Process Performance Improvement

Effect of ISO15288 and ISO15504-6 on the improvement of the process performance in civil infrastructure projects in the Netherlands

MSc thesis | Coen Spelt
Delft, February 2017

Process performance improvement in Civil Infrastructure Projects

Effect of ISO15288 and ISO15504-6 on the improvement of the process performance in civil infrastructure project in the Netherlands

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Delft, February 2017

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Management summary

The size and complexity of today's construction projects require new methods to control and manage the project's processes to successfully deliver a project. In the past years, the implementation of the ISO15288 framework and the achievement of predefined ISO15504-6 capability levels are prescribed in civil infrastructure projects executed according to design, construct, finance and maintain contracts. ISO15288 consists of a framework of processes within the life cycle of a system. This framework describes the purpose, output and activities for each process; these are expressed in observable results that can be translated to the success of the process. ISO15504-6 is the process assessment model developed to assess the results generated by ISO15288. The standard serves as a guideline to guarantee a repeatable assessment and translates the performance of a process into a relative and comparable value called the capability level. Furthermore, the combination of standards aims to increase the performance of the project processes. The goal of this research is to determine if the implementation of the combination of standards results in the perceived process performance improvement. Hence, this research is steered by the following question:

What is the effect of the ISO/IEC/IEEE 15288 framework and the ISO/IEC 15504 assessments on process performance improvement in civil infrastructure projects?

An empirical analysis elaborates upon nine infrastructure construction projects in the Netherlands. Out of these projects, five case study projects are used in a quantitative analysis on process performance indicators to answer this research question. This research is comprised of five steps: I: setting up this research, defining the problem and approach, II: Determining the fit for purpose of the standards on civil infrastructure projects, III: Evaluate the difference in practical application and proposed application, IV: Gather quantitative measurements and determine the increase in process performance. V: Expert validation of the findings out of the previous parts to substantiate conclusions about the effect of the combination of standards. Concluding this research with a discussion on those findings and recommendation.

II

The second step of this research determines the purpose and fit of the standard on civil infrastructure projects. The purpose of the standards depends on the aim of the contractor: achieving contractual requirements, differentiate from other contractors or the actual purpose achieving process performance improvement.

The evaluation of the fit is performed by comparing the life cycle of an infrastructure project with the life cycle applicable for ISO15288. These life cycles showed an overlap in all applicable phases for an infrastructure project. However, the framework of processes provided by the ISO standard is not considered to be complete in order to successfully execute a project. With the help of an adaptation procedure provided by the standards, the list of processes can be adapted to include the necessary processes for an infrastructure project. Moreover, the described sequence of application of the technical processes does not fit the characteristics of an infrastructure project. With small adjustments, ISO15288 should be applicable to infrastructure construction projects.

III

The confirmation on the fit for purpose resulted in an evaluation of the practical application of ISO15504-6 in current infrastructure projects. An empirical analysis of nine case study projects showed inconsistency in the prescribed and applied project phases and capability levels. The findings out of this section lead to a new design for the applicable capability level in each phase of an infrastructure project. This recommendation builds on the confirmation that the project management system of the contractors applies similar principles as described in capability level

3 of ISO15504-6. In the recommended design the ISO standards are already included for the project supporting processes of the procurement phase. This decreases the duration to achieve capability level in the later phases. The change of dynamics and activities in the maintenance phase make a number of the processes out of the earlier phases superfluous, only the most important processes in this phase remain. Validation of the new design is needed to confirm its effectiveness.

IV

Quantitative indicators are used to analyse the effect of the ISO standards on the performance of the processes. These quantitative indicators are the Performance Indicators (PI) defined by the five case studies. The PI is analysed on the variation in the measurements and the distance between the average and the target value, shown in figure 10. Based on the prerequisites the 38 PIs provide sufficient information to analyse the performance of seven processes. The analysis focuses on the effect of the standards on the process performance improvement caused by the increase of a capability level. The improvement on processes increasing from capability level two to three and from level three to four are analysed. Both increases in capability level show a similar improvement in 60% of the indicators in the reduction of variation and an increase in the distance towards achieving the business goal. However, the increase in the performance parameters did not translate into the achievement of a higher percentage of a target value, which remained constant around 40%.

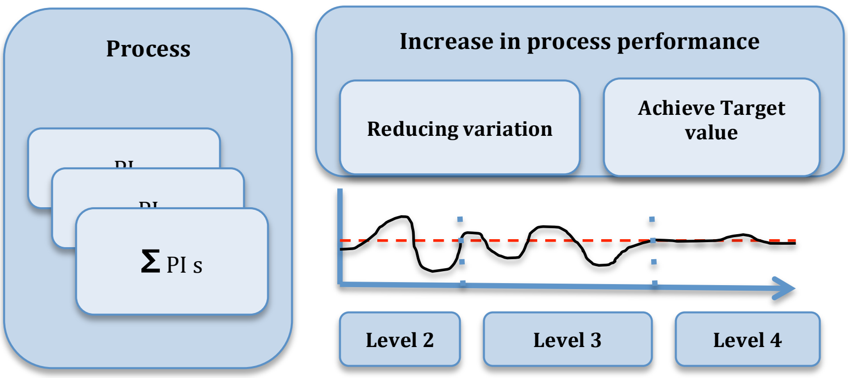

Figure 1: Process improvement used in this research

V

The combination of standards increases the focus of the project organisation on the monitoring and evaluation of its processes. Moreover, this research shows that the standards manage to achieve an increase in the parameters representing process performance, however, this did not lead to an increase in achieving target values. The positive effect of the standard is visible, although the analysis of the performance does not translate to the achievement purpose of the standard. The standard is used to achieve secondary goals rather than pursuing process performance improvement and achieving the target values of the performance indicators.

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Abbreviations

AGR	Agreement Processes
CL	Capability Level
CMM	Capability Maturity Model
DBFM	Design Build Finance Maintain
ENT	Organisational Project-Enabling Processes
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organisation for Standardisation
IT	Information Technology
NEN	Dutch national Standards
PA	Process Attribute
PI	Performance Indicator
PPI	Process Performance Indicator
PRJ	Project Processes
RWS	Rijkswaterstaat
SD	Standard Deviation
SE	Systems Engineering
SPICE	Process Improvement for Construction Enterprises
TEC	Technical Process

Symbols

U	Average
Z-score	Standard score
Δ	Delta (average-threshold)
σ	Standard Deviation

Glossary

Term	Definition
Analytical framework:	Framework used to transfer PI measurements into comparable dimensionless measurements
Business goal:	The highest goals an organisation aims to achieve, level determined by the organisation itself
Capability level:	A relative value used by ISO15504-6, ranging from 1 to 5, to expresses the performance of a process. In the report, the term level(s) refers to Capability level.
Client	Acquirer of the civil infrastructure project
Contractor	Supplier of the civil infrastructure project
Delta	Distance between the average of the PI measurements and the threshold value
ISO processes	Always refers to the list of processes described in ISO15288 and ISO15504-6 (shown in figure 1)
ISO standards	Always refers to ISO 15288 and ISO15504-6
ISO15288	ISO/IEC/IEEE 15288 System life cycle standard, framework processes used to facilitate the process from the conception of idea to the retirement of a system
ISO15504-6	ISO/IEC 15504-6 System life cycle process assessment model, a structured approach to transfer the performance of the ISO15288 processes into a relative value
ISO24748-2	NPR-ISO/IEC TR 24748-2 Guide to the application of ISO/IEC/IEEE 15288
Performance Indicator	Quantifiable indicator that provides measurements of a specific part of the process, combination of PI's are used to measure the project goal
Process performance	The degree of the PI achieving threshold values and the variation within these measurements.
Process performance improvement	Increase in the achievement of threshold values and reduction of variation in the PI measurements
Process Performance Indicator	Quantitative objectives that represent the performance of the process
Project goal:	Represent the goals an infrastructure construction project aims to achieve, the level is determined by the project organisation itself.
Threshold value:	Limit the PI aims to achieve, determined by the project organisation
Trend	Direction of the slope of the PI measurements
Variation	Degree of dispersion in the PI measurements

-I-

Introduction

1 Introduction into the problem

This chapter is the introduction into this research. The first paragraph describes the subject, following into the problem this research aims to investigate. In the next paragraph, the intention for the investigated standards is described. The chapter ends with the structure of the report.

1.1 Introduction to the subject

The scope of civil infrastructure projects is growing and becoming more and more complex while the demand for safety, sustainability and the number of stakeholders is increasing. Consequently, projects in these complex conditions are characterised by a high degree of uncertainty (Locatelli, Mancini, & Romano, 2014; Lukszo, Weijnen, Negenborn, De Schutter, & Ilic, 2006). Assessment of the performance of the construction industry shows it is not effective in achieving the objectives of these complex projects. The problems range from the inability to meet requirements to the exceedance of planning and budget (Chen & Chen, 2007; Locatelli et al., 2014). Despite multiple efforts to increase the performance of infrastructure projects, the construction sector still copes with a large percentage of avoidable costs and underachieving projects (Santema, Rijt van de, & Hompes, 2010). The scope of the contractor increased from design and construct to the responsibility for the entire life cycle of the project. Moreover, due to the increased size and complexity of today's projects, traditional performance measurements are regarded to be insufficient in determining the performance of projects (Houdt & Vrancken, 2013).

In order to deliver this kind of complex projects, new measures are needed and unavoidable. The implementation of the ISO15288 System Life Cycle standard into civil infrastructure projects is one of these measures. ISO15288 aims to manage projects within complex environments and to improve the process implementation and optimisation. The standard serves as a structured framework into which the contractors' processes can be implemented (ISO/IEC/IEEE, 2015). The standard describes a collection of tools and techniques to manage projects within the entire life cycle of complex system environments (Locatelli et al., 2014). The standard was introduced in the early Design, Build, Finance and Maintain contracts for infrastructure projects in the Netherlands. Coherently, the implementation of ISO15288 another ISO standards was introduced, ISO15504-6 System Life Cycle processes assessment model. The procedures of ISO15504-6 express the performance of processes in a relative and comparable value. The height of this value, called the capability level, is prescribed as a requirement in the DBFM contract.

ISO15288 and ISO15504-6 are not the first measures to increase the performance in construction projects. According to Haponava and Al-Jibouri (2010), the performance in construction projects is related to the performance of associative processes, previous efforts did not result in an increase of the process performance. This research aims to determine the effect of ISO15288 and ISO15504-6 on the increase of process performance.

1.2 Problem definition

The ISO 15288 framework and ISO 15504-6 assessment originated from the IT sector and is specially designed for iterative processes and procedures (ISO/IEC, 2011). The characteristics of a civil infrastructure project differ from the characteristics of an IT project. Civil infrastructure projects are considered as unique projects since these projects are often developed in a dynamic environment. Moreover, infrastructure projects continuously need to interact with other systems. This research aims to determine if ISO15288 and ISO15504-6 fit the purpose of civil infrastructure projects. Recently, the first projects developed according to the ISO15288 and ISO15504-6 standard were completed. Since more projects are currently executed it is important to identify whether or not the implementation of these standards results in an improvement of the performance of project processes and if the implementation is able to acquire the goals of the contractor. To determine the effect of ISO15288 and ISO15504-6 on the improvement of the processes performance within infrastructure projects, this research aims to study a threefold problem. This threefold problem consists of fit for purpose of the standards, the practical application of the standards and the analysis on the effect of the standards on the process performance.

1.3 Context of the standards

Now the intentions of this research are clear, in-depth information about the proposed effect and application of ISO15288 and ISO15504-6 is given. Since the independent research about the application of these standards is limited the information is based on the descriptions provided by the authors of the standards, the International Organization for Standardisation (ISO). The accurateness of this proposed effect within infrastructure projects is investigated in the remainder of this research.

1.3.1 Guide to ISO15288

Complex man-made systems lead to new opportunities, but also to increased challenges for the organisations that create and operate these systems. To cope with these challenges a joint technical committee which consists of the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE) developed an International Standard with a defined set of processes to facilitate processes from the conception of idea through to the retirement of a system. These processes help to improve communication and cooperation among the parties that create, utilise and manage modern systems in such a manner that these processes work in an integrated, coherent fashion. This international standard is named: ISO/IEC/IEEE 15288 Systems and Software engineering – System life cycle processes.

Application

ISO 15288 contains a framework of process descriptions for activities within the life cycle of a system. These activities are designed to manage and achieve a result within the system life cycle stages of the project (ISO/IEC/IEEE, 2015). The standard is especially applicable to systems containing hardware, software, data, humans, processes, procedures, facilities, materials and naturally occurring entities. Within the ISO standardisation, ISO 15288 is seen as a process standard that belongs to the software and systems engineering groups (ISO/IEC/IEEE, 2015).
In ISO 15288 the preselected processes that can be performed during the life cycle of a system are divided into four process groups: agreement processes, organisational project-enabling processes, technical management processes, and technical processes. This is shown in **Figure 3**. For each process, ISO 15288 describes its purpose, desired outcome and lists the tasks and activities that should be accomplished in order to achieve the desired outcome (ISO/IEC/IEEE,

2015). It is important to note that the processes described by the ISO standard are not a finite list. The user of a system is encouraged to include additional processes, which they find useful. Also, the standard should not be seen as a strict guideline, system developers are allowed to adapt the processes in order to fit these into their own systems.
The standard is designed to provide processes that support the definition, control and improvement in the life cycle of a system. The standard helps to define roles and facilitate communication among all stakeholders. By performing the processes in the defined method, the outcomes will be expressed in observable results that can be translated to the success of the process

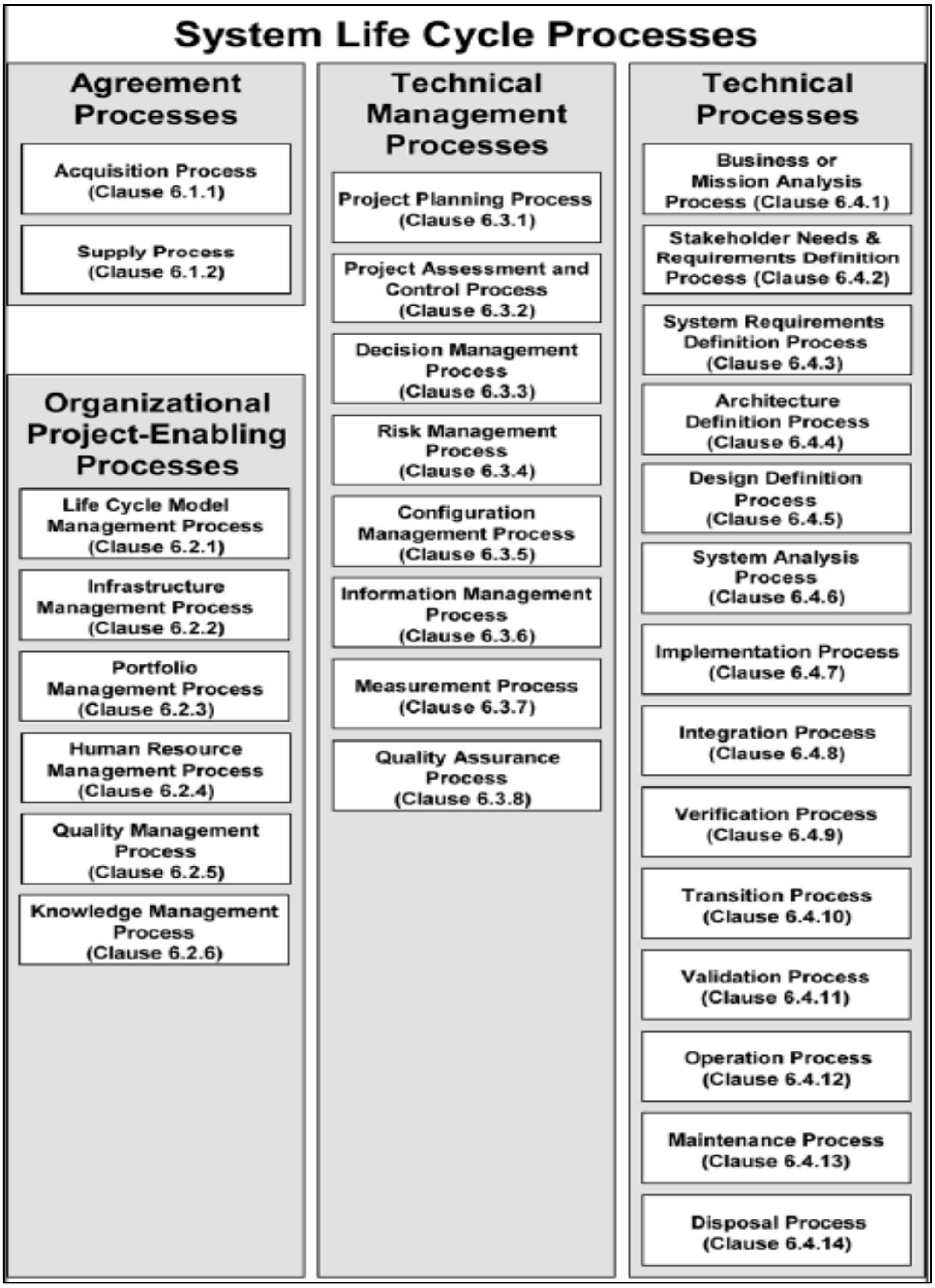


Figure 3: Categorisation of System Life Cycle Processes (ISO/IEC/IEEE, 2005, p. 21)

1.3.2 Guide to ISO15504-6

A system developed according to process framework can be assessed on its performance by a process assessment model. The process assessment model that is designed to assess ISO 15288 is ISO/IEC 15504-6: information technology – process assessment. The assessment model translates the performance of the processes into a relative value, so it can be used to compare the performance of different processes and projects.

Application

The overall performance of a process is measured in capability levels rating from zero to five. ISO 15504 describes the minimum requirements for performing the assessment in order to ensure consistency and repeatability of the ratings and to come to a certain capability level. ISO 15504-6 is considered in relation with ISO15288 but the essence of the assessment model can be used in any process framework. ISO 15504 also belongs to the Software group (ISO/IEC, 2013).
ISO/IEC 15504 uses capability levels to express the performance of processes; the levels represent a performance and provide a rational way of measuring the capability of any process. Each capability level is defined by a set of process attributes that work together to provide an improvement in the capability to perform a process. **Table 1** shows the expected outcome at each capability level. After an independent assessor performs the assessment, the achieved capability level is granted to the organisation. The desired capability level can deviate per process, the importance or the impact of the process results in the desired capability level (ISO/IEC, 2013). According to the standard, an increase in capability level represents an increase in process performance. Over the duration of the project, an organisation requires or is required to achieve a certain capability level. The standard relates a higher capability level to improving the effectiveness of the process to achieve business goals (ISO/IEC, 2013).

Table 1: Details capability levels based on ISO15504-6 (2013)

Capability level	**Prescribed outcome**
Level 0: **Incomplete process**	The process does not generate an identifiable outcome/output, generally a failed process.
Level 1: **Performed process**	An outcome is achieved but it cannot be attributed to the process, individuals have taken actions.
Level 2: **Managed process**	The process delivers work products within defined timescales and according to defined standards and requirements. The process is planned and managed in order to achieve a defined outcome.
Level 3: **Established process**	The process is managed by a defined process procedure; it exists of documented standardised procedures and all the resources are in place to deliver the defined outcome.
Level 4: **Predictable process**	The defined process performs within set control limits, details of the process are monitored and analysed in order to make adjustments if the control limits are exceeded.
Level 5: **Optimizing Process**	Continuous monitoring of the process against the business goals, goals are established and the process is optimised to meet the defined goals.

1.4 Structure of the report

The report is divided into five segments, the chapters within each segment all contribute in answering the corresponding research questions. This principle will be further explained in the methodology.

I

In the first segment, the basis of this research is described. The report commences with an introduction to the problem and insight into the investigated ISO standards. In Chapter 2 explains the applied methodology. This chapter explains the goal and defines the main research question and a set of sub-research questions to steer this research towards its goal. This research approach in section 2.3 divides this research into four segments, each segment aims to answer a specific part of this research goal. The literature review follows from the applied methodology. Chapter 3.1 focuses on the differences between the construction sector and the IT sector to provide input on the fit of the standards. Chapter 3.2 assesses the extent of underachieving projects in the Netherlands and concluding on the factors leading to this performance. Chapter 3.3 reviews the effect of standardisation and the effect is measured relative to the performance. Most of this research is based on empirical data gathered from case study projects, these projects described in chapter 4.

II

The second segment focuses on the fit of the standard within civil infrastructure projects. Chapter 5 explains the contractors' purpose for implementing the standards, the relation between the standards its position within an infrastructure construction project. Chapter 6 focuses specifically on ISO15288; chapter 6.2 determines the fit of the standard via evaluation over the different life cycles.

III

The third segment focuses on the differences in the application of the standards. Chapter 7 evaluates the differences in the application of the standards within the case study projects. Chapter 7.2 evaluates the differences between the existing project management system and the framework implemented by the standards. The recommended application over the project phases is explained in chapter 7.3. The segment is concluded with chapter 8, which proposes a new design for the application ISO15504-6 in a civil infrastructure project.

IV

The fourth segment focuses on determining process performance based on a quantitative analysis. In chapter 9 the differences between definitions of performance used in this research and used in the ISO assessment are described. In chapter 10 the PI measurements out of the case studies are gathered and analysed on the parameters determining performance. This information is used to determine if an increase in process performance is achieved.

V

The fifth segment evaluates conclusions out of the previous segments to form conclusions and discussions on the findings. In chapter 11 experts validate the findings. After this validation, this research questions are answered in chapter 12. This research is concluded with a discussion on the findings and recommendations on the application of the standards and further research.

2 Methodology

In this chapter, the goal and main research question are formulated. Sub-research questions help to answer this research questions. In the approach, five segments are linked to the corresponding sub-research question.

2.1 Research Goals

The goal of this research is to investigate the effect of the System Life Cycle Standards on civil infrastructure projects, or in other words, determine if the combined approach of the ISO 15288 framework and the ISO 15504 assessments result in achieving process performance improvement. In this research, process improvement is solely approached from the perspective of the contractor. Case study process measurements will serve as a basis for the quantitative analysis in identifying process improvement. A pre-requisite for this evaluation is to investigate the fit-for-purpose of the System Life Cycle Standard on the life cycle of civil infrastructure projects. In addition, this research aims to identify at which level of process performance the combined standard approach is an improvement over the management system an organisation is currently using.

