone is completely performed, managed and established (the verification process is able to produce the required outcome, the organization is able to control and maintain the verification process and the verification is well-known within the whole organization). The results suggest that a complete achievement of the established process characteristics (category 3) can also be achieved by using an ISO 9001
verification process set-up. With respect to the consequent execution and quantitative steering on the verification process (category 4), verification processes with ISO 15288 characteristics are achieving the related characteristics more. If an organization would like to focus on continuous improvement characteristics (category 5) of the process, the process set-up according to the ISO 15288 is not preferred. The results suggest that an ISO 9001 set-up scores the same or even better. A better result is achieved with an ISO 9001 set-up combined with some ISO 15288 aspects.

Figure 27 Capability profile of verification process case study projects

It must be mentioned that projects score better on their capability categories when there are no conflicting statements with respect to the state of affairs within the organization. A good communication between the different layers of the organization is a must for a good verification process capability score. The following conflicts, which could negatively influence verification process performance, are found:

- The conditions for verification set by RWS are not exactly known by the people who are involved with the verification process.
- The designers are not involved in setting up the verification process and therefore do not feel encouraged to work in accordance with it.
- There is miscommunication about the usefulness and necessity of verification and the need of implementing improvements with regard to this process.
Chapter 6
6 Discussion

In this chapter the results from the research are discussed, insight in the validity and reliability of the results is given. To obtain these insights, the research methodology is evaluated on its strength and weaknesses. Secondly, the limitations of the research are mentioned. Finally, the results are evaluated and put into a broader perspective.

6.1 Discussing the research methodology

In literature there are various opinions about the use of case study research in scientific research. In this research three cases were investigated. The results of the case study are based on a combination of quantitative and qualitative research methods. Researchers tend to focus on just one of the two research methods. However, Flyvberg (2006) states: ‘more often than not, a combination of qualitative and quantitative methods will do the tasks best. Fortunately, there seems currently to be a general relaxation in the old and unproductive separation of qualitative and quantitative methods’. Part of the results is based on interviews performed with professionals on projects. A case study protocol is formulated with the accompanying measures to improve the objectiveness of the interviews. For instance the transcriptions of the interviews are confirmed with the interviewees to guarantee they support the statements used in this thesis. However the interpretation of the results is still done by the researcher. The influence of the researcher’s perspective on the interpretation of the data cannot by excluded in this research. Another frequently heard weakness of case study research is that the validity of the results for external use is disputable because of the low amount of cases. It becomes more difficult to apply the results to a broader population or interest (Verschuren & Doorewaard, 2010). For the quantitative research information from 190 requirements was analyzed. Although these are not all the requirements of the projects, it is considered as a good indication about the state of affairs because a case study research is perfect for obtaining a general picture, is flexible in its execution and has a high probability of acceptance in the field because of the closer role of the researcher (Verschuren & Doorewaard, 2010). Flyvberg (2006) is nuancing this statement by saying: ‘One can often generalize on the basis of a single case, and the case study may be central to scientific development via generalization as supplement or alternative to other methods. But formal generalization is overvalued as a source of scientific development, whereas ‘the force of example’ is underestimated.’ The results from this case study contribute to the scientific development because in-depth information on the subject is gathered. Of course the case study is useful for
generating hypotheses and testing them, but is not limited to these research activities alone (Flyvberg, 2006). Case studies can be conducted with many different motives, these motives can vary from the presentation of individual cases to the motive to arrive at broad generalizations (Yin, 2009). In this case the motive is not to arrive at broad generalizations but presenting the information from the case studies separately and comparing them.

6.2 Limitations of the research

In this research assumptions are made with respect to certain factors which could be of possible influence on the result of this case study research. This section is aimed at nuancing the results of the research. First, the basic assumptions are mentioned; next the performance indicators for defining the verification process performance are elaborated. Finally the verification process capability assessment is evaluated.

6.2.1 Basic assumptions

The use of ISO 15288 should in theory result in the following advantages compared to ISO 9001 (Werkgroep Leidraad Systems Engineering, 2013):

- Reducing failing costs

Failing costs in the construction sector are caused by: inefficient progress of the construction process, not complying with the agreed quality requirements of the end product and repairing or replacing things (Brokelman, L & Vermande, H, 2005). This advantage coheres with the ‘first-time-right’ principle. When you think carefully about everything beforehand you should prevent problems later in the process. When you build first-time-right it prevents having to perform your work again. Performing work again is accompanied with extra time and money spends.

- Better customer satisfaction

Meet the demands and wishes of the customer. In this case the requirements need to be satisfied in a demonstrable and controlled way. A demonstrable way means that the verification of the requirements needs to be founded with evidence. A controlled way implies a process which is performed with the least waste of time, effort and within a desired range. The desired range is defined by the customer.
6.2.2 Verification process characteristics

Earlier in the thesis specific characteristics of the verification process were selected. In this section the characteristics are elaborated and their potential flaws are mentioned.

- Number of proof documents

For every requirement it is checked if a reference to a proof document is added to the verification report. This reference serves as substantiation of the verification. The reference serves as an indication that the verification is completed legitimate. Adding proof documents contributes to the demonstrability of the verification process. A reference to a proof document does not say anything about the quality of the document and if the content of this proof document is correct for substantiating the verification. The reliability of this characteristic can be improved by not only checking the reference but also checking the content of the proof documents in future research.

- Number of objective proof documents

For every requirement it is checked if a reference to an objective proof document is added to the verification report. In this case explicit references to a standard and/or guideline are counted. These references serve as an indication that the requirements are completed legitimate and based on a known method. The reference itself does not say however that the design is actually performed according to this standard. It is not a guarantee but it gives some confidence about the possible method used. The reliability of this characteristic can be improved by not only checking the reference but also checking the content of the proof documents in future research.

- Review frequency

Reviews are used for checking and maintaining the category of quality and improving this. The information about the review frequency is gathered from project documents. It gives an indication about how many times a review is formally done. It does not guarantee however that in practice these amounts of reviews are performed. The frequency can be higher or lower. The reliability of this characteristic can be improved by checking the review frequency in future research with employees who are performing these reviews.
- Presence of working instructions

The presence of working instructions provides a certain degree of standardization in the method of working. The information about the presence of working instructions is gathered from project documents. Therefore it just gives an indication that working instructions are formally present, but it is not a guarantee. It also does not say anything about the quality of the content of the working instructions. If they are present it again does not mean that the working instructions are used in practice. The reliability of this characteristic can be improved in future research by checking the content, quality and use of the working instructions with the employees on the projects.

- Presence of verification & validation plan

A verification & validation plan gives the involved employees the information about the verification process. It gives an overview of the structure, responsibilities and with what action the process is started. The presence of a verification & validation plan does not give the guarantee that employees in practice actually are using the information from this plan to perform their tasks in the verification process. The presence of the plan does not give any information about the quality of this plan. The reliability of this characteristic can be improved in future research by checking the content, quality and use of the verification & validation plan with the employees on the projects.

6.2.3 Verification process performance measurement

In this section the verification process performance measurement is evaluated.

Source of information

In this research step information from verification reports of the three projects is taken. The reasons of using the information from the verification reports are:

- The verification report is the output of the verification process and contains the registration with respect to the verification process.
- The verification report gives insight in the registration process, which is an important aspect of verification.
- It gives insight in the fact whether the projects are complying with the requirements.
- Comparable verification reports are used on all three the projects.
Description of the performance indicators

In this section an elaboration of the chosen performance indicators is given. The performance indicators are chosen in such a way that they give insight in the possible failure costs and customer satisfaction. Earlier in the research assumptions about the interpretation of the performance indicators was done. In the following section the performance indicators are described and evaluated on their added value in relation to the main research question.

- **Revisions**

**Assumption:**

It is assumed that this indicator measures that the performance of the verification process is better when the amount of revisions is low.

**Description and limitations:**

- A 1.0 revision implies that the working package responsible is directly satisfied with the way the registration of the requirements is objectively demonstrated (aangetoond). It is assumed that the working package responsible is well-known with the requirements which RWS demands for the objective demonstration of fulfilling requirements. For instance, when a 2.0 revision is necessary this means the requirement is not satisfied directly and needs to be revised. When the amount of revisions is lower on a project with the ISO 15288 this suggest that the use of the ISO 15288 has a positive influence on the verification process performance because the objective demonstration is accomplished better.

- In this case the amount of revisions is an indication that the current results of the process do not comply with the requirements of RWS and needs to be revised.

- It is not sure if RWS is actually is satisfied with the way the 1.0 revision is performed.

- It is also possible that the requirement is satisfied in practice but it is not registered in the right way.

- The criteria used for scaling up a revision version are unknown. It is for instance possible that before the formal revision version is defined some other revising steps are performed without upgrading the revision version.
• A revision can also be necessary when an external factor causes a change in process input. This research tries to minimize the impact of this weakness by using requirements from the definitive design phase. In the definitive design phase all the elementary requirements are defined and also the interfaces with other disciplines are already coordinated.

*Link with influence on process performance:*

When the amount of revisions is low this suggests that according to the first-time-right principle less extra work needs to be performed because the registration of the requirements is performed more efficient. A higher amount of revisions necessary means a worse customer satisfaction and possible higher failing costs because of the extra work performed.

*Improvement of reliability:*

The reliability of this performance indicator can be improved by defining the criteria for scaling up the revision number on the projects. The external influences which cause revisions can be investigated.

• **Average amount of processing verification report time days**

*Assumption:*

It is assumed that this indicator measures that the performance of the verification process is better when the average amount of processing time verification report days is low.

*Description and limitations:*

• This performance indicator says something about the functioning of the verification process. Because a combination of the ISO 15288 and the ISO 15504 (which assesses the functioning of processes) is applied the functioning needs to be tested. The average amount days of processing time verification report days gives an indication of the influence of the ISO 15504 on the functioning of the verification process. When the average amount of days is lower on the project with the ISO 15288+15504 this suggests that the application of the ISO 15504 has a positive influence on the verification process performance.
In this case it is assumed that a lower average amount of processing time days implies that less time is spend on performing extra work.

The average amount of processing time verification report days gives insight in the time necessary to fill in the verification report from the person responsible for the verification to the authorization by the design leader (the person responsible for the work package).

By comparing the average amount of processing time verification report days between the case study projects you can say something about the duration of the registration processes.

The indicator says only something about the second step of the verification, the time spend on filling out and completing the verification report. It does not say anything about the time spend on the other step of verification, making a verification plan.

It is not known if the verification report is directly filled in when this is possible. The amount of days is dependent on the working method of the work package responsible.

A lower average amount of processing time verification report days does not guarantee that the quality of the verification performed is good.

Link with influence on process performance:

When the average amount of processing time verification report days is low this suggest that the process is performed with the least waste of time and less extra work is spend which suggests lower failing costs.

Improvement of reliability:

The reliability of this performance indicator can be improved by investigating in future research how much of the processing time days actually is spend on performing extra work. Also the processing time of all the activities in the verification process can be measured to improve the insight in the whole process.

- Range of processing verification report time days

Assumption:

It is assumed that this indicator measures that the performance of the verification process is better when the range of the processing time verification report days is smaller.

Description and limitations:
• This performance indicator gives insight if a combination of the ISO 15288 and ISO 15504 has a positive influence on the functioning of the verification process. When the range of processing time verification report days is smaller on a project with the ISO 15288+15504 this implies that the ISO 15504 indeed has a positive influence on the functioning of processes and therefore on verification process performance.

• In this case it is assumed that a smaller range of processing time days is an indication of better process control. Because less time is necessary for performing extra work less failure costs are suggested.