2.2 Research questions

To steer this research towards its goal a set of research questions are formulated. The main research question is deconstructed into a set of six sub-research questions. Answering the sub-research questions results in the answer for the more complex main research question. The main research question follows from the goal of this research: determine if the System Life Cycle standards result in an increase in process performance within infrastructure projects (RQ). Before concluding on the effect, the fit of these standards, developed for another sector, on infrastructure projects will be analysed (SQ1). The current project management system is compared with ISO framework to conclude how the framework relates to the existing project management structure (SQ2) and advises on the right capability level in each project phase (SQ3). To detect improvement the definition process performance is defined (SQ4), by this definition an analytical framework is developed to quantify process performance and applied on case studies to measure process performance within the capability levels (SQ5). Analysing the extent to which process improvement relates to achieving the contractors' goals (SQ6) provides the input to answer the main research question.

RQ: What is the effect of the ISO 15288 framework and the ISO 15504 assessments on process performance improvement in civil infrastructure projects?

Relates to ISO 15288 framework:
SQ 1: How does the ISO/IEC/IEEE 15288 framework fit within civil infrastructure projects?

Relates to ISO 15504 assessment:
SQ 2: How does working according to the project management system relates to achieving ISO/IEC 15504-6 capability levels?
SQ 3: How should the ISO/IEC 15504-6 capability levels be arranged per project phase?
SQ 4: How is process performance defined in a civil infrastructure project?
SQ 5: How does process performance proceed over increasing capability levels within the case study projects?
SQ 6: How does process performance improvement relate to achieving contractors' goals?

2.3 Research approach

Desk research is the selected research approach after evaluating the key decisions areas. This research benefits from a wide approach and conclusions are drawn on the basis of performance measurements out of case studies (Verschuren & Doorewaard, 2010). As described in chapter 1, this research exists out of five segments. Within each segment a selection of the sub-research questions is answered, leading to answering the main research question and fulfilling this research goal. The approach is schematically displayed in **Figure 4: Schematized research framework**. The five segments used in this research are:

I. Introduction
II. Fit for purpose of the life cycle standard
III. Practical application of ISO15288 & ISO15504-6
IV. Process improvement analysis
V. Advice

The first segment consists of the introduction, methodology and the application of the theoretical framework. This segment is used to determine the right approach for this research and form a scientific basis.

The second segment follows from the literature review and organisation analysis to determine the motivation, use and needs for life cycle standards in the construction of civil infrastructure projects. The ISO15288 life cycle standard is compared with the life cycle of a civil infrastructure project to conclude on the fit-for-purpose of the standard in the construction sector, answering SQ 1.

The third step determines the differences in the application of the standard and the effect of the implementation for the contractor. Large infrastructure projects already work in a standardised matter by following a project management system. In chapter 7 the answer to SQ2 is given by evaluating the project management system against the capability level out of ISO 15504. The second step will be concluded by recommendations on right design for the framework and assessment and answering SQ3.

To conclude on the increase in process improvement, a definition of process performance is derived from the available case study performance measurements and based on the literature review and performance attributes out of the Life Cycle Standard, thereby answering SQ4. In chapter 9, an analytical framework is developed and used to transform the contractors' measurements to performance information. The framework uses the degree of variation and the achievement of business goals to determine the performance of a process. The framework will be used in chapter 10 to analyse the change in process performance per capability level. Moreover, this framework will be valuable in order to indicate the degree of process improvement and answering SQ5. The gathered data is analysed in a quantitative approach, comparing the outcomes results in findings on the improvement of process performance.

The last step of this research consists of the validation. A questionnaire is used to validate the findings of each step of this research with experienced practitioners. The validation is also used to determine if the life cycle standard achieves the goals of the contractor and answers SQ6. The combination of SQ leads to the answer of the main research question. The findings are discussed and recommendations for further application and further research are given.

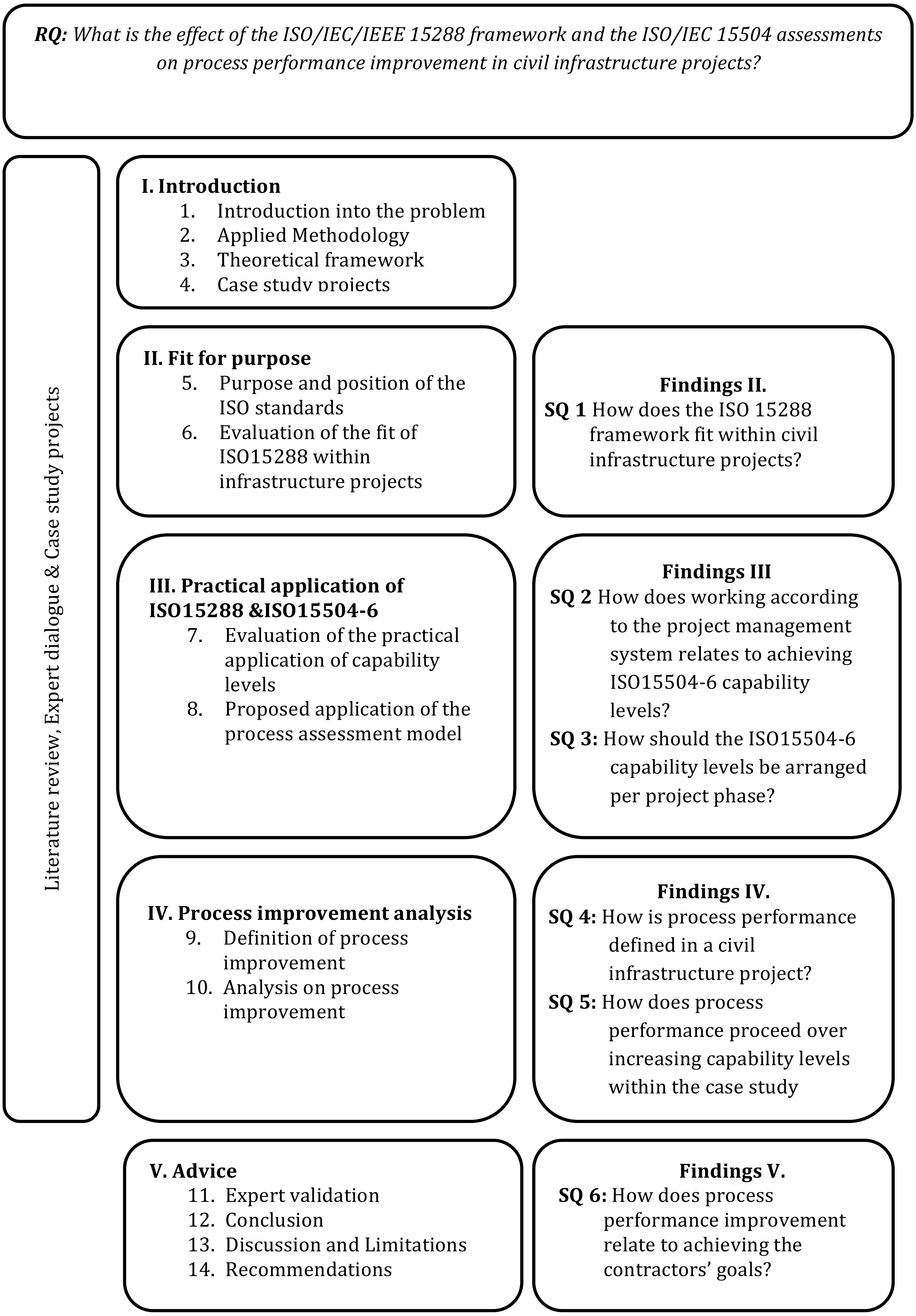


Figure 4: Schematized research framework

3 Theoretical framework

The literature review aims elaborate on the details provided in the introduction. The chapter discusses the differences between an infrastructure project and an IT project and describes the situation of underachieving projects in the Netherlands. The theoretical effect of standardisation on the performance of processes is described. The chapter focuses on how to measure process performance and describes effects of the application in practice.

3.1 Differences in sector characteristics

The standards are designed for the IT sector, which is much different from the civil infrastructure sector. The characteristics of an infrastructure project are compared against those of an IT project. The differences serve as input for the evaluation of the fit in chapter 5.

- Civil infrastructure:

Fragmentation, typically a construction project is executed by a large number of firms and, holds a strong division between the project team in design and construction stages, both causing difficulties on coordination and integration. (Alaswal & Sik-Way Fong, 2015) Physical domain, an infrastructure project is a definite system when the construction has started. The system is constructed within the physical domain of functioning systems and is paired with physical changes to the environment. (Pinto & Covin, 1989; Wasson, 2006) Dynamic environment and immediate interaction, during the construction of an infrastructure project the system is constructed within the system boundaries of interacting systems. During every phase of the construction, the functioning of the system of interest has to be guaranteed. This means an infrastructure project has to interact with the other systems before it is completed (Winch, 2010).

- IT

An IT project uses hardware, software and networks to create a product or service. The rapid development in the sector causes technology to be out-dated before the project is completed. In the project, there is a large focus on security and data management (Schwalbe, 2015). In IT project a large part of the budget is spent during the development of the project, the costs of the execution are considerable smaller.

3.2 Underachieving construction projects

Failure costs are one of the factors causing underachieving projects. Failure costs are considered avoidable costs. Failure costs can occur in all project phases and have different causes; the factors leading to failure costs are not often directly seen and can originate from an earlier project phase. Inefficiencies and failure in the design, inefficient work preparation, planning issues, delayed supplies or failures in supplies, waste, unskilled workforce, bad quality of work and communication issues can strongly affect the outcome of the construction project (BouwKennis, 2015). Failure costs can have a major effect on the outcome of a construction project. In the Dutch construction sector profit margins are small while the failure costs are large, for example, on an average project a contractor works with an approximate profit margin of 2% while the failure rate was 7.7% of the total turnover in 2001 and increased to 10.3% in 2010 (Santema et al., 2010); (Wal, 2015) PWC (2015) estimated the failure cost in the construction sector between 8 and 13% of the total construction output of 52 billion euro. Over time the sector gained awareness for a combined effort between constructors, their suppliers and their clients to lower the failure costs. Santema et al. (2010) argue that the lack of communication and information transfer, inadequate attention for a feasible design, and the delivery of quality to the end user as the biggest priority points for the sector. As an approach to reduce failure costs the Dutch construction industry introduced integrated contracts and quality

based tender selections. The effects of these efforts are visible in certain areas but more problems have to be overcome. (Boes & Dorée, 2008)
Janssen and Klievink (2012) identify five categories of failure factors that can lead to the failure costs in the development of projects, in this research the process category is further evaluated:

- Organisational network: consists of disagreements in the regarding the certain roles involved and aims of the collaborating organisations.
- People: consists of the lack of motivation, capabilities, and the internal relations of people contributing to the project.
- Process: consists of inefficiencies, underestimation, segmentation, and no stakeholder involvement in the processes needed to successfully achieve a project.
- Product: consists of unclear objectives and ambitious requirements of the project.
- Technology: consists of too many and overestimating innovations, and an addition of new risks and changes during the project.

Need in construction sector
Construction projects can be defined as complex, due to the many disciplines and stakeholders, fragmented processes, temporary duration, are these construction projects unique in each project (Chan & Chan, 2004; Horstman & Witteveen, 2013). With the addition of quality standards, integrated contracts and performance contracts, the responsibility for the contractor gradually increased. The scope of current civil infrastructure projects is growing and therefore becoming more complex while the demand for safety and sustainability is increasing and costs need to be reduced. (SE, 2013) The civil infrastructure sector changed from solely designing and constructing objects to providing the full service for the consumer. In this switch from a solution- oriented to a problem-oriented approach, contractors are expected to design, built, finance, maintain and operate these complex projects in a multi-stakeholder environment (Horstman & Witteveen, 2013; Houdt & Vrancken, 2013). In a problem-oriented approach the responsibilities of design, realisation and in some cases exploitation shifts from client to the contractor. Clients deliberately take a step back and transfer actions to the contractor, for example, the supervision changed from checking each individual object to auditing the internal processes of the contractor. To manage projects with increased complex environments, to shift responsibilities and to reduce the failure cost, both parties adopted standardisation as a method to achieve an improvement in process implementation and optimisation.

3.3 Effect of standardisation on process performance

The most frequent mentioned benefit of standardisation is the reduction of variation. Reduction in process variability results in an increase of quality, delivery time and cost (Santos, Formoso, & Tookey, 2002). The variability in one process can effect the input of successive processes; resulting in a far greater variation which might even lead to an unacceptable process output (Santos et al., 2002) Therefore, reducing variability can increase the level of competitiveness of an organisation (Polesie, 2013; Santos et al., 2002; Sommerville, Craig, & Bowden, 2004). The knowledge and resources of an organisation are fully exploited in the development of standardised procedures; operators of procedures do not need to obtain the expertise to develop these actions. The conserved time can be used to solve unique and complex problems. (Wears, 2014). The anticipated levels of performance improvement in the construction sector are supported by results of standardisation of processes in other sectors (Edum-Fotwe, Gibb, & Befort-Miller, 2004)
Standardisation also has its downsides; the knowledge used to develop standard procedures is out-dated and therefore decreases the efficiency of organisations (Wears, 2014). Especially the construction sector might experience difficulties when implementing standardisation. Construction projects are generally seen as unique systems and the course of construction is

difficult to predict. Implementing standards is experienced as difficult and might not benefit the organisation (Polesie, 2013; Wears, 2014). Adopting a standard does not guarantee result; correct implementation and continuously reviewing and improving are an important part of achieving a result (Santos et al., 2002). ISO standardisation is a tool to implement standardisation in the construction industry; measuring the effect of ISO standardisation on construction processes provides a quantitative indicator of its effect.

Performance measurement

Implementing the system life cycle standard to improve process performance is paired with the use of performance measurement. Performance measurement provides organisations additional information to control their processes. This information brings transparency, is a motivation to increase output, and appoints accountability within an organisation (Bruijn, 2002). In the construction industry, performance indicators (PI) are often used as an input for these performance measurements. PI provides organisations quantitative indicators, which visually display the performance of the measurement (Sanchez & Robert, 2010). PI can be leading and be lagging as well as quantitative and qualitative. Lagging PI indicates past results while leading PI provides the opportunity to forecast and steer on the achievement of objectives (Horstman & Witteveen, 2013; Sanchez & Robert, 2010). The use of PI also has its downsides; firstly, contractors experience difficulties in the collection and benchmarking of data, secondly, indicators are difficult to quantify, thirdly, the measurements are time and resource consuming, fourthly, the use of PI places a heavy burden on the personnel, and lastly, the attention for the indicators falls as the project advances (Chan & Chan, 2004; Horstman & Witteveen, 2013; Sanchez & Robert, 2010). As a measure de Bruijn (2002) proposes to prevent measurement on output. Standardised process measurements, adopted by both parties and supported by an industry-wide benchmarking achieve a greater result and would justify the input of resources (Bruijn, 2002; Horstman & Witteveen, 2013).

Performance measurements form the basis to determine the process capability of an organisation. Process maturity is used to translate process capability into relative values. The process assessment model and the process maturity model use a similar scale to determine the capability of an organisation.(Boehm, Port, & Basili, 2001) However, a capability level does not have to reflect the actual performance of a project. External factors can influence the performance of a project, however, mature organisations are regarded as being more able to adjust to these factors (Sarshar, Haigh, Finnemore, Aoaud, & Baldery, 2000). Reaching higher capability and maturity levels are some tools in order to achieve process improvement. The aim for process improvement is driven by the search to increase productivity and limiting reworks.

Results of process improvement caused maturity

Over the years multiple process improvement models based on maturity are developed. Schweigert, Vohwinkel, Korsaa, Nevalainen, and Biro (2013) found forty different maturity models. Most maturity models are based on the principles for change and reorganisation in software development. Maturity models are also used in the construction industry; two examples of these models are Process Improvement for Construction Enterprises (SPICE) and Capability Maturity Model (CMM). Both models are based on process capability and process maturity. Process capability uses a five level framework in predicting the outcome of the process. Incensement in the capability levels increases the predictability of process. Process maturity uses the same 5 level frameworks as process capability, while maturity reflects on the entire organisation (Sarshar et al., 2000). ISO15504-6 strives to a similar stepwise improvement in process capability and in maturity; therefore the standard can be interpreted as an advanced model of SPICE and CMM. Results out of the software sector show that the stepwise improvement results in actual performance improvement (Dion, 1993; Dorling, 1993).

4 Case study projects

In this chapter the empirical gathered for this research is divided into contractual information and project specific information. The gathered information and the types of projects are described in the table.

4.1 Types of information

Existing research on the framework and assessment is limited therefore a large part of the input for this research consists out of information gathered from case study projects. To obtain valuable information the prerequisites for the case studies are arrangements of the processes according to the ISO15288 framework and assessment of capability levels by an external assessor. The information obtained from the case studies can be divided into the contractual information and the process specific information.

- The contractual information consists of the tailoring of the contractors' processes on the ISO15288 processes and the required, offered and obtained capability levels per project phase. Since the required information does not contain project sensitive information, the pool of projects consists of eight case study projects.
- The project specific information consists of measurements on performance indicators gathered by the contractors itself. An additional prerequisite for this type of information is the existence of minimal half a year of performance measurements. Six months of measurements are necessary to detect a reliable development in the process performance. The pool of case study projects that fit these requirements and are willing to share the specific information is considerable smaller. To draw significant conclusions over the measurements, four case study projects are desirable and two case study projects are the minimum to obtain information. Based on these criteria this research processes are selected in chapter 10.

This research is primarily based on case study results, it is considered as explorative and the outcomes as hypotheses. Expert validation is used to ratify these hypotheses, however, future research into a larger pool of case study projects is advised.

4.1 Selected case studies

All selected case study projects are civil infrastructure projects located in the Netherlands. Most DBFM contracts prescribed the implementation of the ISO15288 framework and ISO15504 assessment; therefore seven out of the eight projects are constructed or maintained by a DBFM agreement. The range case study projects cover all the different projects phases, with projects ranging from the development phase until the maintenance phase. The projects are made anonymous in a request of the project organisations. In the following chapters of this research, only the project number is used to indicate the designated project. The number corresponds to the projects displayed in table 2.

Table 2: Case study projects

#	Details	Information	
		Contractual	**Project specific**
Project 1	*Type*: Dry DBFM project *Specifics:* Road expansion *Project phase:* Maintenance phase	X	X
Project 2	*Type*: Dry & wet DBFM project *Specifics*: Road expansion *Project phase:* End of realisation phase	X	X
Project 3	*Type*: Wet DBFM project *Specifics:* Sluice expansion *Project phase:* Begin realisation phase	X	X
Project 4	*Type*: Dry PDC project *Specifics:* Road expansion *Project phase:* In planning phase	X	X
Project 5	*Type*: Wet DBFM project *Specifics:* Sluice expansion *Project phase:* End realisation phase	X	X
Project 6	*Type*: Dry DBFM project *Specifics:* Road expansion *Project phase:* Begin realisation phase	X	
Project 7	*Type*: Dry DBFM project *Specifics:* Road expansion *Project phase:* Realisation phase	X	
Project 8	*Type*: Dry DBFM project *Specifics:* Road expansion *Project phase:* Begin realisation phase	X	

-II-

Fit for purpose

5 Position and purpose of the ISO standards

ISO15504-6 is one of many audits systems operating in an infrastructure project. The position of ISO15504-6 within these standards and purpose for the contractor for implementing ISO15504-6 are evaluated in the following paragraphs.

5.1 Position of the standards in an infrastructure project

During the execution of an infrastructure project, a range of audit system measures the contractors' performance. These systems are used to compare the operating levels and performance indicators against the requirements and target values (Hastings, 2015). The audit systems within an infrastructure project can be divided into internal and external audits. The internal audits are performed by the project organisation itself, the external audits are performed by the client or entrusted to specialised organisations. Internal audits are used to check if the processes comply with the quality standards of the contractor, the contractual requirements and covers requirements out of external audits. External audits are used to determine if the project complies with audit specific requirements. An external audit is focussed a specific subject, however, an overlap between the audits is possible. Typical external audits in a Dutch infrastructure construction project are:

- Electronic Data Processing audit (EDP): Monitors the accurateness and functioning of data management systems. The audit varies from the financial systems to the document management systems.(Wilson, 2012)
- System-oriented contract audit (SCB): Auditing the quality management system of the contractor to ensure the quality of the end product fulfils the requirements of the client. (Rijkswaterstaat)
- Safety, Health and Environment (VCA): Certificate intended to increase the safety and accidents of an organisation.
- Safety Performance Indicator Contractor (SPIC): Monitoring safety performance of the entire chain of contractors involved in a project. SPIC is only used for monitoring, measures resulting from the SPIC can be imposed by the SCB. (Weger, 2012)
- ISO 9001 Quality Management system: Audits the quality of the management system, used to ensure and demonstrate the quality of the products meet the client and regulatory requirements. (ISO, 2015)
- ISO 15504-6 Process assessment – System life cycle: Used to assess the performance of the system life cycle processes (ISO 15288), provides repeatable methods and relative values to repeat and compare assessments. (ISO/IEC, 2013)

Position of ISO15504-6

ISO15504 is an assessment model that monitors the capability to assess the performance of processes. The standard serves as a handhold to perform a consisted assessment (ISO/IEC, 2013). ISO15504 exist out of ten parts, part 6 of ISO15504 is specifically developed to assess processes that are arranged according to the ISO15288 framework. The relation between the standards causes this research to interpret the standards as a combined approach. ISO15504-6 assesses all processes included in the life cycle of a system; therefore an overlap with other audits is possible. For example, while assessing the quality management process according to ISO15504-6 an overlap between the attributes related to the ISO9001 Quality management system and the SCB audit occurs. ISO15504-6 distinguishes itself as an assessment model, while ISO9001 is a performance audit. In the assessment model, the performance of the process is expressed in a relative value; the assessment provides requirements for the process to achieve this value. The audit checks if the system achieves the requirements for the specific subject.

5.2 Purpose

In the Dutch construction sector, the client prescribes the implementation of the ISO 15288 framework and the ISO 15504-6 assessment in most DBFM contracts (Rijkswaterstaat, 2016). Out of the eight case studies used in this research, only one project implemented the standards out of its own intention. It is seen, contractors often apply a higher capability level as contractual prescribed by the client, this will be further elaborated in Chapter 7. Based on this knowledge, the contractor pursues multiple goals with the implementation of the standards; the goals are prescribed in the non-specific order.