• The range of processing time verification report days gives insight in the time which is minimal and maximal necessary to fill in the verification report from the person responsible for the verification to the authorization by the design leader (the person responsible for the work package).

• A range with a higher maximum implies that for some of the requirements more time is necessary for a successful verification registration. More time spent on the registration is an indication of extra work performed.

• It is not known if the verification report is directly filled in when this is possible. The amount of days is dependent on the working method of the work package responsible.

• The indicator says only something about the second step of the verification, the time spent on filling out and completing the verification report. It does not say anything about the time spent on the other step of verification, making a verification plan.

• A smaller range of processing time verification report days does not guarantee a better verification quality.

• A broader range of processing time verification report days does not imply that all the requirements do cost more time.

• For projects with a broader range you have to take into account the possibility of an outlying amount of days spent on the verification registration process. This possibly has influence on planning and scheduling activities.

Link with influence on process performance:

When the range of processing time verification report days is small this suggests that the process is performed with the least waste of time, better process control and therefore better customer satisfaction and less failure costs.
Improvement of reliability:

The reliability of this process performance indicator can be improved with investigating in future research which factors influences the longer processing time verification report days. Also the actual amount of days actual is spend on extra work can be checked by the employees. Check the total time spends on all verification activities.

Possible extra performance indicator

- Deviations

Assumption:

It is assumed that this indicator measures that the performance of the verification process is better when the amount of deviations is low.

Description and limitations:

- The review characteristic of the verification process, which is demanded by the ISO 15288 has the goal of finding non-conformities. In an ideal situation a deviation should possibly result in a non-conformity found. In this case a deviation found, is an indication for the amount of non-conformities. The weakness of this performance indicator is that the relation between non-conformities and deviations is not measurable. It is difficult to say if the amount of deviations says something about the amount of requirements met and therefor about the influence of the review characteristic on the verification process performance.
- In this case the deviation is a deviation which is written when the contractor deviates from one of the 190 requirements or otherwise is not able to comply with the contents of the agreement with RWS, which the contractor in first instance could have complied with. The deviation is internally detected and concerns the design discipline within the organization.
- In practice there are also other kinds of deviations possible: deviations for the realization disciplines, improvement proposals, modification proposals, possible shortcoming and deviations detected by an internal and/or external audit.
- It is assumed but not known if all the deviations found are caused by verification activities.
- In this case the deviations which are measured are an indication of how many times the responsible persons actually registered a deviation. It is possible that a part of the total amount
of deviations found is internally solved without writing a formal deviation. The conditions for registering a deviation are unknown.

- When deviations are adequately handled of product conformity is still possible.
- In practice a deviation is accompanied with a control measure which is eliminating the non-conformity. It is a corrective measure to improve the quality. However writing a deviation is not a guarantee that the corrective action is taken.
- In this case it is assumed that the amount of deviations in this case gives an indication about how much non-conformities there are on the process. More non-conformities mean that less requirements are satisfied and therefore the performance of the process is worse when more deviations are found.

*Link with influence on process performance:*

A lower amount of deviations suggests a better customer satisfaction because the main prerequisite of a good customer satisfaction is that the requirements are met. A deviation suggests that this is not the case.

*Improvement of reliability:*

The reliability of this performance indicator can be improved by checking the conditions for registering a deviation with the employees on the projects. Also the internally solved and the other deviations types can be counted. Check what happens with the deviation after the registration. Also check if the deviation is detected by verification activities.

6.2.4 Verification process capability assessment

With the verification process capability assessment the verification process is tested on its maturity and functioning. This assessment can also be used to test if the verification process is implemented correctly. By assessing the process regularly the organization generates information to grow to the preferred maturity category.

*Source of information*

- A self-designed capability assessment is performed on the projects. 4 interviews are performed in line with the ISO 15504. The verification processes are assessed on specific characteristics subdivided in 5 categories:
Category 1: gives insight if the verification process is able to produce the required outcome.
Category 2: gives insight in the organization is able to control and maintain the verification process.
Category 3: gives insight if the verification is well-known within the whole organization.
Category 4: gives insight if the verification process is consequently executed and if quantitative steering is performed.
Category 5: gives insight if continuous improvement is applied on the verification process.

- The outcome gives a capability profile which is an indication of the achievement of the characteristics per category. The analysis gives insight in the influence of the used quality standards on the characteristics of the verification process and how well the verification process performs.
- The assessment focusses on the compliance with the criteria per category specific. For instance, when a project fully achieves category 5 (focused on continuous improvement) this means that the verification process 85% to 100% is complies with the criteria for continuous improving process.
- Complying with the criteria for continuous improvement does not mean the verification process complies completely with the criteria of lower category. This assumption differs from the 'normal' ISO 15504 assessments. This assumption is made because when for instance the criteria for continuous improvement (category 5) are fully achieved this does not directly mean that quantitative steering (category 4) is also fully achieved.
- The assessment gives insight how the process is implemented per project and has as purpose to identify the specific characteristics of the processes instead of just give the projects a rank. In order to achieve a category 5 maturity the categories 1 until 4 first need to be fully achieved in practice.
- Using this standard and consulting a quality expert from an independent assessment organization for the practical insights should provide in the objectivity of the research set-up. This should exclude the potential tendency of the researcher to confirm its preconceived notions for the outcomes of the research.
- The data collected is from a temporary nature. Continuous measurement is necessary to define the current status of the verification process.
- The information found is a reflection of the opinion of the persons on the projects.
• The reliability of this assessment can be improved by interviewing more people on more projects.