- The use of ISO15288 and ISO15504-6 is prescribed in the bindings agreement of a DBFM project. The DBFM agreement assigns three penalty points for not achieving the capability levels within the designated time frame and another four penalty points for not recovering in the next designated timeframe. The weight of these penalty points is relatively high, it can be compared with the penalty for critical safety issues related to causing an unsafe situation for road users (Rijkswaterstaat, 2016). The contractor has a contractual obligation to implement the framework and achieve certain capability levels within a designated timeframe. Not achieving this obligation results in a financial loss.

- The second goal proceeds out of the literature review. The failure cost in construction projects consumes a considerable part of the total budget, between 7 and 13% (PWC, 2015). Standardisation of project processes can reduce the variation and increase the competitiveness of the contractor (Polesie, 2013; Santos et al., 2002; Sommerville et al., 2004). The ISO 15288 framework and the ISO 15504-6 assessment are considered as one of these standardisations. The standards claim to provide procedures able to reduce the variation and provide the ability to monitor the performance and to be able to steer processes to achieve business goals. (ISO/IEC, 2013). If the combination of standards achieves the claimed increase of process performance, then indirect the ISO 15288 framework and the ISO 15504-6 assessments help to reduce the failure cost in infrastructure construction projects. However, an increase in process performance is only a reduction in one of the five categories of failure factors mentioned by Janssen and Klievink (2012). The other factors organisational network, people, product and technology are still in play.

- The third goal is indirectly linked to the implementation of the standards. By including the ISO 15288 framework and the ISO 15504-6 assessments as a whole or only including higher capability levels as contractual required in the tender bid, the contractor can differentiate itself from the other bids. Disregarding the positive effects of standardisation, the capability levels allegedly represent a relative value that represents the capability of the project processes. The goal for the contractor is to differentiate itself from the other bids and increase its chances of winning during the procurement of a project.

6 Evaluation of the fit of ISO15288

The first step to determine the effect of the ISO standards is to evaluate the fit of the standards on civil infrastructure projects. This evaluation is performed by evaluating theoretical life cycle of ISO15288 and the life cycle of an infrastructure project.

6.1 Theoretical life cycle evaluation

A joint technical committee of Information Technology, Software and Systems Engineering and Computer Society Systems designed the ISO 15288 System Life Cycle Standard for the development of IT systems. The latest version of the standard claims to establish a framework for "*all man-made systems*" (ISO/IEC/IEEE, 2015, p. 5). As mentioned in chapter 1, the standard works as a structured guideline in the arrangement of processes in the life cycle of a system. Sarshar et al. (2000) states that an innovation designed in another sector needs to fit the context and conditions of the implemented sector in order to achieve the intended result. Based on this statement the fit of the ISO15288 on a civil infrastructure project is evaluated. ISO15288 is considered as a System Life Cycle standard, therefore an evaluation of the fit between the applied life cycle in the standard and the life cycle of an infrastructure project is considered as the starting point in this research.
The characteristics of an infrastructure and an IT project are described in chapter 3.1. Based on these characterises the life cycle of ISO15288 and the life cycle of an infrastructure project are evaluated.

Life Cycle of an Infrastructure project
The fit of the standard is determined by comparing the life cycle of an infrastructure project with the life cycle supported by ISO15288. The life cycle of an infrastructure is defined by combining the definitions of (Bull, 2015; PMI, 2008; Wasson, 2006). The stages and essence are shown in **Table 3**.

Stages					
Definition	Procurement	Development	Construction	Operations & maintenance	Retirement
Feasibility study Operational need	Proposal Preliminary design, planning & costing	System design Planning & costing	Method and phases of construction	Payment maintenance	Disposal End of life cycle

Table 3: Combined infrastructure life cycle model and purpose

Life cycle of ISO15288
The purpose of ISO 15288 is to provide a defined set of processes to facilitate communication among acquirers, suppliers and other stakeholders during the life cycle of a system. (ISO/IEC, 2010) The group name for life cycles of different products and services is called a life cycle model. A life cycle model is divided into life cycle stages, a system progresses through these stages during its life cycle. There is limitless variety in the number of life cycle models. However, essential characteristics life cycle stages exist in the life cycle of any system. ISO 24748 *guide for life cycle management* uses the following principles applicable for life cycle models:

- The stages do not have to progress in a successive order; interaction between the stages is possible.
- Enabling tools and attributes should be available for each stage in order to achieve the outcomes of the stage.
- Progression to another stage requires fulfilment of exit conditions of the present stage

Evaluation

The compatibility of ISO15288 to an infrastructure project is determined by evaluating if the life cycle of an infrastructure project fits within, one or a combination of, the domain life cycles supported by the standard. The life cycle models and stages currently supported by ISO 15288 are shown in **Table 4**. In this table, the stages that are comparable with the stages of an infrastructure project (shown in **Table 3**) are highlighted. The highlighted stages cover the entire life of the model and of the infrastructure project. The flexibility and adaptation of the life cycle model supported by ISO15288 combined already highlighted stages shown in **Table 4** indicate ISO15288 is applicable on the life cycle of an infrastructure project. However, the non-highlighted cell still cover half of the supported models. Not all process included in the standard have to be applicable to an infrastructure project. Also, it is not confirmed all processes associated with the development of an infrastructure project are included in the process framework of ISO15288.

Table 4: Domain life cycle models supported by ISO15288 (based on ISO/IEC, 2010, p.44)

Models	Stages								
System	Concept	Development		Production		Utilisation		Support	Retirement
Software	Concept	Development		Operation & maintenance					Retirement
Hardware	Concept	Design	Fabrication	Operation & Maintenance					Retirement
Services	Service strategy	Service design	Service transition	Service operation			Continual service improvement		
Human	Skill needs definition	Acquisition		Training	Skills use & maturation				Retirement
Facility	Rendering	Structure & site design		Permitting	Construction		Operation & maintenance		Retirement
Process	Output definition	Flowcharting		Write-up	Pilot use		Use & improvement		Retirement
Natural Entity	Acquisition	Development		Exploitation					Retirement

6.2 Practical evaluation

In the case study projects, the practical life cycle stages for the contractor differs from the theoretical life cycle stages shown in **Table 3**. Based on the case study projects the practical life cycle stages for a DBFM project are shown in **Figure 5**.

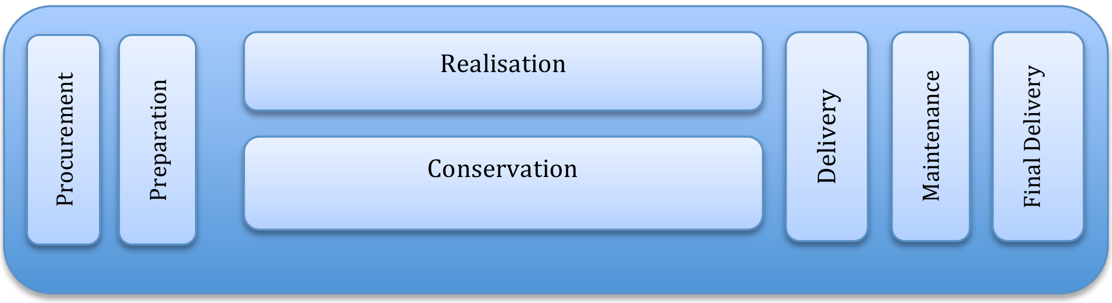


Figure 5: Case study life cycle stages

Before the project is available on the market, the client determines the operational need and feasibility. The project life cycle for the contractor starts at the procurement stage. If the contractor is allowed to execute the project it employs a preparation stage to organise the project team before following to the development stage. During the realisation of the project, the contractor is responsible for the availability of the existing infrastructure (Rijkswaterstaat, 2016). The realisation stage consists of the design, preparation and execution of the work. At the end of the realisation phase, the contractor delivers the project to the client, however it is still responsible for the maintenance of the project. The maintenance stage of the case study projects varies between 20-30 years. After this period, the contractor is no longer responsible for the maintenance of the project and hands over the responsibilities to the client.

Processes included in the ISO15288 framework

ISO15288 provides a list of processes necessary to complete a project, the list consists out of 30 processes divided into four categories (shown in **Figure 3**) This collection of processes is not assumed to be sufficient to complete a project and the categories are designed to create minimum dependencies between the different disciplines in an organisation (ISO/IEC/IEEE, 2015, p. 17):

- *Agreement processes:*

Are used for creating an agreement between the acquirer and supplier. The agreement processes serve as the basis for the initiation and transition to another stage of the project

- *Organisational project-enabling processes*:

Provide resources and infrastructure to create, support and monitor projects

- *Technical management processes:*

Are used to support technical processes, by assuring confirmation to the agreement, planning, risk and decision-making

- *Technical processes*:

Perform technical actions during the entire life cycle of a system; translate the agreement into a product or service.

Technical processes

In this research, the agreement, organisational project enabling and technical management categories are considered supportive in the development of any system. The technical processes are more specific to the realisation of a specific system. The intended application of the technical processes is provided in ISO24748. This standard prescribes the application of the technical processes used for the development of a system-of-interest. **Figure 6** shows this intended application. The application consists of two iterative phases with decision gates between the stages (ISO/IEC, 2011). The first iterative phase consists of the requirements and design processes, into which the design is made based on the stakeholder requirements. The first decision gate is located before the implementation process. The second iterative phase consists of integrating the sub-elements to construct a system-of-interest. The system is verified to determine if it fulfils the requirements and validated to determine if the system fulfils the stakeholder needs.

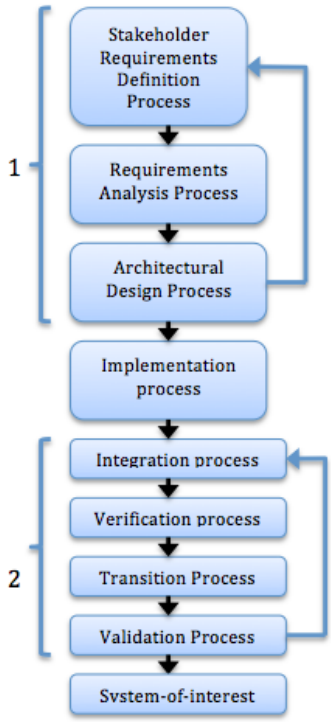


Figure 6: Application of technical processes (ISO/IEC, 2011, p. 30)

The processes can be executed for each sub-systems level and lead to the system-of-interest. Note that a system of interest is composed out of a number of system elements. A system element can be considered as a lower level system by itself since it is again composed by a number of system elements (Wasson, 2006). These system engineering principles are further explained in **appendix A.**

Application of technical processes in an infrastructure project

The proposed application of the technical processes is compared with the processes and activities in the case studies. The applicability of the proposed application, shown in **Figure 6**, is used to determine the fit of the IO15288 processes in an infrastructure project.

- The definitions corresponding to the processes belonging to the first iterative phase of the application are related to the design stage within the life cycle of an infrastructure project, translating the requirements into an architectural design.
- The purpose of the implementation process is to realise a specific system element, relative to the system level within the process is operating(ISO, 2015). When translating the implementation process to a construction project, the process can vary from the construction of a bridge within an infrastructure system to the construction of a bridge element within a bridge system. Within a construction project, the implementation process contains the actual realisation of a system.
- The purpose of the second iterative phase is to integrate the system elements into a system and verify the system meets its requirements (ISO/IEC, 2010). These processes can be related to the construction and delivery phase in a construction project.

The characteristics of an infrastructure construction project make it not desirable to follow the sequence of application described by ISO24748. As described in Chapter 3.1, an infrastructure project physically changes the environment (Pinto & Covin, 1989) making it undesirable to verify and validate the system after it is constructed. In the case study projects, the project is also validated before the execution of the work, changes that might occur during this stage do not cause changes to the physical environment.

6.3 ISO15288 process framework

ISO 24748 described the application of the standard in sectors other than the IT sector. ISO24748 specifically mentions the civil engineering discipline in their advice for achieving the best outcome:

> "*Life cycle models would not need to be developed or adapted for a specific discipline (such as mechanical engineering, electrical engineering, civil engineering). Instead, the processes associated with the life cycle model(s) in which that discipline is used would be adapted to reflect the overall considerations, ... , possibly with additional adaptation for the discipline itself.* " (ISO/IEC, 2010, p. 74)

The development of a new life cycle model fit for civil infrastructure construction is not considered the solution to include all the associated processes; this would lead to a surplus of models for each specific project. ISO 24748-2 recommends organisations to choose the most applicable, or a combination of, life cycle models and adapt the underlying processes to make it fit the purpose of the project.

ISO15288 contains life cycles models supporting hardware, software, data, humans, processes, procedures, facilities, materials and naturally occurring entities system elements (ISO, 2015). The standard does not prescribe any particular life cycle model; it defines a set of processes for the life cycle stages of the systems life cycle model. By adjusting this set of processes deviating life cycle stages can be included in the model. Revising the processes should be done by a structured approach called life cycle adaptation. When adapting the life cycle processes, one should be aware of no removing entry criteria for following processes. The procedure of adaptation is explained in the following section.

6.4 Adaptation for Civil Infrastructure projects

The adaptation procedure is described also described in ISO 24748. Adaptation consists within each of the four process categories, adaptation on the number of categories is not recommended. The procedure consists of including and excluding processes, which do not fit the context of the project or are not considered by ISO15288. The standard provides five mechanisms for adaptation:

- *Process selection:*

Select the processes relevant to their needs and declare (full) conformance to the set

- *Process substitution:*

Use processes from related standards, (such as software, safety)

- *Use of outcomes:*

Conformance is declared by achieving the satisfied outcomes; other actives and tasks may be performed.

- *Use of activities:*

Conformance is declared by achieving the activities; resulting in deviating outcomes but satisfy the organisation.

- *Process tailoring:*

Tailoring the process by selecting specific outcomes, activities, or tasks.

In the case study project only process selection and process tailoring are used as adaptation mechanisms. Process selection consists of excluding processes out of the provided list of thirty processes (shown in figure 1). Process tailoring is executed by only eliminating outcomes out of this list of processes.

Process tailoring and selection

Appendix B provides an overview of the process adaptation used in the case study projects, per case study the tailored and excluded processes are shown. Bound by the contractual agreement all of the case study projects had to declare full conformance on a similar set of eleven processes, an adjustment on these processes is not allowed. The remaining nineteen processes the projects show similar results on excluded processes.

- Portfolio Management Process: *excluded by all eight case studies*

The portfolio management process is used to select the right projects for an organisation. The process monitors the projects in order to justify continuous investments. (ISO/IEC/IEEE, 2015) Organisations argue the project is a single project company and therefore no portfolio is maintained, leading to the elimination of the process. However, the process could be used to determine the strategic objectives of scope changes for an organisation, calculation of additional work. Organisations experience the process as to extensive for the desired outcome.

- Human Resource Management Process: *excluded by six out of eight*

The human resource management process provides the human resource for the organisation to achieve their goals within the agreement requirements. (ISO/IEC, 2011) Organisations justify the elimination by arguing it is a single project company and the process is arranged by the mother organisation. However, the outcomes of the processes relate directly to the skills required and achieving the agreement of this specific project. (ISO/IEC/IEEE, 2015) These outcomes can only be interpreted from a project's perspective, therefore the process is vital to achieving the project result and is best included in the standard.

- Operation Process: *excluded by all eight case studies*

The operation process can be used when the realisation is adequate progressed in order for the system to deliver output for the desired stakeholders (ISO/IEC, 2011). The purpose of the processes is to operate the system in order to deliver its intended result. It establishes requirements to operate the system and monitors the operators' performance (ISO/IEC/IEEE, 2015). Adapting the operation processes is dependent on the content of the agreement. When a contractor is not responsible for the operation of the system the process can be excluded. The outcome: "a) *Operation constraints that influence system requirements, architecture, or design are identified*" (ISO/IEC/IEEE, 2015) should still be achieved by the System Requirements process.

Including project specific processes

The case study projects show common results in excluding processes. However, none of the projects included specific processes for infrastructure projects. The project organisations do execute these processes according to their own management system. Health and Safety, traffic management and environment management are examples of processes the most common executed independently by ISO15288. Adjustment of the standard by including those processes would result in a more uniform approach to the executed processes within a construction project. Case study project six did include all their processes in the ISO15504-6 assessment, health and safety was included in these processes but designed according to their own project management system and separate from ISO15288.

6.5 Findings part II

The application of ISO15288 and ISO15504-6 has multiple incentives, which differ in goal. Within the case studies, the combination of standards is contractual prescribed, not fulfilling these requirements can result in penalty points, the combination can be used to stand-out from the other contractors in terms of claimed performance but the real goal should be achieving an increase in process performance.

The life cycle model of ISO15288 is designed to be applicable on a wide arrange of projects. When comparing this life cycle model with the theoretical and practical life cycle of an infrastructure project, a certain overlap in the project stages is shown. This overlap does not guarantee the presence of all specific project elements. When these elements are not available, it is not desirable to develop a new life cycle model designed to fit a certain sector.

The processes included in the ISO15288 framework are not sufficient to successfully execute a project. Furthermore, the addition of project specific processes is necessary. Adjusting the existing life cycle model, according to all five-adaptation principles, will result in an applicable standard for infrastructure construction projects. By not only excluding but also including project specific processes, ISO15288 is able to contribute to the achievement of a successful project. The most important processes to include are health and safety, and traffic management. In the standards the processes are described by abstract definitions, causing the interpretation of the processes to vary over the practitioners.

The findings out of part II provide input to answer SQ1; with project specific adaptation the ISO15288 standards can fit the civil infrastructure projects. However, more knowledge about the implementation of the framework is needed to use ISO15288 to successfully execute a project.

After the analysis on the fit of ISO15288, this research focuses on the application of ISO15504-6. In part III the practical application of ISO15504-6 within the case studies is evaluated. The differences in application lead to the development of a new design for the application of this standard over the entire life cycle of an infrastructure project.

-III-

Practical application of ISO15288 & ISO15504-6

7 Practical application of capability levels

The differences in the application of ISO15504-6 within the case studies are evaluated. These findings are combined with the theoretical aspects of the ISO standard; this leads to a recommendation on the most applicable capability levels in each phase.

7.1 Variation in capability levels within the case studies

ISO 15504-6 is designed as a process assessment model for the ISO 15288 standard. The model is used to translate the capability of a process into relative and comparable values, called capability levels. The practices of the standard are developed to achieve a consisted and repeatable processes assessment. ISO 15504-6 uses six capability levels that capability of a process. These capability levels are divided into nine process attributes (PA), shown in **Table 5**. These PA determine if a process has reached a certain capability and represent a measurable aspect of the capability level. Each process attribute has associated Generic Practices (GP), Generic Resources (GR) and Generic Work Products (GWP). The assessment is based on objective characteristics used to confirm if certain practices in the processes are performed. The combined achievement of process capability indicators and process attributes translates to a certain capability level. (ISO/IEC, 2013, pp. 7-9).

Table 5: Capability levels and process attributes (ISO/IEC, 2013, p. 8)

Process Attribute	Capability levels and Process Attributes
	Level 0: Incomplete process
	Level 1: Performed process
PA 1.1	Process performance
	Level 2: Management process
PA 2.1	Performance management
PA 2.2	Work products management
	Level 3: Established process
PA 3.1	Process definition
PA 3.2	Process deployment
	Level 4: Predictable process
PA 4.1	Process measurement
PA 4.2	Process control
	Level 5: Optimising process
PA 5.1	Process innovation
PA 5.2	Continuous optimisation

Capability levels in practice

In civil infrastructure projects this combination of GP, GR and GWP is also used to determine the content of each capability level. The bindings agreement between the client and the contractor links the achievement of a certain capability level to the phase of the project. When the project progresses into another phase certain capability levels increase in height.

Since the beginning of the implementation of these standards the required capability levels changes over the project. Out of the eight case study project the height of the capability levels in each phase is known (**shown in appendix C**). An evaluation of these levels indicates variation and similarities in the required capability levels. The most important findings are evaluated to determine the evolvement of the required capability levels.

- Contractors start to implement ISO15288 and ISO15504 into infrastructure projects that do not contractual require the standards. By including the standards in the tender bids the standards are considered part of the final agreement.
- Contractors aim for achieving a higher capability level as contractually required. However, this is only seen for a limited number of processes, no parallels in the selected processes are identified.
- In the latest project, more processes aim to achieve or achieved capability level 4. This is caused by an increased contractual requirement and the effort of the contractor to achieve a level higher than contractual required.
- Different capability levels are required in wet and dry infrastructure projects. In dry projects, the supply process requires capability level 4; in wet projects the acquisition process requires level 4.
- The project duration to achieve a higher capability level is reduced, resulting in less time between succeeding capability level.
    - The achievement of these higher levels is often based on intention rather than achievement. The processes have not started to produce data when the requirements have to be met.
- Reduction in the number of project phases, in one of the DBFM projects the maintenance phase is no longer included in the ISO 15504-6. This is shown **Figure 7**.

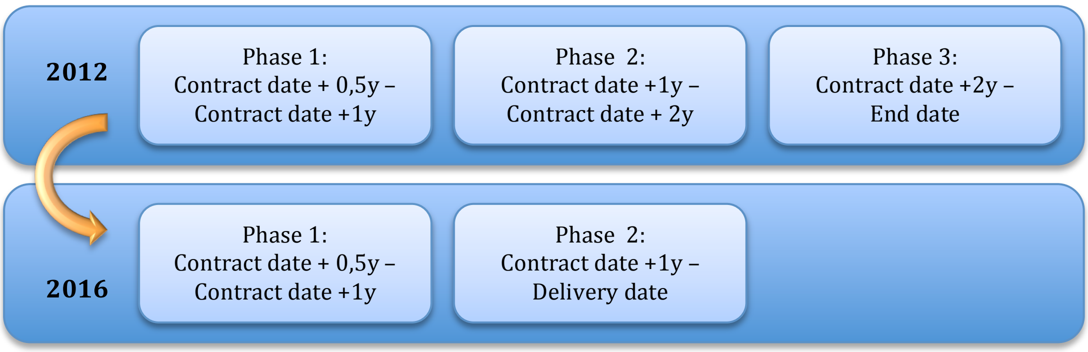


Figure 7: Change in contractual project phases (DBFM contract)

7.2 Capability level of the project management system

Before and during the implementation of the ISO standards, contractors already manage a project management system to control, organise, prepare and execute the development of an infrastructure project. In this project management system procedures and outputs for all the processes are described in order to effectively execute a project (SE, 2013). For most contractors, the project management system is not a one-on-one match with ISO15288. To obtain conformance to ISO15288 the processes are mapped and adjusted to fit the purpose, outcome and activities used in this standard. Contractors experienced in working according to the ISO standards update and improve their management system to achieve the desired capability level. Construction projects are unique. However, the majority of the processes and procedures are applicable to any construction project. The contractor can use its updated project management system in future projects.

Capability levels

The capability levels of ISO15504-6 describe a number of activities and outputs the processes need to execute in order to comply with a certain capability level. A comparison is made between the described activities and outputs and the project management system of the contractor. With this evaluation, the added value of the standards on extra to the project management system is evaluated. This evaluation starts with determining the activities and outputs relating to each capability level. Level 0 and level 5 are not applicable in case studies.

> *Level 1: Performed process*
>
> Work products are produced to provide evidence for process outcome. For each process base practices define the content of the work products. (ISO/IEC, 2013, p. 7)
>
> *Level 2: Managed process*
>
> The process delivers work products within defined timescales and according to defined standards and requirements. The process is planned and managed in order to achieve a defined outcome. (ISO/IEC, 2013, p. 71)
>
> *Level 3: Established process*
>
> The process is managed by a defined process procedure; it exists of documented standardised procedures and all the resources are in place to deliver the defined outcome. Level 3.1 contains the definition of the process; the second part is the deployment of the defined process. (ISO/IEC, 2013, p. 77)
>
> *Level 4: Predictable process*
>
> The established process is controlled and analysed to demonstrate it operates according to the organisations' goals. This information provides the ability to make adjustments in order to achieve those goals. (ISO/IEC, 2013, p. 81)

Project Management System

Results out of case study 6 and 7 achieve capability level 3 at the start of the project. These results show an experienced contractor is able to design and work according to a project management system which can be compared to achieving capability level 3, an established process. Additionally, the characteristics of an established process: standardised processes, interactions with other processes, competences and responsibilities, necessary work environment and methods for monitoring are all incorporated in the investigated project management systems. The level of standardisation in these management systems concedes with the definition of processes according to PA 3.1. Hypothetical the management system can operate at capability level three, however defining the process according to PA 3.1 does not guarantee deployment according to PA 3.2. Assessment should indicate if the design requirements are actually achieved.

7.3 Project phases

The binding agreement between the client and the contractor divides the project into phases into which a certain capability level for the project processes is required (Rijkswaterstaat, 2016). As explained in chapter 7.1, these phases within the investigated case studies. The applied phases in the case studies (shown in **Figure 7**) are mapped on the life cycle of a DBFM infrastructure project (defined in chapter 6). Based on this analysis the following conclusions are drawn.

1. The phases in 2012 show: the ISO Standards overlap the entire project life cycle phases except for the procurement and preparation phase. The capability level required in the realisation phase is similar to the required level in the maintenance phase.
2. The phases in 2015 show: the ISO Standards overlap a smaller section of the project life cycle. The standard is implemented from the design stage until the delivery stage. During the maintenance stage, a capability level is no longer contractual required.

8 Proposed new design for the ISO standards

The findings out of chapter 7 let to a new design for the recommended implementation of the ISO standards. This recommended design deviates in the number of project phases as well as the required capability levels in each phase. The new design should be considered as a preliminary as it is not tested on its effectiveness in this research.

8.1 Project phases

Both of the contractual phases described in chapter 7 do not overlap the entire project life cycle. Based on these findings a recommendation is given to adjust the project phases in future projects. The goal of ISO15288 is to support processes throughout the entire life cycle of a project, from the concept of an idea until the retirement of the system (ISO/IEC, 2010).

By enlarging the scope of the standards it accommodates the processes throughout the entire life cycle of the project. By including standards in the procurement and maintenance stage, the entire life cycle of the project is supported by the same framework; this is shown in **Figure 8**. Since projects differ in length the boundaries of the phases are defined by the dates out of the DBFM contract. The transition to the next phase interpreted as flexible. This flexibility provides a project organisation to the opportunity to prepare and achieve measurements that can actually be used to improve the process. In practice around half a year is needed to prepare the organisation and to gather enough performance measurements to evolve to the next phase.

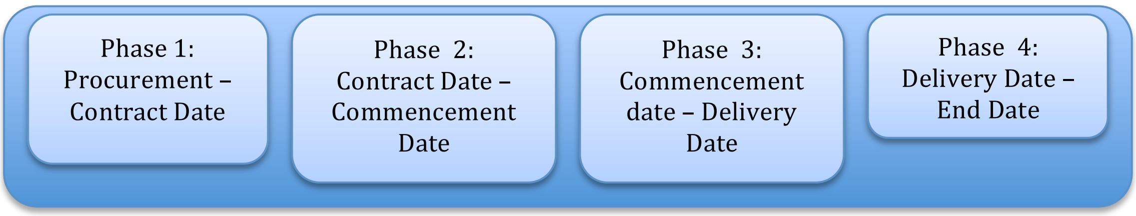


Figure 8: Flexible project phases

8.2 Advised capability levels

Not all processes, to successfully deliver a project, are needed in each phase. The useful set of processes changes as the project progresses. Also, the importance and capability of process change as the project progresses. Based on the expanded project phases and the statement working according to the management system is achieving capability level 3, the advised capability levels per project phase are defined. This results in a new design for the capability levels per project phase. The design is made for a DBFM dry infrastructure project. The result of this exercise is shown in **Table 6**.

Explanation of design:

Phase 1*:* In practice, the tender phase overlaps with phase one, only the agreement. Organisation project enabling and project processes are applicable in the tender phase. The organisation can benefit from arranging these processes in an early stage and used them to have a head start in phase 2. The technical processes: Stakeholder Requirements definition, requirements analysis and architectural design process provide the requirements for the tender design.

Phase 2: Consists of the preparation phase resulting in the formation of a project team. The project management system should be adjusted to fit the specific project. To create uniformity, capability level 3 is applicable for all-important processes.

Phase 3: The realisation phase of an infrastructure project overlaps with phase 3. All processes are active and by working according to the Project Management System achieve capability level 3. A higher capability level is required on processes that are repeatable and are subjected to a lot of interactions.

Phase 4: During the maintenance phase of an infrastructure project the project organisation needs to fulfil two objectives: maintaining the system to guarantee its service and to be able to implement requested changes. The process out of the categories agreement, organisational project-enabling and project processes are active according to the management system. Maintenance is split up into maintaining the current system and renewal when the lifetime of an element is finished. According to the ISO standard, the maintenance process exists out of the plan and performance of the maintenance, repair and renewal of the system, to guarantee the system provides its service. (ISO/IEC/IEEE, 2015) Based on the magnitude of the change, technical processes are required to effectively execute these tasks; these processes are not continuously active but can be reinstalled when required.

Assessment of capability levels

In the first phase, the assessment can help the organisation in organising the procedures in their processes. In this phase, there are no contractual requirements to achieving a capability level. In the second and third phase, a yearly assessment of all project processes is advised. Results from the case studies show an increase in information after an assessment; by updating the process, new measurements or just the knowledge of an external party. In the fourth phase the capability levels remain similar for a period of thirty years, it is advisable to assess the supporting processes in a larger interval of five years. Yearly assessment of the maintenance processes is advised to prevent slack within the organisation.

Table 6: New capability level design

DBFM	Dry infrastructure project	Advised Capability level			
		Phase 1	Phase 2	Phase 3	Phase 4
	Agreement Processes				
AGR 1	Acquisition process	2	3	3	2
AGR 2	Supply process	2	3	4	3
	Organisational project- enabling processes				
ENT. 1	Life Cycle Model Management Process	2	2	2	2
ENT. 2	Infrastructure Management Process	2	2	2	2
ENT. 3	Project Portfolio Management Process	2	-	-	-
ENT. 4	Human Resource Management Process	2	2	2	2
ENT. 5	Quality Management Process	2	3	4	3
	Project Processes				
PRJ. 1	Project Planning Process	2	3	4	3
PRJ. 2	Project Assessment and Control Process	2	3	4	3
PRJ. 3	Decision Management Process	2	3	3	3
PRJ. 4	Risk Management Process	2	3	3	3
PRJ. 5	Configuration Management Process	2	3	3	3
PRJ. 6	Information Management Process	2	3	3	3
PRJ. 7	Measurement Process	2	3	3	3
	Technical Processes				
TEC. 1	Stakeholder Requirements Definition Process	2	3	3	2*
TEC. 2	Requirements Analysis Process	2	3	3	2*
TEC. 3	Architectural Design Process	2	3	3	2*
TEC. 4	Implementation Process	2	3	3	2*
TEC. 5	Integration Process	-	2	3	2*
TEC. 6	Verification Process	-	3	4	2*
TEC. 7	Transition Process	-	2	3	2*
TEC. 8	Validation Process	-	3	4	2*
TEC. 9	Operation Process	-	-	-	-
TEC. 10	Maintenance Process	-	3	3	4
TEC. 11	Disposal Process	-	2	2	3
		Procurement – Contract Date	Contract Date – Commencement Date	Commencement Date – Delivery Date	Delivery date – End Date
	*Only active at change procedure				

8.3 Findings part III

The achievement of capability levels is required in the binding agreement between the client and the contractor. However, limited consistency is seen in the height of these capability levels and how the project is divided into project phases. On certain processes the contractor tries to achieve a higher capability level, resulting in an increase in the height of the average capability levels. The procedures and attributes described in the project management system of the contractor also provide the support to manage an infrastructure project. The findings in the case study projects and comparison between the procedures described in the standards and in the project management system indicate working according to the project management system can be compared to achieving capability level 3.

The inconsistencies and findings on the project management system let to the development of a new design for the application of capability levels within infrastructure projects. By including ISO15288 and ISO15504 in the tender phase the project organisation constructs the foundation of its processes in an early phase. This can translate into the achievement of a higher capability level at the start of the project. Consequently, in the maintenance phase, the project is stable for multiple years; only a selection of the processes is active during this period. The accurateness of this design should be validated when results of actual application in a project are available.

In the following section on this research, the process performance improvement is analysed. This analysis is based on the definition for performance. The performance used in this research differs from the performance used in the ISO standards. PIs out of 5 case study projects provide the input for this analysis.

-IV-

Process improvement Analysis

9 Process improvement

This research does not aim to repeat or verify the procedure executed by the ISO15504-6 assessment. Process improvement in this research is related to the achievement of target values and the variation in PI measurements. Process improvement in ISO15504-6 is related to the capability of the process. The following paragraph determines the definition of both types of process improvement.

9.1 Process improvement in ISO15504-6

ISO15504-6 is the processes assessment model of ISO15288. Each process is organised according to the framework of ISO15288, this framework describes the purpose, outcome and activities the process has to achieve.

- *" The purpose describes the highest-level objective of performing the process*
- *The outcome expresses the observable results expected from the successful performance of the process.*
- *The activities are the set of cohesive tasks of a process to achieve the outcome " (ISO/IEC/IEEE, 2015, p. 15)*

In ISO15504-6 a structured approach of process attributes describes the capability of managing and improving the effectiveness of a process in achieving its purpose and contributing to the achievement of the business goals of the organisation (ISO/IEC, 2013, p. 7). The capability of the process is expressed in rational capability levels. Each capability level represents an enhancement in capability compared to the previous level.

Level 0: Incomplete process
"The process is not implemented, or fails to achieve its process purpose" (ISO/IEC, 2013, p. 7)

Level 1: Performed process
"The implemented process achieves its process purpose" (ISO/IEC, 2013, p. 7). The process produces work products to achieve the outcome.

Level 2: Managed process
"The previously described performed process is now implemented in a managed fashion (planned, monitored and adjusted) and its work products are appropriately established, controlled and maintained" (ISO/IEC, 2013, p. 7). The process delivers work products within defined timescales and according to defined standards and requirements. The process is planned and managed in order to achieve a defined outcome (ISO/IEC, 2013, p. 71).

Level 3: Established process
"The previously described managed process is now implemented using a defined process that is capable of achieving its process outcomes" (ISO/IEC, 2013, p. 7) The process is managed by a defined process procedure; it exists of documented standardised procedures and all the resources are in place to deliver the defined outcome. Level 3.1 contains the definition of the process; Level 3.2 is the deployment of the defined process (ISO/IEC, 2013, p. 77).

Level 4: Predictable process
"The previously described established process now operates within defined limits to achieve its process outcomes" (ISO/IEC, 2013, p. 7). The established process is controlled and analysed to

demonstrate whether it operates according to the business goals. This information provides the ability to make adjustments in order to achieve those goals (ISO/IEC, 2013, p. 81).

Level 5: Optimising process
"The previously described predictable process is continuously improved to meet relevant current and project business goals" (ISO/IEC, 2013, p. 7). The optimising process uses the information gathered by the previous processes to improve the objectives of the process. Opportunities to improve the objectives are identified and monitored to determine its results in the desired effect (ISO/IEC, 2013, p. 85).

The achievement of the activities and outcomes at each level determine the capability of the process. ISO15504-6 only checks if these activities and outcomes are performed, the degree of actually achieving the objectives associated with these activities is not evaluated in the assessment. In ISO15504-6 process improvement is therefore related to the increase of information and possibilities to adjust the process. This is shown in **Figure 9: Process improvement based on ISO15504-6.**

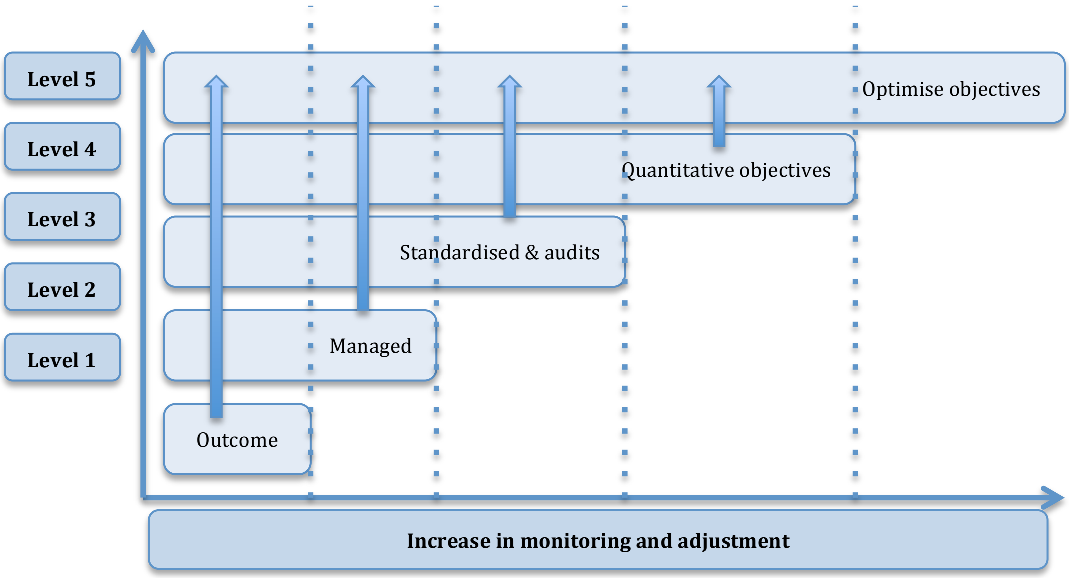


Figure 9: Process improvement based on ISO15504-6

9.2 Process improvement in this research

The definition for process improvement in this research is based on the definitions of ISO15504-6. In this standard, the achievement of capability level 1 relates to the process achieving the outcome, without regarding how to achieve this outcome. As the capability levels progress the focus on the matter to perform these activities and outcome increases. The process attributes of capability level 4 require the processes to establish quantitative objectives for the performance of the process. These objectives are called Process Performance Indicators (PPI) (ISO/IEC, 2013, p. 81). PPI are established to explicitly reflect the business goals of the project. These business goals represent the highest goals a project aims to achieve, for example executing the project on time or within budget. The achievement of the PPI is determined by a number of Performance Indicators (PIs) with corresponding target values. This relation is shown in table 7. Theoretically, the achievement of the target values of the sum of the PIs relates to the achievement of the PPI. The achievement of all PPIs relates to the achievement of the business goals.

Table 7: Example of distribution of project goals to PI

Business goal	PPI	PI	Target value
Within budget	AGR 1: Acquire the right product	25% Mitigation measures executed on time	> 85%
		25% On time delivery of quarterly statement	<14 days
		25% Delay on critical path larger than one week	<1%
		25% Mitigation measures with concept status	< 5%
	AGR 2: Supply the right product	60% Deployment of maintenance costs within contractual agreement	> 50%
		40% Changes in maintenance strategy	< 5

The achievement of capability level 4 and the achievement of PPI can be related to the achievement of the business goals (ISO/IEC, 2013, p. 81). More aspects than process performance alone affect the achievement of business goals; the information about the achievement of the business goals is not evaluated in this research. This research aims to analyses the relation between the achievement of the capability levels and the achievement of PI target values, with the help of the standard these values reflect the business goals. The analysed relation is shown in **Figure 10**.

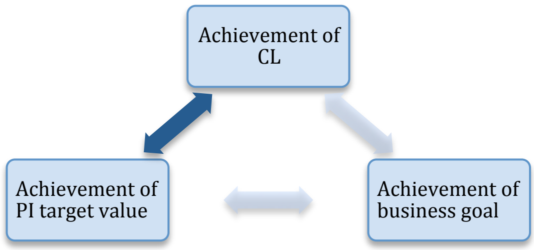


Figure 10: relation between achieving PI, CL and business goal

Research
Excessive to the requirements of ISO15504-6, the case studies already establish PI at the start of the project. This provides the opportunity to evaluate the achievement of the PI target values as the project and the capability levels progress. The goal of the analysis is to determine if an increase in the capability level of a process results in an improvement of the process performance. The process performance is defined by achieving the PI target values and the variation in the PI measurements. The analysis is shown **Figure 11**; the graph represents the PI measurements with the red line representing the target value. The analysis aims to determine if an increase in the capability level results in an increase in the achievement of target values and in a reduction of the PI measurements. The analysis of the factors variation and achieving target values will be further explained in the next chapter.

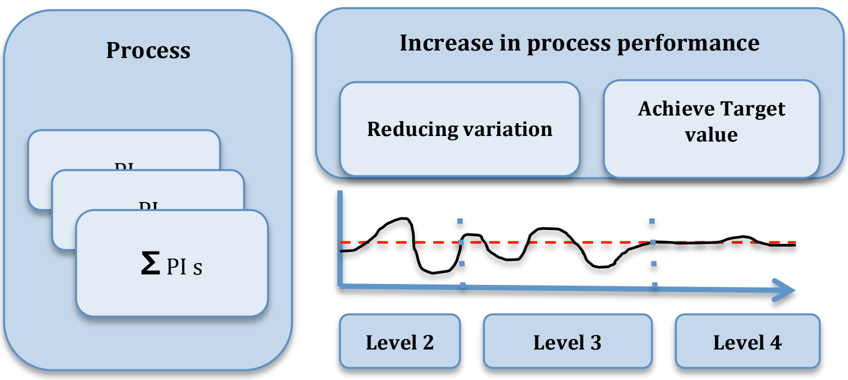


Figure 11: Process improvement used in this research

10 Analysis on process improvement

In the previous chapters, the fit of ISO15288 and the application of ISO15504-6 within infrastructure projects are analysed. Based on these results a quantitative method is developed to determine if the combination of ISO15288 and ISO15504-6 achieves an increase in process performance. To analyse process performance the definition for performance used in this research is determined. Performance Indicators (PI) out of five case study projects provides the input for the quantitative analysis. PI measurements out of the case study project are transferred to comparable values by an analytical framework. The results are analysed and a conclusion on the increase in capability level and the increase in process performance is drawn.

10.1 Application of analytical framework

The performance is analysed with the help of PIs out of five case study projects. These projects are described in chapter 4. During the collection of the PIs, these projects were active in different stages of the life cycle, ranging from the initiation to the maintenance phase. Combining these projects resulted in a collection of 38 PI. The PIs provide information for six ISO15288 processes and the independently executed safety process. The list of unique used PIs is shown in **appendix D.** The selected processes achieve the minimum requirements of two case studies and four PIs. Based on this requirement the following processes are selected:

- AGR.2 Supply Process
- ENT.5 Quality Management Process
- PRJ.3 Assessment and Control Process
- PRJ.5 Risk Management Process
- PRJ.7 Information Management Process
- TEC.10 Maintenance Process
- Safety Process

Chapter 9 describes the definition of process performance improvement used in the analysis. This definition is based on the two parameters: the reduction of variation and the achievement of PI target values. One of the main objectives of ISO15504-6 capability level 4 is to establish quantitative objectives for the performance of the process, which reflect the business goals (ISO/IEC, 2013, p. 81). These quantitative objectives are represented by PI measurements. In the case study projects, the contractors' project management system also gathers PIs in the earlier phases of the project. This gives the opportunity to analyse the PIs present from capability level 2 until capability level 4.

Variation

The literature review describes the benefits of a predictable process. A predictable process increases the process efficiency and therefore the competitiveness of an organisation (Polesie, 2013; Santos et al., 2002; Sommerville et al., 2004). Variability in a process strongly determines its predictability. Based on this theoretical statement, a reduced variability can result in an increased competitiveness of an organisation. Since processes are arranged sequential, the variability in one process can have an even larger influence on the final outcome. To validate if the combination of ISO 15288 and ISO15504 results in the reduction of variation the Standard Deviation (SD) is used. The SD is a measure to express the dispersion in the PI measurements. In each process, the variation in the PI measurements is expressed in the SD per capability level. A low SD value represents less dispersion. Process improvement would result in a reduction of the SD in successive capability levels.

Achieving PI target values

The business goals of an infrastructure project are translated into target values within PIs. The distance between the target value and the PI measurement indicates in what matter the objectives are achieved and indicate the performance of the process. In this research, this distance is called the delta. Process improvement should show a decrease in the delta and an increase in achieving the target values of the individual PI.

The PI measures different aspects of the process, therefore the dimensions of the measurements range from percentage to working days, the used indicators and dimension are shown in **appendix D.** To be able to compare these different dimensions the measurements are transformed to dimensionless Z-values. Z-values express the average of the measurements as the mean and the dispersion in both directions in the standard deviation.

Z-value (z):

$$z = \frac{x - \mu}{\sigma}$$

Per capability level the PI measurements are transformed into z-values, this implicates that the mean over the interval is even to zero. The corresponding mean and standard deviation of this interval are used to transform the target value to the applicable z-value. Because of this, the delta between the target value and mean is a dimensionless relative value. This makes the delta comparable between all measurements. Achieving the target value results in a positive value. Process improvement should show an increase in the delta over the capability levels.

Trend

Not all projects increased a capability level or were able to retrieve the PI measurements of previous capability levels. To be able to use the PI of processes acting on a single capability level, the trend over the z-values is determined. Since all the measurements are translated into z-values is it possible to compare the trend lines of the different PI. A positive trend line is interpreted as an increase in process performance.