6.3 Discussion of the results and projects used

When comparing the three projects on their basic characteristics you can observe a difference in the basic project characteristics. You have to take into account that SAAone had a relative long preparation time for setting up a management system compared to A4all and WillemsUnie. Having more time for a implementing a management system could result in advantages compared to A4all and WillemsUnie where the management systems were used and developed at the same time. With respect to the project budget it must be considered that projects with a bigger budget possibly have more budgets available for setting up an expensive and extensive quality system. It could be possible that on WillemsUnie, which has the lowest project budget, a decision is made by the top management to lay less focus on the quality management aspects. It is assumed, because all three the projects are VolkerWessels project, that the approach of the top management is the same with respect to the implementation of quality management on the project. For instance the way of communication and carrying out the internal audits is considered the same. In this research an analysis of the costs of performing quality management on the different projects is not included. From this research it is also not known what the actual outcomes of the projects are when they are finished. It is not known if the projects exceeded the budget or were within budget. This can be solved by investigating the projects again in later phases. It is also not known to which extent RWS is satisfied with the results. The role of RWS related to the specific requirements (quality standards combined with specific management specifications) demanded for the verification process changes a lot. It can be discussed if a continuous changing RWS is good for the performance of processes. This can also be investigated in further research.
6.4 Conclusion

From the discussion the following conclusions about the research can be drawn.

The used research method seems to be right choice because:

- The case study research where a combination of quantitative and qualitative research is performed is considered a valuable research method to perform an in-depth research with not too many cases.
- For this research it is tried to keep the objectivity as much as possible by using a case study protocol, the basis of the international standard ISO 15504 and the help of an independent assessment expert for practical insights in the assessment work of the capability assessment.

However the results can be less reliable because:

- In the research assumptions are made about the interpretation of certain performance indicators and process characteristics.
- The focus lies on the registration part of the verification process, no all the steps in the verification process are investigated.
- For the qualitative part of the research the reader should keep in mind that the interpretation of data is potentially influenced by the perception of the researcher.

The reliability of the results can be improved by taking notice of the following aspects in future research:

- Go into more depth with how in practice is dealt with verification process characteristics.
- Check the criteria for the registration of the performance indicators with employees on the projects. Check the relation between the performance indicators and the verification process.
- Check if the registered indicators correspond with the indicators in practice.
- Investigate more than the registration part to gain insight in more than the registration process of verification. Investigate all the steps in verification instead of only the drawing up of the verification report.
- Check if the amount of deviations found relates to verification process activities and what is done with this deviations.
- Investigate more requirements and processes within the organizations.
- Measure on more projects, also other than VolkerWessels projects.
• Measure the customer satisfaction at RWS.
• Measure the final result when the projects are finished.
7 Conclusions

In this chapter the conclusions are drawn from the results found in the case study research. The conclusions give answer on the sub questions formulated and eventually on the main research question of this thesis. The research is aimed at defining the influence of the different quality standards on the verification process performance.

The main research question central in this research is:

*What is the influence of the use of different quality standards applied in Dutch integrated contracts on the verification process performance within large infrastructure projects?*

7.1 Contracting and procurement

In this section the answer on sub question a given:

*How is contracting and procurement organized for large public-private infrastructure projects in the Netherlands?*

For the ground, road and waterway construction projects in the Netherlands of which Rijkswaterstaat is responsible for, contracts are tendered. When new infrastructure projects in the road and waterway sector needs to be constructed, RWS involves private contractors to execute this work. In order to use the specific qualities of the private contractors and make optimal use of the market capacity, public-private cooperation’s are set-up. The integration of the various aspects in one contract results also in a different distribution of risks between RWS and contractor. In an integrated contract the risks are allocated to the party who can control the risks the best (VROM, 2008). After the procurement, the responsibilities between RWS and the private contractors are written down in a building contract. RWS wants to involve and give the private sector more responsibility in the life cycle of projects (Rijkswaterstaat, 2011a). Integrated contract are used between the private sector and RWS. In the construction sector the most commonly used contracts by RWS are the Design & Construct (D&C) and the Design, Build, Finance & Maintain (DBFM) contracts (Rijkswaterstaat, 2013).
7.2 Types of quality management

This section is used for answering sub question b:

*What types of quality management are imposed for the control of large infrastructure projects?*

RWS uses the *system based contract control* method for controlling their integrated contracts. In these contracts RWS enforces the contractor to set-up their management system based upon the ISO 9001 or the combination of the ISO 9001 and ISO 15228 standard. Not always are the processes in the management system fully conforming to the provisions from the standards. RWS use the management specifications and/or requirements specifications to impose a restriction, detailing and possibly a supplementation to the requirements from the quality standards. In practice the requirements from management- and requirement specifications prevail. ISO 15504 is used to determine the process capability and is in fact assessing the functioning of the processes in the management system. It gives RWS proof about the degree of compliance with the requirements and gives the client a degree of certainty about the ability of the contractor to control its processes. The advantages of introducing the ISO 15288 are the reduction of failure costs and better customer satisfaction. The basis of the system based contract control is that the contractors have to demonstrate they comply with the requirements by performing verification.

7.3 Verification process set-up

Sub question c reads:

*How is the verification process set-up within large infrastructure projects?*

The quality standards ISO 9001 and ISO 15288 both give guidelines about the set-up of processes within an organization. For the verification process two big similarities are present on all the three projects. The two main steps are; drawing up a verification plan first followed by drawing up a verification report. The difference between the verification processes lies within the small variations in input variables. It can be concluded that the design of the SAAone verification process is very much based on the requirements of ISO 15288. This implies more objective proof documents, a higher review frequency the presence of working instructions and the presence of a verification & validation plan. It results in a relatively complex process compared to the other processes. From the processes of the A4all and the WillemsUnie we can conclude that only guidance from ISO 9001 was not sufficient for establishing the verification process. RWS demanded specific complementary
requirements (the requirements specifications) next to the demands from the quality standards. It is also noticed that the verification process of A4all has ISO 15288 characteristics. Compared to WillemsUnie this means more objective proof documents, a higher review frequency and the presence of working instructions.

7.4 Verification process performance

The last sub question, sub question d reads:

*What is the performance of the verification process within large infrastructure projects?*

The answer on this sub question can be extracted from the verification process measurement (quantitative analysis) and the verification process capability assessment (qualitative analysis).

The results of the verification process performance measurement suggest that SAAone score relatively well on the established performance indicators, because most of the registrations of the requirements are successful in one revision. A 1.0 revision implies that the working package responsible is directly satisfied with the way the registration of the requirements is objectively demonstrated. Given the fact that it is assumed that the working package responsible is well-known with the requirements which RWS demands for the objective demonstration of fulfilling requirements, it could be stated that SAAone, which has the ISO 15288, has the lowest amount of revisions. Since the amount of revisions is lower on a project were the ISO 15288 is applied, this suggest that the use of the ISO 15288 has a positive influence on the verification process performance because the objective demonstration is accomplished better.

Since the ISO 15504 is applied on one of the projects the functioning is tested. The lower average amount of processing time verification report days on SAAone suggests that the use of the ISO 15504 has a positive influence on the verification process performance. This because the average amount days of processing time days gives an indication of the influence of the ISO 15504 on the functioning of the verification process. And the smaller range of processing time days is an indication if a combination of the ISO 15288 and ISO 15504 has a positive influence on the functioning of the verification process. Since on SAAone the range of processing time verification report days is smaller and the combination of ISO 15288 and ISO15504 is applied, this implies that the ISO 15504 indeed has a positive influence on the functioning of processes and therefore on verification process performance. With respect to the extra performance indicator *deviations*,
keeping in mind the fact that the relation between non-conformities and deviations is not measurable, it could be stated that on A4 all the least deviations are found. The review characteristic demanded from ISO 15288 has the goal of finding non-conformities. However it is difficult to say that fewer deviations found means that less non-conformities are found and therefore more requirements are met, this result can be seen as an indication that the review characteristic has a positive influence on the satisfaction of requirements.

With the interpretation of these results you have to take into account that the performance indicators are subject to assumptions and only tell something about the registrations of 190 requirements on the verification process. The results suggest that a better performance of the indicators can be related to the specific ISO 15288 and ISO 15504 characteristics.

The results from the capability assessment suggests that if you want an organization with a fully achievement of category 1 to 3, a performed, managed and established process, the choice for an ISO 15288 set-up is preferred. If an organization with only an established process is required no difference between set-ups is found. As the organization would like to focus on continuous improvement of the process, the process set-up according to the ISO 15288 is not preferred. The ISO 9001 set-up scores the same or even better, combined with some ISO 15288 aspects. The assessment gives insight how the verification process is implemented per project and has as purpose to identify the specific characteristics of the processes instead of just give the projects a rank.

With respect to the capability assessment it can be mentioned that lower achievement of the categories is often caused by bad communication between the different layers of the organization, combined with an unclear approach towards verification. Lower achievement of the categories is possibly caused by the following conflicts:

- The conditions for verification set by RWS are not exactly known by the people who are involved with the verification process.
- The designers are not involved in setting up the verification process and therefore do not feel encouraged to work in accordance with it.
- There is miscommunication about the usefulness and necessity of verification and the need of implementing improvements with regard to this process.
7.5 Answer to the main research question

The main question of this research is:

*What is the influence of the use of different quality standards applied in Dutch integrated contracts on the verification process performance within large infrastructure projects?*

In this case study three projects are investigated to answer this question. All three the projects, A4all, SAAone and WillemsUnie, are considered large infrastructure projects and are executed based on an integrated contract in the Netherlands. Currently there is a discrepancy between the policy which RWS expresses to the private contractor with the ‘Market, unless...’ policy and the increasing amount of control by imposing more quality standards. There is an increasing concern that the introduction of extra standards is not leading to better performance of the organizations processes. The objective of this research is to gain insight in how quality standards influence the process performance within large infrastructure projects in the Netherlands. In this research the performance of the verification process is investigated. The influence of the ISO 15288 and ISO 15504 standards is compared with the more traditional ISO 9001 standard.

The influence of the different quality standards is determined by two types of analysis. On the basis of the quantitative and qualitative analysis of the case study projects, results are found. The results of the verification process performance measurement (quantitative) suggest that projects where the ISO 15288 and ISO 15504 are applied on the project, advantages for the verification process performance are found. The results shows on the 190 requirements investigated that fewer revisions are necessary. Since the amount of revisions is lower on a project with the ISO 15288 this suggest that the use of the ISO 15288 has a positive influence on the verification process performance because the objective demonstration is accomplished better. Also the average amount of days is lower on the project with the ISO 15288 and ISO 15504, this suggests that the use of the ISO 15504 has a positive influence on the verification process performance. The range of processing time verification report days is smaller on a project with the ISO 15288 and ISO 15504 this implies that the ISO 15504 indeed has a positive influence on the functioning of processes and therefore on verification process performance. However it is difficult to say that fewer deviations found means that less non-conformities are found and therefore more requirements are met, this result can be seen as an indication that the review characteristic has a positive influence on the satisfaction of requirements.
From the verification process capability assessment (qualitative) the implementation and functioning of the verification process is determined. The results suggest that if an organization wants a full achievement of the categories 1 to 3, the choice for an ISO 15288 set-up of the management system is preferred. The verification process of SAAone is completely performed, managed and established (the verification process is able to produce the required outcome, the organization is able to control and maintain the verification process and the verification is well-known within the whole organization). The results suggest that a complete achievement of the established process characteristics (category 3) can also be achieved by using an ISO 9001 verification process set-up. With respect to the consequent execution and quantitative steering on the verification process (category 4), verification processes with ISO 15288 characteristics are achieving the related characteristics more. If an organization would like to focus on continuous improvement characteristics (category 5) of the process, the process set-up according to the ISO 15288 is not preferred. The results suggest that an ISO 9001 set-up scores the same or even better. A better result is achieved with an ISO 9001 set-up combined with some ISO 15288 aspects.