10.2 Presentation of results

The analytical framework translates the PI of the case study projects into comparable values. The framework is applied to the measurement of each of the 38 PI. A summary of the results is shown in **appendix E,** the detailed and graphical displays of the results are shown in **appendix F.**

Summary of results (appendix E)

In the summary of results, the outcome of the analytical framework is displayed for each of the seven processes. The results are displayed in tables, which contain the factors of the analytical framework: the average of the PI measurement, the standard deviation, the delta and the trend. As an example, the results of AGR 2 Supply Process are shown in **Table 8**.

This table shows the evaluation of the supply process. For this evaluation, three case study projects and six different performance measurements are used. All case studies acquired measurements over increasing capability levels. The average (U) is based on the average of the raw data set, it represents the real value; the standard deviation (σ) represents the dispersion from the average of the measurements. The distance to achieving the business goals (Δ), a positive value represents achieving the goal. The slope represents the trend-line over the performance measurements.

Table 8: Supply process summary results

ARG.2 Supply process

	Capability	u	σ	Δ (gem - lim)	Slope		Capability	u	σ	Δ (gem - lim)	Slope
Project 1											
KPI 1	Level 2	29,00	5,43	0,18	0,626	KPI 2	Level 2	99,25	1,30	-0,19	-0,693
	Level 3	33,33	8,67	-0,38	-0,102		Level 3	99,44	0,73	-0,09	0,172
	Level 4	32,45	8,07	-0,30	0,007		Level 4	99,50	0,44	0,00	-0,078
Project 2											
KPI 1	Level 2				0	KPI 2	Level 2				0
	Level 3	8,75	4,92	1,27	-0,427		Level 3	7,59	9,93	-0,36	0,099
	Level 4	16,71	7,87	-0,22	0,186		Level 4	1,33	2,38	1,12	-0,082
Project 3											
KPI 1	Level 2				0	KPI 2	Level 2				0
	Level 3	1,00	1,15	0,87	0,148		Level 3	1,17	1,67	0,50	0,0171
	Level 4	1,17	1,10	0,76	0,045		Level 4	0,17	0,37	4,92	0,0058

The first project out of **Table 8** is evaluated in more detail (shown with a red circle). In this project, the PI measurements are gathered for a period of five and a half years, in this period the project increased from capability level 2 into level 4. KPI1 represented the duration of the delivery of the quarterly statement in days; the contractor set the threshold for this activity on thirty days. The average (U) only stays within this target during capability level 2. The dispersion calculated by the standard deviation (σ) increased from 5,4 in level 2 to above 8 at capability level 4. By transferring the raw values in days into z-scores the relative distance towards the target value is determined. The target values are only achieved in capability level 2. The slope determines the trend-line within the capability levels. The result in level 2 shows an upward trend, while in level 3 the trend is negative and level 4 shows no significant deviation.

Detailed results (appendix F)

The details results show a graphical presentation of the results of the analytical framework**.** In the graphical presentation, the course of the process performance factors is displayed per capability level.

The graphical results are explained with the help of the supply process of project 1, shown in **Figure 12**. The background represents the timeframe into which a certain capability level was achieved. Orange representing capability level 2, blue for capability level 3 and green for capability level 4. The analytical framework uses z-values to compare PI measuring different dimensions, the raw data of KPI1 contains days and KPI2 measures percentage. The same factors representing performance in **Table 8** are used in the graphical presentation. The black line shows the average, which is a z-value and constant in all measurements. The dotted line shows the z-value of the individual PI measurements.

The red and blue lines show the limits of the target values. If the target value acts above the black/average line it relates to the PI achieving its target value. In CL 2, KPI1 achieves its business goals while KPI 2 underachieves. As the CLs increase, the KPI2 improves to achieving eventually achieving the target value in CL 4, while KPI1 decreases.

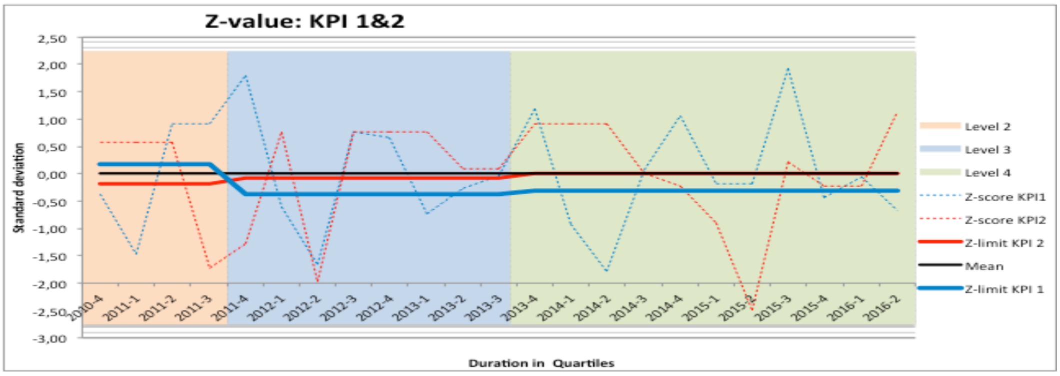


Figure 12: Supply Process graphical presentation of results

10.3 Analysis of results

The results out of chapter 7.3 are analysed to determine the effect of ISO 15288 and ISO 15504-6 on infrastructure processes performance. **Appendix E** and **appendix F** prove the input for the analysis in **appendix G.** The analysis is divided into two parts; the first part determines an increase in performance over increasing capability levels. The second part analyses the performance of individual capability levels.

10.3.1 Analysis of increasing capability levels

In the case studies the capability levels in the processes increase from level 2 to 3 and from level 3 to 4. In both groups, the performance is analysed based on the reduction of variation and reduction of the delta towards achieving the target values. The performance of these parameters is divided into three categories: an increase, similar and decrease of performance. The content of these groups is explained in **Table 9**. Based on these categories the analysis out of **appendix G** is evaluated on the increase in process performance as the capability levels increase.

Table 9: Performance categories

Performance	**Variation**	**Delta**
Increase	Reduction of the SD in the succeeding level	Reduction of the distance between the average and the target value (or achieving the value)
Similar	No significant reduction of the SD in the succeeding level	No significant reduction of the distance between the average and the target value
Decrease	Increase of the SD in the succeeding level	An increase of the distance between the average and the target value.

Variation

The result of the analysis on variation is shown in **Figure 13**. When the process increase from capability level 2 to 3 the analysis shows a reduction in variation in 62% of the processes indicators. However, the remaining 38% shows an increase in the variation, resulting in a decrease of the process performance. The increase from capability level 3 to 4 shows similar results. 55% of the processes indicators show a reduction in variation. In 18% of the processes, the variation remained on a similar level and in 27% of the processes the variation increased, resulting in a decrease of the process performance. Based on these measurements an increase in process performance is seen in 60% of the processes at both capability levels.

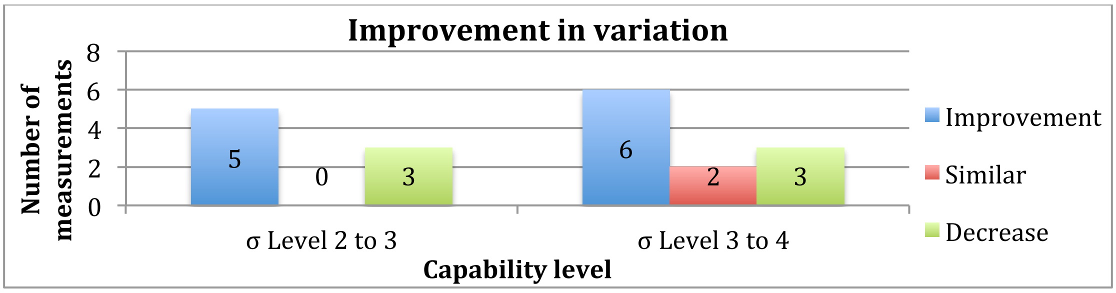


Figure 13: Analysis of variation

Delta

The analysis on the delta between the average and the target value shows similar results as the analysis of variation. The results of this analysis are shown in **Figure 14**. At the increase from capability level 2 to 3, the analysis shows a decrease in the distance towards the target value or achieves the target value in 62% of the processes. The remaining 38% showed an increase in the delta, resulting in a decrease in the process performance. From level 3 to 4 an increase in the performance of 55% of the processes is analysed. The performance is decreased in 27% of the processes. Between 50-60% of the processes increased in performance when increasing a capability level. However, this increase does not directly translate to achieving target values. This is explained in the analysis within a capability level.

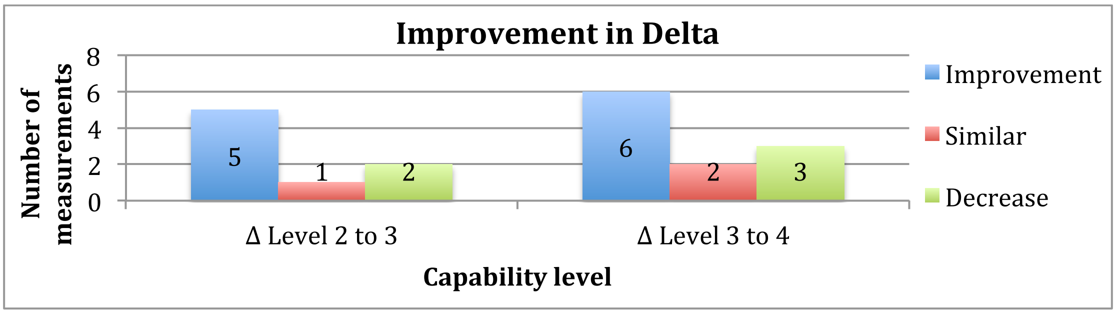


Figure 14: Analysis in delta

Correlation

The PIs improving on the factor variation are almost similar to the PIs improving in Delta. In an increase in capability level 2 to 3 the same PI, which improve on variation, improved in achieving business goals. This result is similar to the increase from level 3 to 4.

10.3.2 Analysis within a capability level

Alternatively to the analysis on an increased capability level, the analysis is performed on a constant capability level. The achievement of target values and the trend of these PI determine the performance within these levels. The results of the analysis for achieving the target value are shown in **Figure 15**. The bar graph shows the total number of PI, out of these PI the red bars show the number that achieved their target value. The difference in achieving the target value in each capability level is analysed.

Achieving target values

Processes acting on capability level 2 achieve their business goals in 41% of the PI. In capability level 3 and 4 this percentage remained around 44% and 41%. These results indicate a higher capability level does not translate to the achievement of a higher percentage of the target values.

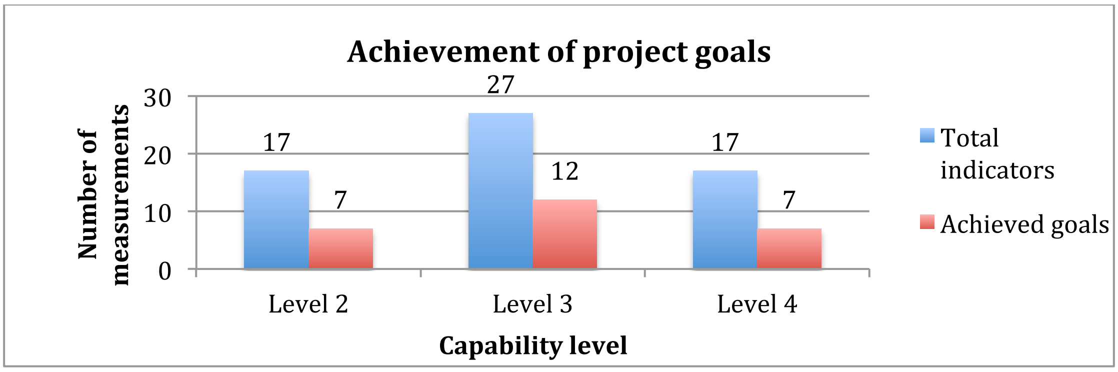


Figure 15: Analysis in achieving business goal

Trend

A similar analysis is conducted on the trend of the PI, shown in **Figure 16**. An upward trend within a PI is conceived as an increase in the performance. Processes acting on capability level 2 achieve an upward trend in 29% of the PI, in capability level 3 and 4 this percentage increased to 59%. For certain PI the target value set at 100%, if this value is achieved the trend might not always be positive. The trend is not always a good indication of the performance.

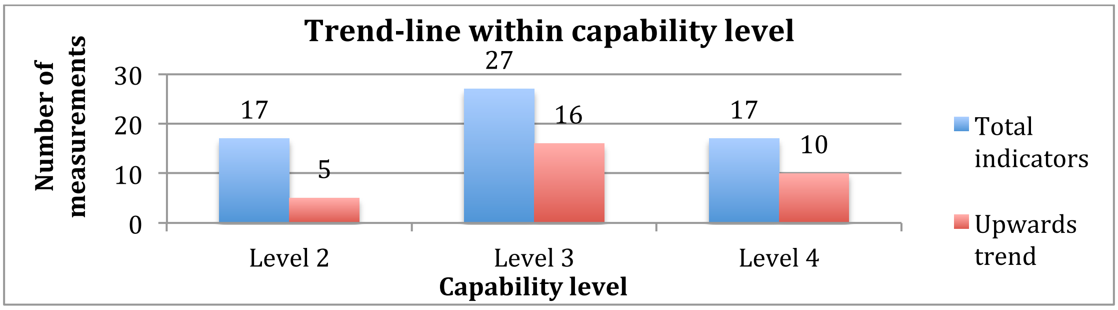


Figure 16: Analysis trend-line

Availability of information

ISO15504-6 prescribes the collection and analysis of performance measurements. The level of monitoring the process increases as the capability levels increase (ISO/IEC, 2013, p. 79)The use of performance measurements is also prescribed by the DBFM contract and the contractors' project management system. These performance measurements not always correlate with the requirements of ISO15504-6. A higher capability level forces the contractor to adjust its method en measure the information according to the standard. This information differs from the information the contractor was previously measuring of was not measuring the process at all. ISO15504-6 provides the project organisation with information on the performance of the process. Since the measurements are based on existing information it is not possible to determine why and how the change in performance measurements occurred. The change in the measurements being in the period of the assessment indicates there is a relation. Multiple of these examples are seen in the case study project, one of these examples is the risk management process of project 2, shown in **Figure 17**.

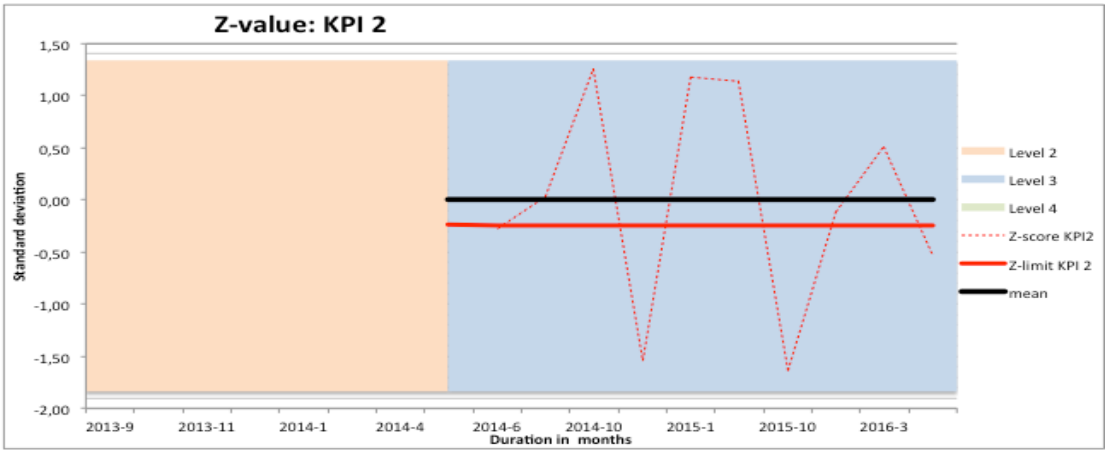


Figure 17: Change in measurement information

10.4 Processes without ISO15288 and ISO15504-6

Contractors also execute processes independently from the ISO standards, for example the safety and environment process. The performance in these processes is evaluated similar to the analysis performed on the ISO processes. The phases within the processes correspond to the dates that the capability levels over the ISO processes increased in height.
The performance of the safety process is based on four performance indicators out of three case study projects. The measurements are shown in **appendix F,** and the analysis is shown in **appendix G.** Consequently, all the target values were achieved in all capability levels.

10.5 Findings part IV

PIs out of five case study projects are used to make a quantitative analysis on the improvement of process performance caused by the combination of ISO15288 and ISO15504-6. Based on the information available in these case studies the definition for process performance improvement is defined. Process performance is constructed out of the factors variation and achievement of target values in the PI. The reduction of variation and reducing the distance or achieving the target values relates to an increase in the process performance. This information is used to determine the increase in process performance at increased capability levels.
The increases from capability level 2 to 3 and from 3 to 4 are analysed. In all capability levels, 60% of the PI showed an improvement in the variation and the distance towards achieving the target values. However, a higher capability level did not translate to the achievement of a higher percentage of the target values. The assessment caused an increase in the monitoring and information on the performance of the process, it is not possible to quantify the effect caused by the ISO standards.
In the following section, the findings out of IV and the previous sections are validated and these combined results lead to conclusions. These conclusions are discussed and recommendation on the future application of the standards and further research are given.

-V-

Advice

11 Validation of the findings

The fifth step of this research starts with validating the findings and results from the preceding chapters. These outcomes provide the input to substantiate the conclusion about the effect of the ISO/IEC/IEEE 15288 framework and ISO/IEC 15504-6 assessment on the improvement of infrastructure project process performance.

11.1 Procedure

The findings are validated with experienced practitioners. To compare the outcomes of the validation the results are made quantifiable. The conclusions out of segment II, III and IV are translated into 19 statements. These statements can be rated from one to, with one corresponding to fully disagree and five corresponding to fully agree. Examples of these responses are shown in **Figure 18**. Additionally, the experts are allowed to substantiate their answer. Experts experienced with the implementation and execution of ISO 15288 and ISO15504-6 are requested to answer the questionnaire. As a result thirteen experts were included in the validation, three from the perspective of the client and ten from the perspective of the contractor. A summary of the responses is shown in **appendix H.**

11.2 Responses

The most important statements are evaluated. Overall the expert responses do not show consistent answers, in 16 out of the 19 statements at least four out of the five options are rated. The disunity of the answers can be related to the unawareness in the outcome of the application of the standards and contributes to the relevance of this research. Before validating the results the goal of the implementation of the standards in infrastructure projects is evaluated. The disunity in the responses might indicate it is difficult to determine the actual goal for the implementation of the standards. Experts from both parties believe the standards are not solely implemented to achieve processes performance. The experts agree the secondary effects and cherry picking might determine the implementation of the standard.

Part II: fit for purpose

The experts agree small adjustments are needed to fit the standard on an infrastructure project; these adjustments largely contain the addition of project and sector-specific processes. The experts agree the standard can fit infrastructure construction projects with these adjustments.
The experts indicate the knowledge of the contractors is growing, this might indicate the limitations shown in the evaluation of the case studies. The dispersion in the responses on the accurateness of the tailoring principles contributes to this statement.

Part III: Practical application of the ISO standards

The responses incline to confirm on the overlap between the ISO15504-6 assessment and the other external audits within an infrastructure project. The responses agree on an experienced project organisation, working according to the project management system, is equal to the requirements needed to achieve capability level three. This contributes to the recommendation to increase the capability levels in an earlier stage of the project. Also, a large portion of the experts agrees on the benefits to include the standards in the procurement phase. However, the standards should not contain a substantial percentage of the tender costs. The experts largely acknowledge the recommendation on the modification of the maintenance phase.

Part III ends with a proposed new design for the application of the capability levels and phases within infrastructure projects. The experts shared their opinion on the accurateness of the design. Frequently mentioned is the limitation for an infrastructure project to reach capability level 4. An infrastructure project would not be able to achieve capability level 4 within the duration of the construction. In the overall perception of the expert's level 4 does not necessary benefit the processes of an infrastructure project.

Part IV: Measurement and analysis of process improvement

According to the experts, PIs represent the performance of a process. However, there is no consensus between the relation of achieving the target value of these PI and the achievement of the business goals. The experts largely agree on the findings of the analysis on process improvement. All of the experts recognise a higher capability level does not necessary translate to the achievement of project goals. Most experts agree on the benefit of increasing a capability level and thereby reducing the variation and delta. Overall the experts recognise the benefit of the combination of standards. However, the human factors still influence the performance of a project.

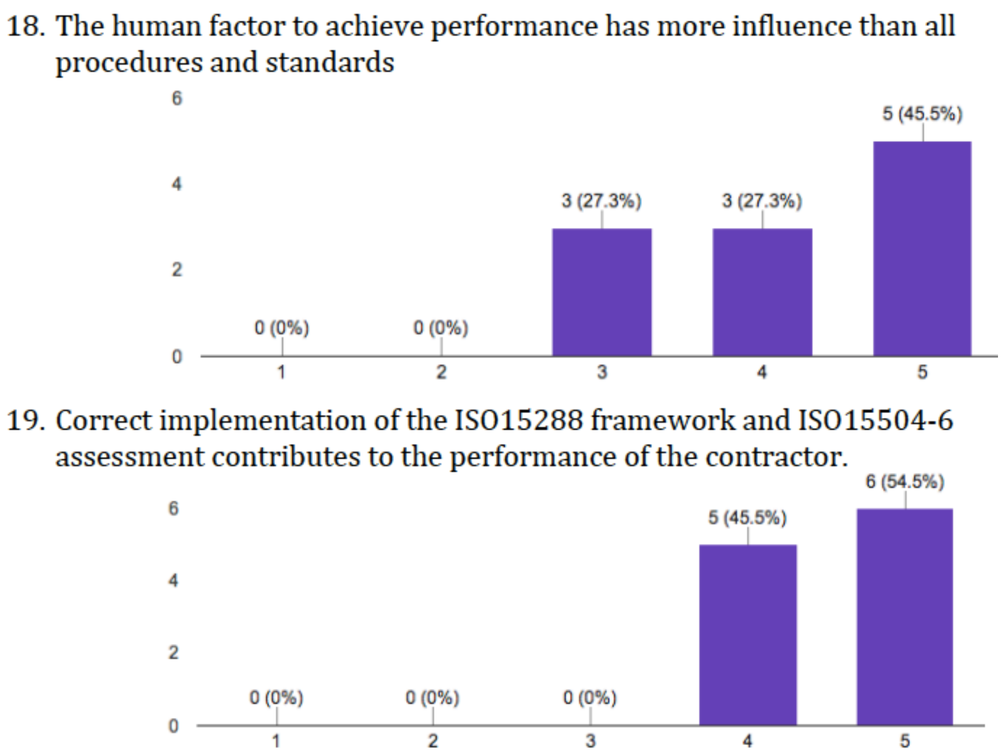


Figure 18: Selection of validation responses

12 Conclusion

In the conclusion, the answer to the sub-research questions is given. The combination of these answers leads to the answer of the main research question. The conclusions are drawn on the findings out of a limited number of case studies; from this perspective, the conclusions should be considered as a hypothesis.