The results from the case study point in the direction those verification processes where ISO 15288 and ISO 15504 standards are demanded, perform better than just using an ISO 9001 set-up. However, there are reasons why these conclusions may not be stated so firmly. The values of the performance indicators do not necessarily say something about the specific content of the verification procedure. There could be more certainty obtained about these indicative results by investigating more processes than only the registration part of the verification process, examine more projects, check the relations of verification process characteristics with the performance indicators, check the opinion of RWS and investigating the influence of human behavior.

With respect to the discrepancy between the ‘Market, unless…’ policy and the increasing amount of control by imposing more quality standards, this research is considered as an indication that imposing extra quality standards, in this case the ISO 15288 and ISO 15504, result in potential advantages for the verification process performance.
Chapter 8
8 Recommendations

Based on the results and conclusions from this research recommendations can be drawn up. First recommendations for further research are given. Since this thesis is written on behalf of the master Construction Management & Engineering, recommendations for the managerial category of VolkerInfra for improving the approach to the verification process are given.

8.1 Recommendations for further research

The results presented in this thesis contributes to the research field of quality management with respect to the usefulness and influence of the ISO 9001 and ISO 15288 quality standards in the infrastructure sector. A first contribution to the closing of the knowledge gap is made; more insight is gained in the influence of the ISO 9001 and ISO 15288 on the process performance of the verification process.

Further research on this topic can be performed in various ways. The following topics came up during the research and are worthwhile performing a research into to improve the acceptability of the results:

- Investigating the relation between non-conformities and deviations in order to improve the reliability of the performance indicator deviations.
- To define the specific influence of the verification process characteristics a larger quantitative survey on the relations between ISO 15288 characteristics and the process performance indicators as indicated in Figure 26 can be performed. Involve more projects to test this presumed relations on more projects and arrive at broad generalizations.
- Check the interpretation of the performance indicators with RWS.
- The qualitative part of the research is focused on the registration aspects of the verification process within the design discipline. In order to be able to make a broader statement about process performance within infrastructure project the full verification process and more processes can be investigated. Also more infrastructure projects can be investigated to create broader support of the findings.
- Investigate the processing time of the whole verification process.
- Investigate if the amount of deviations is dependent of the activities in the verification process.
- A validation step is necessary to define if the results found are corresponding with similar other projects.
• Even though in this research the performance of verification process is evaluated in two ways, the final result of the projects is not known yet. A feedback moment when the projects are finished can be planned to evaluate the outcomes and learning moments.

• The reliability of the capability assessment can be improved by interviewing more people on more projects.

• Perform a research on the labour and budget spends on quality management activities in relation with process performance.

The research was performed within a limited scope and therefore other interesting related topics could not be investigated. The following topics are encountered during the research and are worthwhile performing a research into:

• The influence of the ISO 15504 on the process performance was difficult to explore because it does not seem to influence specific process characteristics. During the interviews it was discovered that hiring an independent assessment organization is expensive and the result of this certification was doubted by contractor and RWS. RWS is using this standard to be able to get more insight in provability of requirements. Performing a research on how provability can be improved without this standard can be an idea for further research.

• Perform a research on how the communication between the different disciplines, projects and project organizations can be improved in order to improve the maturity of the construction sector by learning from experiences of other projects.

• The ISO 9001 and ISO 15288 are not specifically designed for the construction sector and therefore leaves room for interpretation. Perform a research to develop a construction sector specific quality standard.
8.2 Managerial implications

From the verification process performance measurement and the verification process capability assessment potential advantages for the verification process are detected. The semi-structured interviews gave a good impression of what is happening in the organizations. The following recommendations are considered useful for VolkerInfra by the researcher. Based on this information the following recommendations for the managerial level of VolkerInfra can be made:

1. Use an ISO 15288 set-up for the verification process in your project organization.

The results from the performance measurement suggest that there are potential advantages found with respect to the processing time and the amount revisions necessary. Assuming that managers from VolkerInfra prefer this identified advantages, an ISO 15288 set-up is recommended. From the interviews the following potential relevant tips are given: Apply the ISO 15288 set-up from the start of the project; it avoids discussions about the set-up of the basic processes. Involve the people which have to work with the process in the implementation of project specific processes to get them more acquainted with the process.

2. Be clear in communicating the goal and the added value of performing verification.

On the interviews an often heard complaint was that people who set-up the processes do not involve the people working with it enough. This results in miscommunication about the goal and necessity of verification. The following tips were given: communicate the usefulness and necessity of verification to every new employee on the project, communicate the conditions for verification set by RWS throughout the organization using standard template and communicate the difficulties found with respect to the verification process between the disciplines and within the organization.
References


Appendices

Appendix 1 Conference Rijkswaterstaat

On May 30 the PPS werkt! Conference was visited. Two workshops were followed.

- Workshop one: Awarded a contract, now what? Towards effective contract control.

  How do client and contractor start their project together? And how do you shape contract control? As a participant in this workshop you'll be challenged to share your experiences in this domain.

- Workshop two: Cooperate to success.

  Cooperation in PPPs is crucial to achieve the goals of both public and private actors. But what does it mean in practice? And what can you do to make this cooperation a successful one?
Appendix 2 Interview protocol Round 1

This interview protocol is made for the orientating part of the research. The goal of the interviews is obtaining information regarding the implementation of the quality standards. Professionals at Rijkswaterstaat, SQS and VolkerInfra are interviewed to get a basic idea of the current practices.

1. Why are the quality standards introduced?
2. How is the client/contractor handling SCB?
3. What are the goals of introducing quality standards?
4. What is the role of the client/contractor?
5. What are observed (dis)advantages?
6. Do the contractors have problems with proving the quality of projects?
7. Are these standards the future?
8. What do you think about the intention to investigate the verification process?