12.1 Answer to the sub-research questions

In this research project, the effect of ISO15288 and ISO15504-6 on civil infrastructure projects is analysed. After determining this research methodology the theories behind standardisation and process measurements were evaluated. Based on the characteristics of infrastructure projects and the theory on the standards the fit of the framework within civil infrastructure projects is evaluated. Subsequently, an empirical analysis on the practical application of the standards within current infrastructure projects was conducted. These findings are included in a new design for a proposed application of the standards. After concluding on the fit and application of the standards this research followed to determine the increase in processes performance by a quantitative analysis. With the help of experts, the findings out of the previous chapters are validated to answer this research questions.

SQ 1: How does the ISO 15288 framework fit within civil infrastructure projects?

With small adjustments to the provided list of processes and a well-developed sequence of the processes, the ISO15288 framework fits within the characteristics of civil infrastructure projects.

The framework of ISO15288 is developed to be applicable to a wide arrange of projects. The life cycle used to develop ISO15288 shows overlap with the life cycle of an infrastructure project. However, the list of processes provided by ISO15288 is not considered to be complete in order to successfully finish any project, this research shows it is also not complete for an infrastructure project. It is advised to incorporate infrastructure or project specific processes, such as the health and safety process, to achieve a complete collection of processes. The case studies show, these project specific processes are already been executed but independently of the framework. Including these processes in the ISO15288 framework could create an uniform approach for all processes in an infrastructure project. Small adjustments in including an excluding processes are needed to fit the ISO15288 framework within civil infrastructure project. In this research the project supporting categories out of ISO15288 are considered to be applicable to any project, the technical processes however need adjustment to fit within a civil infrastructure project. ISO15288 considers the technical processes in two iterative loops, being able to adjust and return to the beginning of the loop if irregularities in the output are detected. The characteristics of an infrastructure project make it undesirable to apply the loop described by the standard.

SQ 2: How does working according to the project management system relates to achieving ISO 15504-6 capability levels?

A contractor experienced in working according to ISO 15288 and ISO15504-6 relates to the achievement of capability level 3, an established process.

Before the implementation of ISO15504-6 the contractor already used procedures described in its internal project management system to organise and monitor processes. The activities and outputs described in ISO15504-6 largely match the content of this project management system. An experienced contractor updates his project management system to with procedures that fulfil the latest requirements. This results in a match between ISO15504-6 capability level 3 and the project management system of the contractor. Results out of the case study projects and the expert validation confirm these findings. It is important to notice an internal project management system can hypothetically operate according to capability level 3, however defining the process according to capability level 3 does not guarantee compliance according to this level. The achievement of the capability levels will depend on the compliance to the standards and procedures implemented in the project.

SQ 3: How should the ISO 15504-6 capability levels be arranged per project phase?

In current projects, the contractually required capability levels, as well as the applied project phases, are inconsistent over the case study projects. To solve these inconsistencies a proposed designed for the application of capability levels in the different stages of an infrastructure project are proposed. The author proposes a new preliminary design from the perspective of the contractor and suitable for a road project contracted by a DBFM agreement. (This is shown in table 6). The main features of the new design are, including the tender phase in the framework and the adjustments in the maintenance phase. By including the framework in the tender phase it is considered the contractor can benefit from this foundation in the rest of the project. The procedures applied in the project supporting processes such as information management process and human resource management process can benefit the contractor in the starting phase of the actual project. In an infrastructure project, the activities in the maintenance phase differ to the activities in the execution phase. In the maintenance phase, the active processes are reduced to only the most important. Also, the height of the capability levels and frequency in the assessment are reduced in the maintenance phase. The new design is considered to increase the applicability of the standards in infrastructure projects; the application should be tested in in order to draw conclusions on its effectiveness.

SQ 4: How is process performance defined in a civil infrastructure project?

Process performance is defined by the achievement of the target value and the variation in the PI

The process performance in civil infrastructure projects is determined by multiple factors. A large part of the performance is related to the professionals executing the process. The application of standardised procedure the project become less dependent on the human factor. The main goals of the project are decided on a high level, for example finishing on time and within budget. To achieve and measure the aspects determining the achievement of these goals performance indicators are used. The business goals of a project are distributed into processes and into measurable PI. Each PI measures a quantifiable aspect of the process. In this research, the performance of the process is related to the achievement of the target values and variations within these PI. The target values represent the limit the contractor aims to achieve. Multiple authors describe the reduction of variation as the main feature to propose standardised procedures (Polesie, 2013; Santos et al., 2002; Sommerville et al., 2004). An increase process performance would result in a reduction of the variation and a reduction of the distance towards achieving the target value.

SQ 5: How does process performance proceed over increasing capability levels within the case study projects?

The standards achieve an increase in the parameters that determine performance but are not used to steer the processes and achieve more target values. A higher capability level does not contribute to the increase in achieving the business goals.

The definition for process performance out of SQ 4 is used to determine the process performance improvement within the case study projects. The PIs out of five case study projects provides the input for an analytical framework, which evaluates the differences in variation and the achievement of target values within each capability level. The process performance is analysed at an increase from capability level two to three and from three to four. At both increases in capability levels, 60% of the PI reduced in variation and reduced the distance towards achieving the target value. However, the percentage of PI actually achieving their target value did not increase at a higher capability level. The PI measurement in capability level 2, 3 and 4 show similar results in achieving their target value, all at 40%. Additionally, the trend within the measurements was analysed, in level 2 an upward trend was noticed in 30% of the PI, in level 3 and 4 this percentage increased to 60%. Based on these results it is concluded the parameters determining process performance in this research increase, however, this increase does not lead to the achievement of a higher percentage of the business goals. Not directly quantifiable aspects such as the increased focus on the monitoring of processes are also detected, resulting in the presence of information that was not available before the implementation of the standards.

SQ 6: How does the achievement of ISO15504-6 capability levels contribute to achieving contractors' goals?

In this research three goals for the achievement of capability levels are identified: fulfilling contractual requirements, secondary effects and process performance improvement.

- In eight out of the nine case studies the client prescribes the standards. Not achieving these requirements can result in penalty points and an increase of costs. In the current approach, contractors achieve the capability levels and meet the requirements of the client.
- For some processes, the contractor applies higher capability level than contractually required. The responses out of the expert validation indicate the application of the standard can be linked to cherry picking. The intention of the contractor to manage ISO15504-6 and achieve higher capability level is to differentiate itself from the other contractors, rather than the intention to improve the performance of the processes.
- The conclusions of SQ 5 show a higher capability level does not result in the achievement of a higher percentage of the target values. However, it does show a decrease in the variation and a reduction in the distance towards the target value. Achieving the capability level does not contribute to achieving process performance improvement.
- The relation between achievement of the target values and the business goals is not evaluated. It is not possible to make a substantiated conclusion about the reduction of the failure costs. The relation between the parameters determining performance and the failure costs should be further evaluated to draw substantiated conclusions.

12.2 Answer to this research Question

The answer to the sub-research questions and the findings out of the previous chapters lead to the answer regarding the main research question and the conclusion of this research.

> **RQ:** What is the effect of the ISO/IEC/IEEE 15288 framework and the ISO/IEC 15504-6 assessments on process performance improvement in civil infrastructure projects?

The ISO15288 framework and ISO15504-6 assessment can have a positive effect on the process performance improvement in civil infrastructure projects. Nevertheless, the effect is dependent on the goal and motivation behind the implementation. With the adjustments elaborated upon in SQ1, ISO15288 and ISO15504-6 fit within civil infrastructure projects. The current approach mainly focuses on achieving the contractual requirements of the client rather than achieving process performance improvement. The aim of the implementation does not achieve its intended purpose. The current aim is to achieve a certificate for each capability level and not necessarily strive for the purpose of process performance improvement. The increase in capability levels according to the standards does not translate into the achievement of a higher percentage of the target values related to the business goals of the contractor. However, even with the current approach, the effect of (one of) the parameters, variation and achieving target value, defining process performance is analysed. The combination of standards increases the focus on the monitoring and analysis of processes. This additional information is not used to effectively steer the processes into the achievement of business goals.

13 Discussion

Within the limited time and resources, this research led to findings on the effect of ISO15288 and ISO15504-6 on infrastructure construction projects. These findings and limitations are discussed from the perspective of the author.

13.1 Discussion on the findings

The goal of this research was to identify the effect of ISO15288 and ISO15504-6 on the increase of process performance in infrastructure construction projects. To approach the problem from an objective perspective, a quantitative approach was used to determine the effect of the standards on process performance. The PI out of five case study projects provided the input for these measurements. Analysing the PI measurements showed improvement in the factors determining performance in this research but no increase in the achievement of project goals. It can be noticed the implementation of the standards let to an increase in monitoring and analysis of the PI measurements. However, the increase in information is not used to achieve the actual business goals. Therefore, it is not known if the measured improvements contribute to, the actual purpose of implementing the standard, the process performance improvement of the project. In the current approach the purpose of the implementation shifts from, the actual goal, increasing the performance of the project towards achieving the requirements of the standard. In this approach the usefulness to achieve the actual goal of the standards is questionable.

- Above described findings can relate to the questionable applicability of the highest capability levels within infrastructure projects. Consequently, due to the short duration of most infrastructure construction projects capability level 5, to optimise the process is not achievable. Most experts even question the applicability of capability level 4 at most processes, related to the non-repetitive activities within infrastructure projects. Not achieving the highest level does not necessitate the contractor to take actions, since optimising is only required in level 5. In the current approach, the process information is gathered but not used to improve the process.
- The findings out of the analysis indicate the achievement of target values does not increase at increasing capability levels. This conclusion can be related to the capability of the management system of the contractor. In SQ 2 the capability of a contractor following to its project management system is comparable to achieving ISO15504-6 capability level 3. If the contractor follows the procedures described in this management system it is evident the differences in achieving the target values between capability level 2 and 3 will be limited. In the period the process was assessed according to the required level 2 the contractor might actually be working according to level 3. The limited differences between capability level 3 and 4 can be ascribed to the short duration of these processes in a project. The results and added benefit of applying capability level 4 will only be visible for a longer duration (+ six months) of analysing and adjusting the process according to the observations. The PI measurements used in this research cover a shorter period. The effect on process performance improvement can become visible after this period, which is only useful for processes that actually achieve capability level 4 for a longer period.

- In five case studies over thirty different PIs are used to monitor the same seven processes. Even projects from the same contractor do not manage the same PI in their projects. The accurateness of these PI's was not included in this research. However, some of the PI measurements were ambiguous or contained that many errors the data was not interpretable. Consequently, it is not uncommon to analyse PI measurements that did not achieve the threshold value for a period longer than six months. Still, these measurements were distributed throughout the organisation without an improvement was implemented. These findings question the importance of the PI's for the contractor, contributing to the conclusion the standards do not contribute to the improvement of the process.
- Most of this research was conducted from the perspective of the contractor. The link in a few occasions the link with the client was observed. For example, the contractual deviations in prescribed capability levels indicate the ideal setup is still under development. Also, the motivation and intention for the prescription of the standards could not be identified when consulting experts from the client.

In my opinion, above observations indicate the biggest issues when applying the standards in infrastructure construction projects. Although analysis shows the standards achieve a certain increase in the parameters representing performance they are not used to steer on the achievement of target values. In other words, the processes are analysed but the analysis is not used achieve business goals. The measured effect of the standards is largely related to the implementation and execution of both parties rather than the content of the standards. All consulted experts agree processes that are properly implemented and executed according to the ISO standards can increase the performance of the process, unfortunately, currently only the contractual requirements are achieved. I share this opinion and believe the additionally generated information can be used to increase the performance of processes in infrastructure construction projects.

13.2 Limitations

This research is subjected to a number of limitations. The most important limitations are discussed in the following paragraph.

- The main limitation of this research relates to the significance of the results. The conclusions on the increase in process performance are drawn on a limited number of five case studies. Consequently to the willingness to share information and the limited amount of projects working with the standards it was difficult to increase the number of case studies. The number of measurements determines the significance when determining the variation and average within the capability levels. One large outlier can largely affect the performance of the indicator. To detect fluctuations with the significant difference the value of the F-test needs to be higher than the F-critical (Dekking, 2005). In this analysis number of measurements required to draw significant conclusions is not reached. Since the findings did show a consistent outcome over the case studies it is chosen not to consider the significance in when conducting the analysis.
- The limitation in the number of measurements also reflected on the increase in capability levels over the duration of the project. This research is based on the progression of capability level to detect an increase in the process performance. However, the projects are currently applying the standards only for a short period. In two of the case studies, the project progressed to the successive level only two months ago, making it impossible to determine the performance in this level. Consequently, the number of projects that progressed more than one capability level is also limited. Only two of the gathered PI progress from capability level two to four in the duration of the project. The increase in the parameters variation and business goals is determined on different PI, rather than analysing the increase of the same PI over successive capability levels. To draw a more substantiated conclusion on the process performance improvement caused by the standards more PI need to progress over the entire life cycle of the project.
- Concluding the limitations with the differences in project dynamics during the life cycle of an infrastructure project. As the project progresses in time and enters new project phases the capability levels increase. In the earlier phases of the project, the procedures and plans are new and the organisation is subjected to dynamics and changes. In the later phases, the procedures can become habits and the dynamics can decrease. Also if an activity is executed for a longer period a natural increase in performance can develop. The extent to which the difference in dynamics in each projects phase and the natural maturity contributes to the process performance is not considered in this research.

14 Recommendation

Considering the conclusions and findings the following recommendations are proposed to improve the implementation of ISO 15288 and ISO15504-6 in future infrastructure construction projects. These recommendations are considered from the perspective of the author and are applicable for both the client and the contractor. In the second paragraph, the recommendations for further research are described.

14.1 Recommendations on the implementation

The following paragraph describes the four most important recommendations the author finds applicable for an improved implementation of the ISO15288 framework and ISO15504-6 assessment in civil infrastructure projects.

- The author considers the current implementation of the standards not as the right implementation. Developments achieved in past projects should be included in future projects. Requirements that are unachievable, unrealistic or not contributing to the goal of process performance improvement should not be included in future projects. This research proposes a new framework for the implementation of the standards throughout the life cycle of the construction project. This new design includes the findings and conclusions and focuses on achieving the real goal, process improvement. This framework provided in chapter 8, includes the ISO standards throughout the entire life cycle of the project and focuses on the most important processes in each phase. The framework should be flexibly interpreted, the next phase starts when the project is actually entering the next phase and should not be fixed by contractual dates. Implementation in the early project phases should be initiated from the contractor itself. To prove the accurateness of the new framework validation and optimisation for a future project is advised.
- Consequently, for the new framework and the current framework to be a success, both parties should express their purpose when implementing the standard. This purpose should be achieved rather than just achieving capability levels. To achieve the real goal, in process performance improvement, the capability level itself should not be used as a relative value to compare process performance. A higher capability level does not necessary indicate a better process.
- It should be prevented the standards are solely used for cherry picking. If the implementation of the standards is not described in the contract the contractor is free to implement the standard out of it own intention. However, the standards should only be included when the contractor believes in the purpose and uses the standards to increase process performance. If the standards are proposed in the bid, the implementation and monitoring should be substantiated. The contractor can substantiate his case working according to the standards during the procurement of the project. This coincides with the intention of new design framework mentioned in the first recommendation.
- The last recommendation considers the achievement of all capability levels within the short duration of a project. The standards are intended to grow as an organisation; in the construction industry, every project is considered as a separate company, which manages and executes their own process measurements procedures. These construction projects often have a short duration; it could be more effective to learn from your projects and improve the entire company. To be able to properly measure and compare the performance in the different projects, each project should measure the same PI. If the same PI is measured and monitored the performance of the projects can be compared. Application of the standard on a company level creates the opportunity to monitor for a period and might result in the achievement of the highest capability levels.

14.1 Recommendations for further research

Within the limited time and resources, this research was not able to address aspects related to analysing the increase in process performance caused by ISO15288 and ISO15504-6. Also, some findings led to the recommendation for further research.

- The biggest limitation to this research is related to a number of available PIs during the execution of this research. It is recommended to re-evaluate the performance caused by the standards when more projects have completed their entire life cycle. This would not only result in a larger pool of projects to increase the significance of the findings but also more processes would have progressed more capability levels. An analysis based on an increase of three or more capability levels could predict more about the generated performance per capability level.
- Ideally, this pool of projects would contain projects using the recommended new framework for the implementation of the capability levels. This would validate if the framework contributes to an accurate implementation of the ISO standards.
- Within this research, the effect of the standards is solely analysed from the perspective of the contractor. Future research on the achievement of the goals of the client and its intention for the implementation of the standards would reflect on the effect of the standard for both parties. Considering this research from the perspective of the client can also increase the pool of projects since the same client executes most of the civil infrastructure projects.
- The position of the client would also open up more information on the achievement of business goals. In this research, the business goals are distributed into measurable PI. It is recommended to evaluate what is the effect of the achievement of capability levels on the main goals of the project (time, cost and quality) and what is the relation between the achievement of the PI threshold values and the achievement of these project goals. Including these aspects would provide the complete picture of the actual performance of the project and can be related to the implementation of the main purpose of implementing the standards, the reduction of failure costs.

References

Alaswal, A., & Sik-Way Fong, P. (2015). Empirical study to determine fragmentation of construction projects. *Construction Engineering Management, 141*(7).

Boehm, B., Port, D., & Basili, V. (2001). Realising the Benefits of the CMMI with the CeBase Method. *Systems Engineering, 5*(1), 73-88.

Boes, H., & Dorée, A. (2008). Public procurement of local authorities in The Netherlands: A case of breaking tradition for a more strategic approach. *Association of Researchers in Construction Management, 24th Annual ARCOM conference*, 477-486.

BouwKennis. (2015). Faalkosten; Uiting, oorzaken, preventie en remedies. Retrieved from http://www.bouwkennis.nl/wp-content/uploads/2014/03/Faalkosten.pdf

Bruijn, H. (2002). Performance measurement in the public sector: strategies to cope with the risks of performance measurements. *IJPSM, 15*(7), 578-594.

Bull, J. (2015). *Life Cycle Costing*: Whittle's publishing.

Chan, A., & Chan, A. (2004). Key performance indicators for measuring construction success. *Benchmarking: An international journal, 11*(2), 203-221.

Chen, W. T., & Chen, T. (2007). Critical success factors for construction partnering in Taiwan. *International Journal of Project Management, 25*, 475-484.

Dekking, F. K., C.; . (2005). *A modern introduction to probability and statistics*.

Dion, R. (1993). Process improvement and the corporate balance sheet. *IEEE software, 10*(4).

Dorling, A. (1993). SPICE: software process improvement and capability determination. *information and software technology, 35*(6/7), 404-406.

Edum-Fotwe, F., Gibb, A., & Befort-Miller, M. (2004). Reconciling construction innovation and standardisation on major projects. *Engineering, Construction and Architectural, 11*(5), 366-372.

Haponava, T., & Al-Jibouri, S. (2010). Establishing influence of design process performance on end-project goals in construction using process-based model. *Benchmarking: An international journal, 17*(5), 657-676.

Hastings, N. (2015). *Physical Asset Management* (Vol. Second edition): Springer

Horstman, A., & Witteveen, W. (2013). Performance indicators in the best value approach. *Journal for the advancement of performance information and value, 5*(2), 59-76.

Houdt, S., & Vrancken, J. (2013). Rolling out Systems Engineering in the Dutch civil construction industry. *Delft University of Technology*.

ISO. (2015). ISO 9001:2015 Quality Management Systems *Requirements*.

ISO/IEC. (2010). ISO/IEC 24748-1 Systems and Software engineering *Life cycle management part 1: guide for life cycle management*.

ISO/IEC. (2011). ISO/IEC 24748-2 Systems and Software engineering *Life cycle management part 2: Guide to the application of ISO/IEC 14288*.

ISO/IEC. (2013). 15504-6 Information Technology *Process assessment part 6: An examplar system life cycle process assessment model*.

ISO/IEC/IEEE. (2015). ISO/IEC/IEEE 15288 Systems and Software engineering *System life cycle processes*.

Janssen, M., & Klievink, B. (2012). Can enterprise architectures reduce failure in development projects? *Transforming Government: People, Process and Policy, 6*(1), 27-40.

Locatelli, G., Mancini, M., & Romano, E. (2014). Systems Engineering to improve the governance in complex project environments. *International Journal of Project Management, 32*, 1395-1410.

Lukszo, Z., Weijnen, M. P. C., Negenborn, R. R., De Schutter, B., & Ilic, M. (2006). Challenges for process system engineering in infrastructure operation and control. *16th European symposium on computer aided process engineering*

9th International symposium on process systems engineering, 95-100.

Pinto, J., & Covin, J. (1989). Critical factors in project implementation: a comparison of construction and R&D projects. *Technovation, 9*, 49-62.

PMI. (2008). *Construction extension to the PMBOK Guide*.

Polesie, P. (2013). The view of freedom and standardisation among managers in Swedish construction contractor projects. *International Journal of Project Management, 31*, 299-306.

PWC. (2015). *Bouw Performance-meting, Top bouwondernemingen in Nederland*. Retrieved from

Rijkswaterstaat. Systeeemgerichte contractbeheersing. *Werkwijze in GWW.* Retrieved from https://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/werkwijzen/werkwijze-in-gww/systeemgerichte-contractbeheersing.aspx

Rijkswaterstaat. (2016). DBFM-overeenkomst Rijkswaterstaat. *4.3*, 133.

Sanchez, H., & Robert, B. (2010). Measuring portfolio strategic performance using key performance indicators. *Project Management Journal*, 65-73.

Santema, S., Rijt van de, J., & Hompes, M. (2010). The Dutch construction industry: An overview and its use of performance information. *Journal for the advancement of performance information and value*.

Santos, A., Formoso, C., & Tookey, J. (2002). Expanding the meaning of standardisation within construction processes. *The TQM magazine, 14*(1), 22-33.

Sarshar, M., Haigh, R., Finnemore, M., Aoaud, G., & Baldery, D. (2000). SPICE: a business process diagnostic tool for construction projects. *Engineering, Construction and Architectural Management, 7*(3), 241-250.

Schwalbe, K. (2015). *Information Technology project management* (eight ed.): Cengage learning.

Schweigert, T., Vohwinkel, D., Korsaa, M., Nevalainen, R., & Biro, M. (2013). Agile maturity model: analysing agile maturity characteristics from the SPICE perspective. *Journal of Software: Evolution and process*.

SE, W. L. (2013). *Leidraad voor systems engineering binnen de GWW-sector*. Retrieved from

Sommerville, J., Craig, N., & Bowden, S. (2004). The standardisation of construction is snagging. *Structural Survey, 22*(5), 251-258.

Verschuren, P., & Doorewaard, H. (2010). *Designing a research project*: Eleven International Publishing.

Wal, L. (2015). 10 procent faalkosten, 2 procent winst. Retrieved from http://www.cobouw.nl/artikel/1144576-10-procent-faalkosten-2-procent-winst

Wasson, C. (2006). *System analysis, design and development*.

Wears, R. (2014). Standardisation and its discontent. *Cogn Tech Work, 17*, 89-94.

Weger, D. (2012). SPIC - Safety Performance Indicator Contractor. Retrieved from http://www.bouwendnederland.nl/data/sitemanagement/media/Onderdeel Organisatie/Vakgroep Grondwerk/DDW_Dik de Weger_SPIC 121108.pdf

Wilson, S. (2012). Explain the Audit Procedures in an Electronic Data Processing Audit. *Audit procedures.* Retrieved from http://smallbusiness.chron.com/explain-audit-procedures-electronic-data-processing-audit-14715.html

Winch, G. (2010). *Managing Construction projects*.

Appendices

Appendix A: Systems thinking

Frequently used terms in the research are system and system engineering. For these terms multiple definitions on different levels of detail are described by literature. The following section explains the used definition for a system and how to operate with these systems.

System

The following list shows some of the definitions used by literature:

- *Combination of interacting elements organized to achieve one or more stated purposes* (ISO/IEC/IEEE, 2015)
- *A system is an integrated set of elements, subsystems, or assemblies that accomplish a defined objective.* (INCOSE, 2015)
- *An integrated set of interoperable elements, each with explicitly specified and bounded capabilities, working synergistically to perform value-added processing to enable a user to satisfy mission-oriented operational needs in a prescribed operating environment with a specified outcome and probability of success.* (Wasson, 2006)

Based on the definitions out of literature the definition used in the research defined:

A system is regarded as a whole that consist of interacting elements working together to achieve a purpose within a prescribed environment.

The collection of elements that does not belong to the system but interacts with the system is called the operating environment or context. Users of a system are considered within the operating environment. The system boundary defines the line between what belongs to the system and the operating environment. Systems consist of attributes and processes, attributes are variables that represent the output of a system and processes are the operations in addition to the attributes to reach the outcome. A system of interest is composed out of a number of system elements. A system element can be considered as a lower level system by itself since it is again composed by a number of system elements, this hierarchical breakdown is shown in **figure A.** (ISO/IEC/IEEE, 2015)

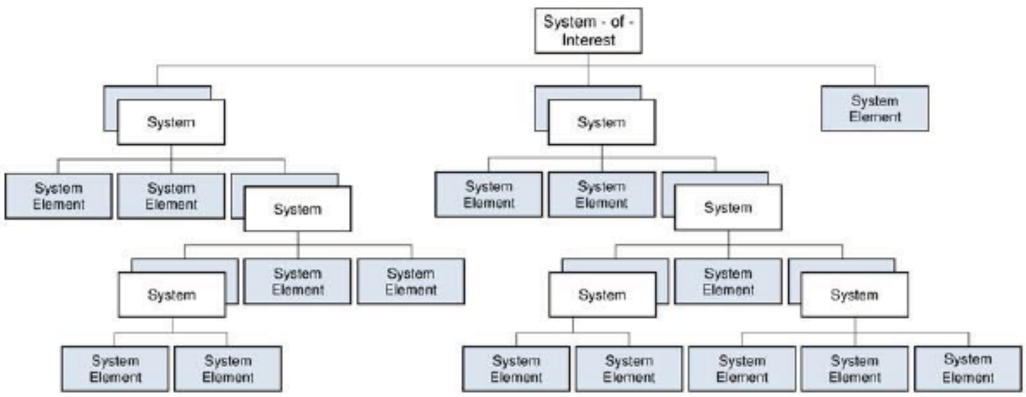


Figure A: System of interest structure

Systems Engineering
The following list shows some of the definitions used by literature:

- *Systems Engineering is the discipline developed to deliver successful projects (and systems) in complex environments* (INCOSE, 2015)
- *Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. Successful systems must satisfy the needs of its customers, users and other stakeholders. (SEBok, 2016)*
- *The multidisciplinary application of analytical, mathematical, and scientific principles to formulating, selecting and developing a solution that has acceptable risk, satisfies user operational need(s), and minimizes development and life cycle costs while balancing stakeholder interests.* (Wasson, 2006)

The definition for System Engineering (SE) is derived out of the citied definitions:

An interdisciplinary approach developed for the realization, operation and retirement of a successful system, which fits the needs of the stakeholders.

According to Wasson (2006), SE is the strategy to bridge the gap between users and system developers. SE translates the users' needs and requirements into a framework of specifications, architectures and designs into which a number of disciplines develop the system. Meeting the requirements often comes with opposed constraints from other disciplines. With SE the designed system is evaluated and balanced in order to come up with a coherent system (Wasson, 2006). SE provides a systems engineer with processes and methods to analyse the status of the system and its underlying sub-systems.

Appendix B: Conformance to ISO 15288

Project			Management specification		Project 1			Project 2			Project 3			Project 4			Project 5		
		Conformance:	Full	Free	Full	Tailored	Excluded	Full	Tailored	Excluded	Full	Tailored	Excluded	Full	Tailored	Excluded	Full	Tailored	Excluded
Agreement processes																			
6.1.1	AGR.1	Acuisition process	X			X		X			X			X			X		
6.1.2	AGR.2	Supply process	X			X		X			X			X			X		
Organizational project-enabling processes																			
6.2.1	ENT.1	Life Cycle Model Management process		X		X		X			X			X			X		
6.2.2	ENT.2	Infrastructure Management Process		X		X		X			X					X	X		
6.2.3	ENT.3	Project Portfolio Management Process		X			X		X				X			X			X
6.2.4	ENT.4	Human Resource Management Process		X		X			X		X					X	X		
6.2.5	ENT.5	Quality Management Process		X		X		X			X			X			X		
Project Processes																			
6.3.1	PRJ.1	Project Planning Process	X			X		X			X			X			X		
6.3.2	PRJ.2	Project Assessment and Control Process	X			X		X			X			X			X		
6.3.3	PRJ.3	Decision Management Process		X		X		X			X			X			X		
6.3.4	PRJ.4	Risk Management Process	X			X		X			X			X			X		
6.3.5	PRJ.5	Configuration Management Process	X			X		X			X			X			X		
6.3.6	PRJ.6	Information Management Process	X			X		X			X			X			X		
6.3.7	PRJ.7	Measurement Process	X			X		X			X			X			X		
Technical Processes																			
6.4.1	TEC.1	Stakeholder Requirements Definition Process	X			X		X			X			X			X		
6.4.2	TEC.2	Requirements Analaysis Process	X			X		X			X			X			X		
6.4.3	TEC.3	Architectural Design Process	X			X		X			X			X			X		
6.4.4	TEC.4	Implementation Process		X		X		X				X		X				X	
6.4.5	TEC.5	Integration Process		X		X		X			X			X			X		
6.4.6	TEC.6	Verification Process	X			X		X			X			X			X		
6.4.7	TEC.7	Transition Process		X		X		X				X				X		X	
6.4.8	TEC.8	Validation Process	X			X		X			X			X			X		
6.4.9	TEC.9	Operation Process		X			X		X			X				X		X	
6.4.10	TEC.10	Maintenance Process	X			X		X				X		X				X	
6.4.11	TEC.11	Disposal Process		X		X		X				X		X				X	

*contractual agreement

*project started before draft ISO15288

Appendix C: Prescribed capability levels

Required ISO15504 Capability levels:			DBFM			DBFM			DBFM			PDC				DBFM		
Project			**Project 1**			**Project 2**			**Project 3**			**Project 4**				**Project 5**		
Timeline			**CD+0,5Y - CD+1,5Y**	**CD+1,5Y - CD +2,5Y**	**CD+2,5Y - ED**	**CD+0,5Y - CD+1,5Y**	**CD+1,5Y - CD +2,5Y**	**CD+2,5Y - ED**	**AD - AD+0,5y**	**AD+0,5Y - BD**	**BD-ED**	**CD +0,5**	**CD +1**	**AD + 0,5**	**AD + 1**	**AD - AD+0,5y**	**AD+0,5Y - BD**	**BD-ED**
			Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 4	Phase 1	Phase 2	Phase 3
Agreement processes																		
6.1.1	AGR.1	Acuisition process	2	3	3	2	3	3	2	3	4	2	3	3	3	2	3	4
6.1.2	AGR.2	Supply process	2	3	4	2	3	4	2	3	3	3	4	4	4	2	3	3
Organizational project-enabling processes																		
6.2.1	ENT.1	Life Cycle Model Management process	2	3	3	2	2	2	2	2	2	2	3	3	3	2	2	2
6.2.2	ENT.2	Infrastructure Management Process	2	3	3	2	2	2	2	2	2					2	2	2
6.2.3	ENT.3	Project Portfolio Management Process																
6.2.4	ENT.4	Human Resource Management Process	2	3	3	2	2	2	2	2	2					2	2	2
6.2.5	ENT.5	Quality Management Process	2	3	4	2	2	2	2	2	2	2	3	3	3	2	2	2
Project Processes																		
6.3.1	PRJ.1	Project Planning Process	2	3	3	2	3	3	2	3	3	3	4	4	4	2	3	3
6.3.2	PRJ.2	Project Assessment and Control Process	2	3	3	2	3	3	2	3	3	3	4	4	4	2	3	3
6.3.3	PRJ.3	Decision Management Process	2	3	3	2	2	2	2	2	2	2	3	3	3	2	2	2
6.3.4	PRJ.4	Risk Management Process	2	3	3	2	3	3	2	3	3	2	3	4	4	2	3	3
6.3.5	PRJ.5	Configuration Management Process	2	3	4	2	3	4	2	3	4	2	3	3	3	2	3	3
6.3.6	PRJ.6	Information Management Process	2	3	4	2	3	4	2	3	4	2	3	3	3	2	3	3
6.3.7	PRJ.7	Measurement Process	2	3	3	2	3	3	3	4	4	2	3	3	3	3	4	4
Technical Processes																		
6.4.1	TEC.1	Stakeholder Requirements Definition Process	2	3	3	2	3	3	2	3	3			3	4	2	3	3
6.4.2	TEC.2	Requirements Analaysis Process	2	3	3	2	3	3	2	3	3	2	3	3	3	2	3	3
6.4.3	TEC.3	Architectural Design Process	2	3	3	2	3	3	2	3	3	3	4	4	4	2	3	3
6.4.4	TEC.4	Implementation Process	2	3	3	2	2	2		2	2			2	3		2	2
6.4.5	TEC.5	Integration Process	2	3	3	2	2	2	2	2	2			2	3	2	2	2
6.4.6	TEC.6	Verification Process	2	3	3	2	3	3	3	4	4	3	4	4	4	3	4	4
6.4.7	TEC.7	Transition Process	2	3	3	2	2	2		2	2						2	2
6.4.8	TEC.8	Validation Process	2	3	3	2	3	3	3	4	4			3	4	3	4	4
6.4.9	TEC.9	Operation Process				2	2	2		2	2						2	2
6.4.10	TEC.10	Maintenance Process	2	3	4	2	3	4		3	4			2	3		3	4
6.4.11	TEC.11	Disposal Process	2	3	3	2	2	2		2	2			2	3		2	2

Required ISO15504 Capability levels:

			DBFM			DBFM			DBFM			DBFM		
Project			**Project 5**			**Project 6**			**Project 7**			**Project 8**		
Timeline			**AD - AD+0,5y** Phase 1	**AD+0,5Y - BD** Phase 2	**BD-ED** Phase 3	**AD - AD+0,5y** Phase 1	**AD+0,5Y - BD** Phase 2	**BD-ED** Phase 3	**AD - AD+0,5y** Phase 1	**AD+0,5Y - BD** Phase 2	**BD-ED** Phase 3	**AD - 0,5y** Phase 1	**0,5Y - ED** Phase 2	
Agreement processes														
6.1.1	AGR.1	Acuisition process	2	3	4	2	3	3	2	3	3	2	3	
6.1.2	AGR.2	Supply process	2	3	3	2	3	4	2	3	4	2	3	
Organizational project-														
6.2.1	ENT.1	Life Cycle Model Management process	2	2	2	2	2	2	2	2	2	2	2	
6.2.2	ENT.2	Infrastructure Management Process	2	2	2							2	2	
6.2.3	ENT.3	Project Portfolio Management Process				2	2	2	2	2	2			
6.2.4	ENT.4	Human Resource Management Process	2	2	2	2	2	2	2	2	2	2	2	
6.2.5	ENT.5	Quality Management Process	2	2	2	2	2	2	2	2	2	2	2	
Project Processes														
6.3.1	PRJ.1	Project Planning Process	2	3	3	2	3	3	2	3	3	2	3	
6.3.2	PRJ.2	Project Assessment and Control Process	2	3	3	2	3	3	2	3	3	2	3	
6.3.3	PRJ.3	Decision Management Process	2	2	2	2	2	2	2	2	2	2	2	
6.3.4	PRJ.4	Risk Management Process	2	3	3	2	3	3	2	3	3	2	3	
6.3.5	PRJ.5	Configuration Management Process	2	3	3	2	3	4	2	3	4	2	3	
6.3.6	PRJ.6	Information Management Process	2	3	3	2	3	4	2	3	4	2	3	
6.3.7	PRJ.7	Measurement Process	3	4	4	2	3	3	2	3	3	2	3	
Technical Processes														
6.4.1	TEC.1	Stakeholder Requirements Definition Process	2	3	3	2	3	3	2	3	3	2	3	
6.4.2	TEC.2	Requirements Analaysis Process	2	3	3	2	3	3	2	3	3	2	3	
6.4.3	TEC.3	Architectural Design Process	2	3	3	2	3	3	2	3	3	2	3	
6.4.4	TEC.4	Implementation Process		2	2	2	2	2	2	2	2		2	
6.4.5	TEC.5	Integration Process	2	2	2	2	2	2	2	2	2		2	
6.4.6	TEC.6	Verification Process	3	4	4	2	3	3	2	3	3	3	3	
6.4.7	TEC.7	Transition Process		2	2	2	2	2	2	2	2		2	
6.4.8	TEC.8	Validation Process	3	4	4	2	3	3	2	3	3	2	3	
6.4.9	TEC.9	Operation Process		2	2	2	2	2	2	2	2		2	
6.4.10	TEC.10	Maintenance Process		3	4	2	3	4	2	3	4		3	
6.4.11	TEC.11	Disposal Process		2	2	2	2	2	2	2	2		2	

Appendix D: List of performance indicators

Indicator	Limit + Dimension
Delay on critical path larger than 1week	0%
Any delay larger than 2 weeks	0-5%
Actual value of planned unavailability of +70hours	<0,94
Actual value of planned unavailability in hour	<15,5 hours
Availability based on probabilistic project planning	>80%
Completion based on probabilistic planning	>80%
Percentage of concept mitigation measures out of total measures	<5%
Percentage of new deviations exceeding 10 days of input	0%
Quantified risks with mitigation measures	>85%
Mitigation measures executed on time	>85%
Percentage executed / planned audits	>80%
Percentage of completed mitigation measures	>80%
Exceedance of mitigation measures with more than 4 weeks	<10%
Percentage of employees educated to work with document management program	>90%
Number of improvement measures which have exceeded their deadline	<5 number
Change management on time	>98%
Change mitigations on time executed	>85%
Number of changes outside mitigation time	<3
Percentage of implementation of changes within 2 days	>95%
Changes in maintenance strategy	0-5 number
On time signing of change agreement by both parties	<18 days
On time delivery of quarterly statement	<14 days
Deployment of maintenance costs within contractual agreements	>50%
Percentage of executed maintenance verifications vs planned	>75%
Number of complains/reports linked to maintenance	<25 number
Percentage executed out of planned safety walks	100%
Percentage implementing findings out of safety walks	90%

Appendix E: Results summarised

Appendix E: Results summarised

Total KPI's	38
Total increases in level	27

Summary

AGR.2 Supply process

Project 1

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	29,00	5,43	0,18	0,626
Level 3	33,33	8,67	-0,38	-0,102
Level 4	32,45	8,07	-0,30	0,007

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	99,25	1,30	-0,19	-0,693
Level 3	99,44	0,73	-0,09	0,172
Level 4	99,50	0,44	0,00	-0,078

Project 2

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				0,000
Level 3	8,75	4,92	1,27	-0,427
Level 4	16,71	7,87	-0,22	0,186

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				0,000
Level 3	7,59	9,93	-0,36	0,099
Level 4	1,33	2,38	1,12	-0,082

Project 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				0,000
Level 3	1,00	1,15	0,87	0,148
Level 4	1,17	1,10	0,76	0,045

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				0,000
Level 3	1,17	1,67	0,50	0,017
Level 4	0,17	0,37	4,92	0,006

ENT.5 Quality management process

Project 1

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2			0,00	0,000
Level 3			0,00	0,000
Level 4	50,53	13,44	-2,94	-0,029

Project 2

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2			0,00	0,000
Level 3	90,00	8,86	-1,13	-0,082
Level 4	93,75	6,50	-0,96	0,693

Project 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	91,03	1,30	0,79	-0,066
Level 3			0,00	0,000
Level 4			0,00	0,000

Project 4

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	51,67	43,08	-0,77	-0,013
Level 3	87,50	2,50	1,00	0,116
Level 4			0,00	0,000

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	39,67	32,46	-1,55	0,252
Level 3	86,83	13,79	-0,23	-0,160
Level 4			0,00	0

Project 5

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	50,40	13,84	-2,50	-0,68
Level 3	97,93	3,45	-0,02	0,17
Level 4	0,00	0,00	0,00	0,00

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	59,40	20,22	-1,27	-0,61
Level 3	69,04	12,80	-1,25	-0,02
Level 4	0,00	0,00	0,00	0,00

PRJ.3 Assessment and Control

Project 1

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	19,50	8,56	1,23	-0,140
Level 3	37,30	13,61	-0,54	-0,187
Level 4			0,00	0

Project 2

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	87,52	13,65	0,55	-0,025
Level 3	80,92	13,26	0,07	0,039
Level 4			0,00	0

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	82,43	11,36	0,21	-0,011
Level 3	80,64	12,14	0,05	0,051
Level 4			0,00	0,000

Project 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2			0	
Level 3	37,75	22,05	-0,56	-0,340
Level 4	60	14,80	0,00	0,027

Project 5

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0	0	0	0
Level 3	0,353	0,923	-0,383	-0,049
Level 4	0	0	0	0

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0	0	0	0
Level 3	3,187	7,160	0,253	-0,065
Level 4	0	0	0	0

PRJ.5 Riskmanagement

Project 1

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2			0,0	
Level 3	71,8	12,1	-1,5	0,00
Level 4			0,0	0,00

Project 2

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0,0	0,0	0,0	0,000
Level 3	10,8	3,5	-0,2	-0,037
Level 4	0,0	0,0	0,0	0,000

Project 3

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	**9,0**	**6,2**	**-0,6**	**0,089**
Level 3			**0,0**	**0,000**
Level 4			**0,0**	**0,000**

Project 5

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	**83,40**	**2,80**	**-0,57**	**0,68**
Level 3	98,00	2,16	6,02	0,20
Level 4	0,00	0,00	0,00	0,00

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	58,00	13,47	-2,00	-0,85
Level 3	70,27	27,60	-0,53	0,09
Level 4	0,00	0,00	6,02	0,00

PRJ.7 Information Management

Project 1

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0	0	0	0,000
Level 3	8,80	6,87	0,90	0,226
Level 4	5,03	3,24	3,07	-0,040

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0	0	0	0,000
Level 3	96,90	3,24	-0,96	0,028
Level 4	98,00	3,58	-0,56	0,011

Project 2

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0	0	0	0,000
Level 3	0	0	0	0,000
Level 4	68,43	29,78	-0,05	0,422

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0	0	0	0,000
Level 3	0	0	0	0,000
Level 4	70,71	10,33	-0,90	0,277

TEC.10 Maintenance process

Project 1

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0,00	0,00	0,00	0,000
Level 3	0,00	0,00	0,00	0,000
Level 4	91,34	5,52	0,24	-0,100

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0,00	0,00	0,00	0,000
Level 3	0,00	0,00	0,00	0,000
Level 4	38,44	8,77	-4,17	0,070

Project 2

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0,00	0,00	0,00	0,000
Level 3	80,93	13,21	0,45	-0,586
Level 4	67,80	16,37	-0,44	-0,097

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0,00	0,00	0,00	0,000
Level 3	23,40	3,38	0,47	0,325
Level 4	38,42	6,84	-1,96	-0,097

Project 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	16,61	0,93	-1,19	-0,254
Level 3	15,67	1,70	-0,10	0,883
Level 4			0,00	0,000

Project 5

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	0,20	0,40	12,00	0,054
Level 4				

Safety process

Project 1

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Fase 1			0,00	0,000
Fase 2	5,75	2,28	0,99	-0,044
Fase 3	5,19	3,11	0,90	0,005

Project 2

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Fase 1			0,00	0,000
Fase 2	9,20	9,52	-0,44	0,168
Fase 3	2,69	3,41	0,68	0,090

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Fase 1			0,00	0,000
Fase 2	92,40	3,20	0,75	-0,625
Fase 3	92,92	2,70	1,08	0,094

Project 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Fase 1	91,25	1,92	0,65	-0,112
Fase 2			0,00	0,000
Fase 3			0,00	0,000