After the interview a concept elaboration of the interview was send to the interviewees. Possible remarks on the concept where processed and the concept turned into the definitive version.

People interviewed Round 1

<table>
<thead>
<tr>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCB Specialist en lead Auditor, Rijkswaterstaat GPO</td>
</tr>
<tr>
<td>Senior Quality consultant, SQS Netherlands</td>
</tr>
<tr>
<td>Project secretaris A4all, Van Hattum &amp; Blankevoort</td>
</tr>
<tr>
<td>Proces manager A4all, Boskalis</td>
</tr>
<tr>
<td>Proces-contract manager SAAone, Volkerinfra</td>
</tr>
<tr>
<td>Manager Projectbeheersing WillemsUnie, Volkerinfra</td>
</tr>
<tr>
<td>Projectorganisator A12, BAM wegen</td>
</tr>
</tbody>
</table>
Appendix 3 Interview protocol Round 2

The interview round 2 is made for performing the qualitative part of the research; the verification process capability assessment.

Interview protocol

The interview protocol is elaborated in the Dutch language. The reason for this is the fact the interviews are held in Dutch and in this way communication with the interviewees was more efficient.

Achtergrond

Dit interview protocol is bestemd voor de interviews die worden afgenomen in het kader van het afstudeeronderzoek van Derk Hordijk, student Construction Management and Engineering aan de TU Delft. Het afstudeeronderzoek richt zich op het onderzoeken van de invloed van ISO standaarden op de inrichting en werking van processen binnen projectorganisaties. De focus van het onderzoek ligt voornamelijk op het verificatieproces tijdens de definitief ontwerpfase (DO).

Doel van het interview

De informatie uit de interviews wordt gebruikt om de invloed van ISO standaarden op de inrichting en werking van processen binnen project organisaties te bepalen. Aan de hand van specifieke projecteigenschappen en data verzameld uit de project databases, ondersteund door informatie van de geïnterviewden met ervaring uit de praktijk, wordt de process performance van de projectorganisaties bepaald. Op deze manier kan er een vergelijk gemaakt worden tussen de drie project en een inzicht verkregen worden in de invloed van ISO standaarden op process performance.

Werkwijze per interview

- De (mogelijk) te interviewen personen worden benaderd of zij mee willen werken aan het onderzoek. Uitleg over het onderwerp wordt verschaft. Bij instemming tot medewerking wordt er een bevestiging per email gestuurd.
- Het betreft een semi gestructureerd interview, het doel is om alle vragen te laten beantwoorden door de geïnterviewde, maar er is ruimte om te verdiepen op bepaalde punten.
- De vragen hebben betrekking op het project waar de geïnterviewde werkzaam is of geweest is.
- Er wordt toestemming gevraagd of het interview mag worden opgenomen.
- Het interview zal ongeveer 1 uur, maximaal 1,5 uur in beslag nemen.
- Er wordt een concept versie uitgewerkt en toegestuurd, de geïnterviewde heeft tien dagen om commentaar hier op te leveren na die termijn wordt de concept versie definitief.
- De uitwerkingen en informatie verkregen tijdens de interviews zal op vertrouwelijke manier worden behandeld, in de publieke versie van het afstudeerwerk zullen geen uitwerkingen van interviews staan.

**Het interview**

Het interview bestaat uit de onderstaande vragen. In het onderdeel 'werking van processen' zijn er termen dikgedrukt. Dit zijn de gegevens die als data uit ViSe worden gehaald. Op basis van de vragen wordt de capabiltiy assessment uitgevoerd.

**Introductie (5 minuten)**

- Wederzijdse kennismaking
- Uitleg onderwerp en verloop interview
- Mag het interview worden opgenomen?

**Belang van ISO standaarden en werkwijze (15 minuten)**

- Volgens welke normen werkt u, worden u opgelegd?
- Heeft de aanwezigheid van de normen invloed op jullie werkwijze?
- Kunt u voorbeelden noemen van hoe de aanwezigheid van normen de werkwijze op het project beïnvloed?
- Wat zijn de *voordelen* van het werken volgens de normen?
- Kunt u voorbeelden noemen van een situatie waarbij het werken volgens de normen tot een positief resultaat heeft geleid? Wat was in dat geval het positieve effect?
- Wat zijn de *nadelen* van het werken volgens de normen?
- Kunt u voorbeelden noemen van een situatie waarbij het werken volgens de normen tot een negatief resultaat heeft geleid? Wat was in dat geval het negatieve effect?
Inrichting van het managementsysteem (15 minuten)

- Wordt er gebruik gemaakt van gestandaardiseerde processen? Welke zijn dit, zijn deze uitgerold over de gehele organisatie? In welke vorm?
- Wordt er gewerkt volgens deze processen? Is er informatie beschikbaar gesteld over de implementatie van de processen? In welke vorm (werkinstructie, overleg ed.)?
- Wat is de reden van afwijken (wanneer er niet volgens het proces wordt gewerkt)?
- De ISO 9001 promoot het werken volgens een procebbenadering, de ISO 15288 stelt een welomlijnde set aan processen. Is het nodig om deze processen zo precies in te richten? Wat levert het op voor de communicatie tussen de opdrachtgevers, leveranciers en andere stakeholders? Kunt u voorbeelden noemen?
- Hoe richten jullie de processen in, doen jullie dit volgens een bepaald tailoring principe? Het verkleinen van de scope.
- Wat bepaalt een goed verloop van de processen en uitvoering daarvan binnen uw organisatie? Wat is bepalend voor een goede output/eindresultaat?

Werking van processen (20 minuten)

- Wordt de beoogde uitkomst van het proces bereikt met de werkwijze die nu in gebruik is?
- Wordt het voldoen aan (ontwerp)eisen onderbouwd met bewijs? Zijn de bewijsdocumenten objectief? [#afgeronde eisen met bewijsdocument], staan deze in verificatierapport?
- Wat voor type verificatiemethodes worden er gebruikt? Zijn deze valide? [#valide bewijsdocumenten]
- Welke activiteiten en/of input dragen bij bij een betere effectiviteit? Waarom?
- Worden de registraties volledig uitgevoerd?
- Wordt het invullen van de verificatiedocumenten op de voorgeschreven manier gedaan? Als dit niet wordt gedaan, waarom wordt dat niet zo gedaan en wat zijn hiervan mogelij het gevolgen?
- Denkt u dat het niet verantwoord omgaan met het afronden van de eisen invloed kan hebben op het aantal fouten?
- Zijn er voldoende bedrijfsmiddelen beschikbaar om de verificatie uit te voeren? Is de aanwezige informatie van voldoende kwaliteit en beschikbaar Nota’s, werkinstructies ed.? Is er een systeem beschikbaar om de verificaties uit te voeren?
- Wordt het proces beheerst uitgevoerd? Is de doorlooptijd van het proces voorspelbaar in de tijd? [#dagen tussen indienen eerste versie verificatierapport en afronden eisen]
- Welke activiteiten en/of input dragen bij bij een betere efficiëntie? Waarom?
- Hoe wordt er in de praktijk omgegaan met non-conformiteiten gevonden tijdens het verificatieproces? [#revisies]
- Wordt er aan continue verbetering gedaan (dmv. PDCA of vergelijkbaar)? Worden de verbetermogelijkheden onderzocht en uitgevoerd? [#afwijkingen]
- Hoe worden de non-conformiteiten gevonden? Wordt er data verzameld om de processen te analyseren? Wordt er kwantitatieve sturing uitgevoerd?
- Zijn er gegevens beschikbaar voor het uitvoeren van correctieve maatregelen? (de resultaten van een review) [review frequentie].
- Welke activiteiten en/of input dragen bij bij een betere kwaliteit? Waarom?

Afsluiting (10 minuten)

- Wvttk
- Aangeven van de termijn van terugkoppeling
- U krijgt een uitwerking van het eindrapport in de vorm van een managementsamenvatting.
- Bent u beschikbaar voor eventuele aanvullende vragen?
- Bedankt!
People interviewed Round 2

<table>
<thead>
<tr>
<th>Function</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manager Project control WillemsUnie</td>
<td></td>
</tr>
<tr>
<td>technical Manager design WillemsUnie</td>
<td></td>
</tr>
<tr>
<td>Senior Project ingenieur geotechnic WillemsUnie</td>
<td></td>
</tr>
<tr>
<td>Senior Project ingenieur waterbouw WillemsUnie</td>
<td></td>
</tr>
<tr>
<td>KAM/IV manager A4all</td>
<td></td>
</tr>
<tr>
<td>Manager design A4all</td>
<td></td>
</tr>
<tr>
<td>Design leader geotechnic A4all</td>
<td></td>
</tr>
<tr>
<td>Senior 3D Modeler A4all</td>
<td></td>
</tr>
<tr>
<td>Coordinator Systems Engineering SAAone</td>
<td></td>
</tr>
<tr>
<td>Design leader GWW SAAone</td>
<td></td>
</tr>
<tr>
<td>System Engineer design SAAone</td>
<td></td>
</tr>
<tr>
<td>Senior 3D Modeler SAAone</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 4 Management systems characteristics of case projects

In this section an impression of the outline of management systems in practice is given. It gives an idea about the fact that management systems not only are based upon the quality standards which are investigated in this thesis, but also upon other requirements.

A4all

The management of the project is a whole of rules and procedures established in the Project Management Plan (PMP). It is a document where the coordinating processes are made project specific. The requirements for the management system can be found in Table 35.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEN-EN-ISO 9001: 2008</td>
<td>Required for parent company, project specific</td>
</tr>
<tr>
<td>VCA**</td>
<td>Safety, health and environment checklist for contractors, A4all needs to be certified</td>
</tr>
<tr>
<td>Requirement specification part 2 (VS2)</td>
<td>Process organization requirement, for the verification process this specification requires the making of a verification plan and verification report, also a review activity is requested.</td>
</tr>
<tr>
<td>C32 W model</td>
<td>Process organization requirement</td>
</tr>
</tbody>
</table>

Table 35 Management system requirements A4

![Figure 28 Outline management system A4](image-url)
SAAone

RWS demands certain requirements from SAAone. These requirements, in Table 36, are transformed to the digital project management system. The corresponding rules and procedures from these standards and norms are grouped according coordinating processes from which an overview can be found in Figure 29. Underneath this ‘top level’ processes more specific processes are defined.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEN-EN-ISO 9001: 2008</td>
<td>Required, SAAone needs to be certified</td>
</tr>
<tr>
<td>VCA**</td>
<td>Safety, health and environment checklist for contractors, SAAone needs to be certified</td>
</tr>
<tr>
<td>NEN-ISO/ IEC 15288: 2008</td>
<td>Management system design, tested by external assessment company</td>
</tr>
<tr>
<td>SPIC</td>
<td>Safety performance indicator contractors, tested by external assessment company</td>
</tr>
</tbody>
</table>

Table 36 Management system requirements A1/A6

Figure 29 Outline management system SAAone
Figure 30 The definitive design process SAAone
The demands of RWS concerning the project management can be found in Table 37. The requirements are transformed into a digital project management system. The interpretation of the requirements into the coordinating processes can be found in the overview of the management system in Figure 32. Underneath this ‘top level’ processes more specific processes are defined.

<table>
<thead>
<tr>
<th>Requirement</th>
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</tr>
</tbody>
</table>

Table 37 Management system requirements Zuid-Willemsvaart

![Figure 32 Outline management system Zuid-Willemsvaart](image-url)
Figure 33 The definitive design process WillemsUnie
Figure 34 Verification process steps WillemsUnie