Appendix F: Detailed results

AGR.2 Supply process

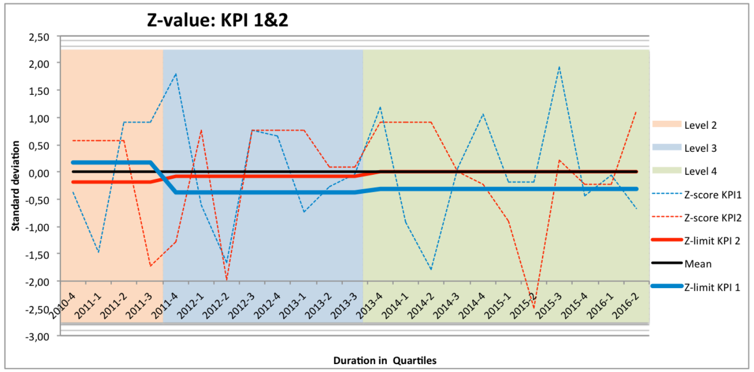
Project 1 — AGR.2 Supply process — level 4

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	29,00	5,43	0,18	0,626
Level 3	33,33	8,67	-0,38	-0,102
Level 4	32,45	8,07	-0,30	0,007

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	99,25	1,30	-0,19	-0,693
Level 3	99,44	0,73	-0,09	0,172
Level 4	99,50	0,44	0,00	-0,078



Draft and delivery quartile statement / Availabilty fee

	LIM < 30Days	Days of delivery	Z-score KPI1 (x-u)/σ		Z-limit KPI 1	Mean	Correlation	LIM >99,5%	%NBV	Z-score (x-u)/σ	Z-score KPI2 omgekeerd	Z-limit KPI 2
1	2010-4	27,00	0,37	-0,37	0,18	0,00	-0,076	2010-4	100,00	0,58	-0,58	-0,19
2	2011-1	21,00	1,47	-1,47	0,18	0,00		2011-1	100,00	0,58	-0,58	-0,19
3	2011-2	34,00	-0,92	0,92	0,18	0,00		2011-2	100,00	0,58	-0,58	-0,19
4	2011-3	34,00	-0,92	0,92	0,18	0,00		2011-3	97,00	-1,73	1,73	-0,19
5	2011-4	49,00	-1,81	1,81	-0,38	0,00		2011-4	98,50	-1,29	1,29	-0,09
6	2012-1	28,00	0,62	-0,62	-0,38	0,00		2012-1	100,00	0,77	-0,77	-0,09
7	2012-2	19,00	1,65	-1,65	-0,38	0,00		2012-2	98,00	-1,98	1,98	-0,09
8	2012-3	40,00	-0,77	0,77	-0,38	0,00		2012-3	100,00	0,77	-0,77	-0,09
9	2012-4	39,00	-0,65	0,65	-0,38	0,00		2012-4	100,00	0,77	-0,77	-0,09
10	2013-1	27,00	0,73	-0,73	-0,38	0,00		2013-1	100,00	0,77	-0,77	-0,09
11	2013-2	31,00	0,27	-0,27	-0,38	0,00		2013-2	99,50	0,09	-0,09	-0,09
12	2013-3	33,00	0,04	-0,04	-0,38	0,00		2013-3	99,50	0,09	-0,09	-0,09
13	2013-4	42,00	-1,18	1,18	-0,30	0,00		2013-4	99,90	0,91	-0,91	0,00
14	2014-1	25,00	0,92	-0,92	-0,30	0,00		2014-1	99,90	0,91	-0,91	0,00
15	2014-2	18,00	1,79	-1,79	-0,30	0,00		2014-2	99,90	0,91	-0,91	0,00
16	2014-3	33,00	-0,07	0,07	-0,30	0,00		2014-3	99,50	0,00	0,00	0,00
17	2014-4	41,00	-1,06	1,06	-0,30	0,00		2014-4	99,40	-0,23	0,23	0,00
18	2015-1	31,00	0,18	-0,18	-0,30	0,00		2015-1	99,10	-0,91	0,91	0,00
19	2015-2	31,00	0,18	-0,18	-0,30	0,00		2015-2	98,40	-2,49	2,49	0,00
20	2015-3	48,00	-1,93	1,93	-0,30	0,00		2015-3	99,60	0,23	-0,23	0,00
21	2015-4	29,00	0,43	-0,43	-0,30	0,00		2015-4	99,40	-0,23	0,23	0,00
22	2016-1	32,00	0,06	-0,06	-0,30	0,00		2016-1	99,40	-0,23	0,23	0,00
23	2016-2	27,00	0,68	-0,68	-0,30	0,00		2016-2	100,00	1,13	-1,13	0,00

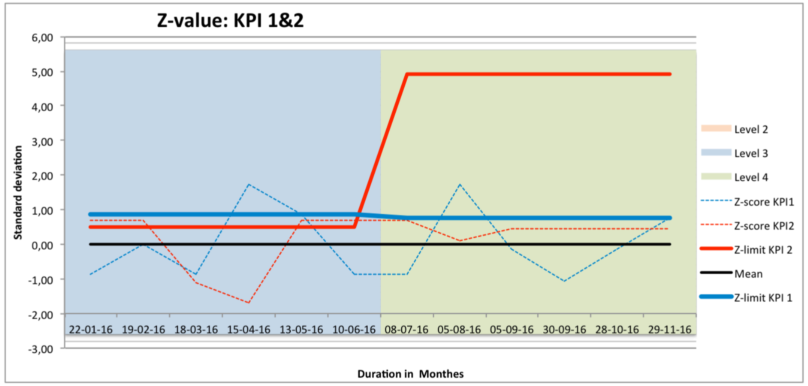
Project 3 — AGR.2 Supply process — level 4

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	1,00	1,15	0,87	0,148
Level 4	1,17	1,10	0,76	0,045

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	1,17	1,67	0,50	0,0171
Level 4	0,17	0,37	4,92	0,0058



Change activities with exeeded deadline / Processing time changes with exeeded deadline

	LIM < 2	number	Z-score KPI1 (x-u)/σ		Z-limit KPI 1	Mean	LIM <2	%NBV	Z-score (x-u)/σ	Z-score KPI2 omgekeerd	Z-limit KPI 2
1	22-01-16	0	0,866	-0,87	0,87	0,00	22-01-16	0	-0,70	0,70	0,50
2	19-02-16	1	0	0,00	0,87	0,00	19-02-16	0	-0,70	0,70	0,50
3	18-03-16	0	0,866	-0,87	0,87	0,00	18-03-16	3	1,09	-1,09	0,50
4	15-04-16	3	-1,732	1,73	0,87	0,00	15-04-16	4	1,69	-1,69	0,50
5	13-05-16	2	-0,866	0,87	0,87	0,00	13-05-16	0	-0,70	0,70	0,50
6	10-06-16	0	0,866	-0,87	0,87	0,00	10-06-16	0	-0,70	0,70	0,50
7	08-07-16	0	0,866	-0,87	0,76	0,00	08-07-16	0	-0,70	0,70	4,92
8	05-08-16	3	-1,732	1,73	0,76	0,00	05-08-16	1	-0,10	0,10	4,92
9	05-09-16	1	0,152	-0,15	0,76	0,00	05-09-16	0	-0,45	0,45	4,92
#	30-09-16	0	1,065	-1,07	0,76	0,00	30-09-16	0	-0,45	0,45	4,92
#	28-10-16	1	0,152	-0,15	0,76	0,00	28-10-16	0	-0,45	0,45	4,92
#	29-11-16	2	-0,761	0,76	0,76	0,00	25-11-16	0	-0,45	0,45	4,92

Project 2 — **AGR.2 Supply process level 4**

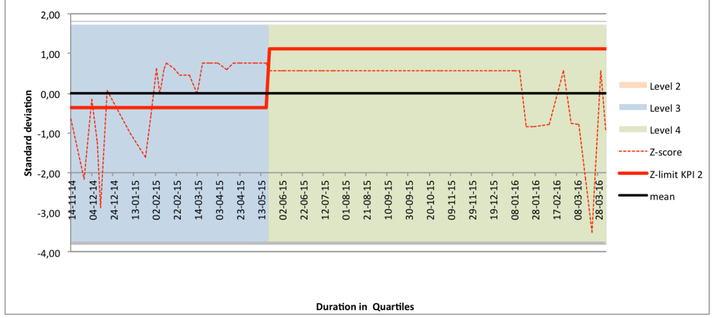
KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	8,75	4,92	1,27	-0,427
Level 4	16,71	7,87	-0,22	0,186

KPI 2

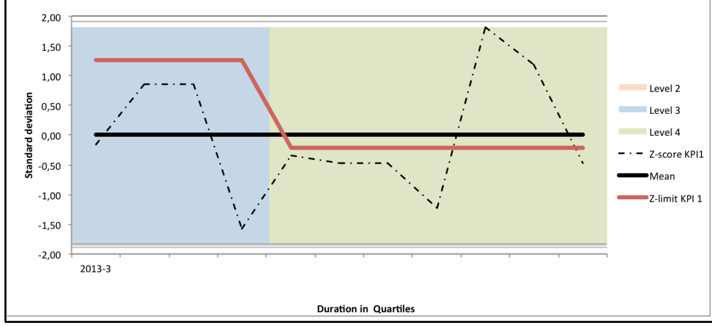
Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	7,59	9,93	-0,36	0,099
Level 4	1,33	2,38	1,12	-0,082

Z-value: KPI 2



		Level 2	Level 3	Level 4
background			35	60
		Level 2	Level 3	Level 4
background			35	65

Z-value: KPI 1



Draft and delivery quartile statement

	LIM <15 days	Days of delivery	Z-score KPI1 (x-u)/σ		Z-limit KPI 1	Mean
1	2013-3	8,00	0,15	-0,15	1,27	0,00
2	2013-4	13,00	-0,86	0,86	1,27	0,00
3	2014-1	13,00	-0,86	0,86	1,27	0,00
4	2014-2	1,00	1,58	-1,58	1,27	0,00
5	2014-3	14,00	0,34	-0,34	-0,22	0,00
6	2014-4	13,00	0,47	-0,47	-0,22	0,00
7	2015-1	13,00	0,47	-0,47	-0,22	0,00
8	2015-2	7,00	1,23	-1,23	-0,22	0,00
9	2015-3	31,00	-1,82	1,82	-0,22	0,00
10	2015-4	26,00	-1,18	1,18	-0,22	0,00
11	2016-1	13,00	0,47	-0,47	-0,22	0,00

Exceedance of change

	LIM <4%	%	Z-score (x-u)/σ	mean		Z-limit KF
1	14-11-14	14,13	-0,66	0,66	0,00	-0,36
2	26-11-14	29,11	-2,17	2,17	0,00	-0,36
3	04-12-14	9,21	-0,16	0,16	0,00	-0,36
4	09-12-14	19,75	-1,23	1,23	0,00	-0,36
5	12-12-14	36,14	-2,88	2,88	0,00	-0,36
6	18-12-14	6,94	0,07	-0,07	0,00	-0,36
7	09-01-15	17,65	-1,01	1,01	0,00	-0,36
8	23-01-15	23,53	-1,61	1,61	0,00	-0,36
9	29-01-15	13,04	-0,55	0,55	0,00	-0,36
10	03-02-15	1,54	0,61	-0,61	0,00	-0,36
11	06-02-15	7,81	-0,02	0,02	0,00	-0,36
12	10-02-15	1,54	0,61	-0,61	0,00	-0,36
13	12-02-15	0,00	0,76	-0,76	0,00	-0,36
14	20-02-15	1,54	0,61	-0,61	0,00	-0,36
15	25-02-15	3,08	0,45	-0,45	0,00	-0,36
16	06-03-15	3,08	0,45	-0,45	0,00	-0,36
17	13-03-15	7,69	-0,01	0,01	0,00	-0,36
18	19-03-15	0,00	0,76	-0,76	0,00	-0,36
19	26-03-15	0,00	0,76	-0,76	0,00	-0,36
20	02-04-15	0,00	0,76	-0,76	0,00	-0,36
21	10-04-15	1,56	0,61	-0,61	0,00	-0,36
22	17-04-15	0,00	0,76	-0,76	0,00	-0,36
23	23-04-15	0,00	0,76	-0,76	0,00	-0,36
24	01-05-15	0	0,76	-0,76	0,00	-0,36
25	08-05-15	0	0,76	-0,76	0,00	-0,36
26	18-05-15	0	0,76	-0,76	0,00	-0,36
27	21-05-15	0	0,56	-0,56	0,00	1,12
28	01-06-15	0	0,56	-0,56	0,00	1,12
29	04-06-15	0	0,56	-0,56	0,00	1,12
30	12-06-15	0	0,56	-0,56	0,00	1,12
31	19-06-15	0	0,56	-0,56	0,00	1,12
32	29-06-15	0	0,56	-0,56	0,00	1,12
33	10-07-15	0	0,56	-0,56	0,00	1,12
34	20-07-15	0	0,56	-0,56	0,00	1,12
35	10-08-15	0	0,56	-0,56	0,00	1,12
36	19-08-15	0	0,56	-0,56	0,00	1,12
37	04-09-15	0	0,56	-0,56	0,00	1,12
38	21-09-15	0	0,56	-0,56	0,00	1,12
39	19-10-15	0	0,56	-0,56	0,00	1,12
40	30-10-15	0	0,56	-0,56	0,00	1,12
41	16-12-15	0	0,56	-0,56	0,00	1,12
42	08-01-16	0	0,56	-0,56	0,00	1,12
43	13-01-16	0	0,56	-0,56	0,00	1,12
44	20-01-16	3,3333	-0,84	0,84	0,00	1,12
45	27-01-16	3,3333	-0,84	0,84	0,00	1,12
46	10-02-16	3,2258	-0,80	0,80	0,00	1,12
47	24-02-16	0	0,56	-0,56	0,00	1,12
48	02-03-16	3,125	-0,75	0,75	0,00	1,12

ENT.5 Quality management process

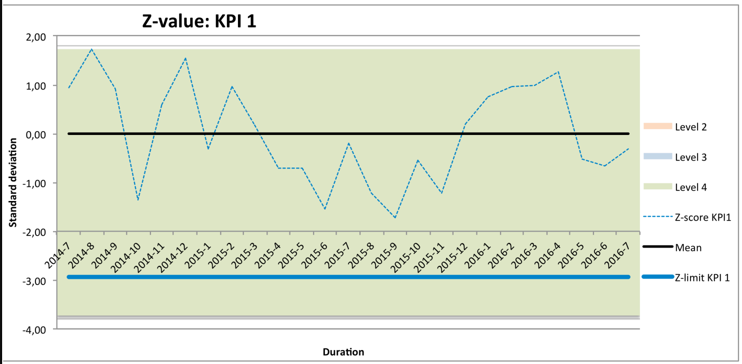
Project 1 — **ENT.5 Quality Management** — **level 4**

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3				
Level 4	50,53	13,44	-2,94	-0,0285522

KPI 2

Capability	u	σ	Δ (gem - lim)
Level 2			
Level 3			
Level 4			



Change proposition

	LIM >90%	%	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean
1	2014-7	63,05	0,93	-2,94	0,00
2	2014-8	73,76	1,73	-2,94	0,00
3	2014-9	62,81	0,91	-2,94	0,00
4	2014-10	32,2	-1,36	-2,94	0,00
5	2014-11	58,65	0,60	-2,94	0,00
6	2014-12	71,33	1,55	-2,94	0,00
7	2015-1	46,22	-0,32	-2,94	0,00
8	2015-2	63,64	0,97	-2,94	0,00
9	2015-3	52,75	0,16	-2,94	0,00
10	2015-4	41,13	-0,70	-2,94	0,00
11	2015-5	41,02	-0,71	-2,94	0,00
12	2015-6	29,64	-1,55	-2,94	0,00
13	2015-7	47,98	-0,19	-2,94	0,00
14	2015-8	34,09	-1,22	-2,94	0,00
15	2015-9	27,38	-1,72	-2,94	0,00
16	2015-10	43,34	-0,54	-2,94	0,00
17	2015-11	34,2	-1,21	-2,94	0,00
18	2015-12	53,11	0,19	-2,94	0,00
19	2016-1	60,61	0,75	-2,94	0,00
20	2016-2	63,64	0,97	-2,94	0,00
21	2016-3	63,97	1,00	-2,94	0,00
22	2016-4	67,47	1,26	-2,94	0,00
23	2016-5	43,39	-0,53	-2,94	0,00
24	2016-6	41,73	-0,65	-2,94	0,00
25	2016-7	46,22	-0,32	-2,94	0,00

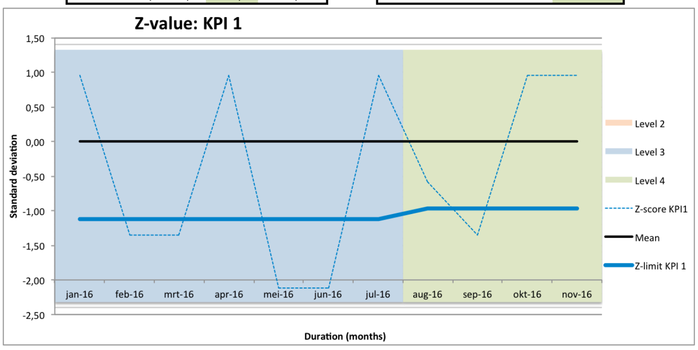
Project 2 — **ENT.5 Quality Management** — **Level 4**

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	90,00	8,86	-1,13	-0,0825
Level 4	93,75	6,50	-0,96	0,6928

KPI 2

Capability	u	σ	Δ (gem - lim)
Level 2			
Level 3			
Level 4			



	LIM >100%	%	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean
1	jan-16	100	0,96	-1,13	0,00
2	feb-16	85	-1,35	-1,13	0,00
3	mrt-16	85	-1,35	-1,13	0,00
4	apr-16	100	0,96	-1,13	0,00
5	mei-16	80	-2,12	-1,13	0,00
6	jun-16	80	-2,12	-1,13	0,00
7	jul-16	100	0,96	-1,13	0,00
8	aug-16	90	-0,58	-0,96	0,00
9	sep-16	85	-1,35	-0,96	0,00
10	okt-16	100	0,96	-0,96	0,00
11	nov-16	100	0,96	-0,96	0,00

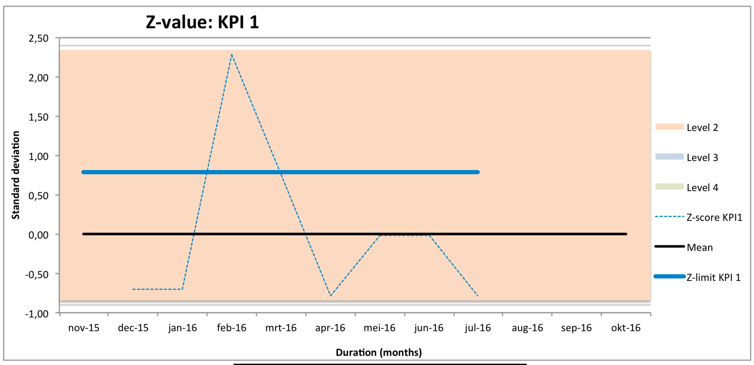
Project 4 — **ENT5. Quality managemen level 2**

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	91,03	1,30	0,79	-0,0657
Level 3				
Level 4				

KPI 2

Capability	u	σ	Δ (gem - lim)
Level 2			
Level 3			
Level 4			



Planned audits executed

	LIM >90	numbe	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean
	nov-15			0,79	0,00
1	dec-15	90,1	-0,71	0,79	0,00
2	jan-16	90,1	-0,71	0,79	0,00
3	feb-16	94	2,28	0,79	0,00
4	mrt-16	92	0,75	0,79	0,00
5	apr-16	90	-0,79	0,79	0,00
6	mei-16	91	-0,02	0,79	0,00
7	jun-16	91	-0,02	0,79	0,00
8	jul-16	90	-0,79	0,79	0,00
9	aug-16				0,00
	sep-16				0,00
	okt-16				0,00

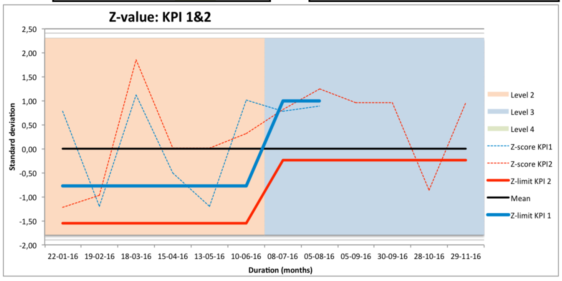
Project 3 ENT5. Quality management level 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	51,67	43,08	-0,77	-0,01327
Level 3	87,50	2,50	1,00	0,11607
Level 4			0,00	

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	39,67	32,46	-1,55	0,2517
Level 3	86,83	13,79	-0,23	-0,1595
Level 4				



	Planned audits executed						review on verified documents				
	LIM >85	number	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean	Correlation	LIM >90	%NBV	Z-score (x-u)/σ	Z-score KPI2 omgekeerd	Z-limit KPI 2
1	22-01-16	85	0,77	-0,77	0,00	0,533	22-01-16	0	-1,22	1,22	-1,55
2	19-02-16	0	-1,20	-0,77	0,00		19-02-16	8	-0,98	0,98	-1,55
3	18-03-16	100	1,12	-0,77	0,00		18-03-16	100	1,86	-1,86	-1,55
4	15-04-16	30	-0,50	-0,77	0,00		15-04-16	40	0,01	-0,01	-1,55
5	13-05-16	0	-1,20	-0,77	0,00		13-05-16	40	0,01	-0,01	-1,55
6	10-06-16	95	1,01	-0,77	0,00		10-06-16	50	0,32	-0,32	-1,55
7	08-07-16	85	0,77	1,00	0,00		08-07-16	66	0,81	-0,81	-0,23
8	05-08-16	90	0,89	1,00	0,00		05-08-16	80	1,24	-1,24	-0,23
9	05-09-16				0,00		05-09-16	100	0,95	-0,95	-0,23
10	30-09-16				0,00		30-09-16	100	0,95	-0,95	-0,23
11	28-10-16				0,00		28-10-16	75	-0,86	0,86	-0,23
12	29-11-16				0,00		29-11-16	100	0,95	-0,95	-0,23

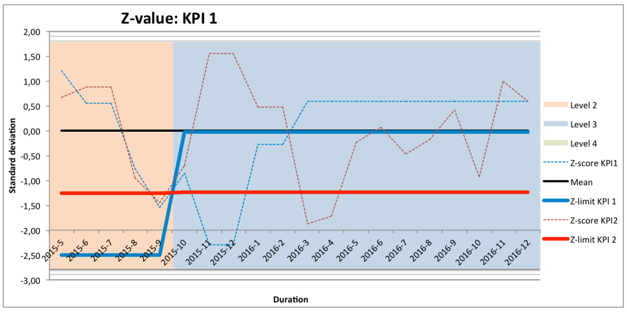
Project 5 ENT.5 Quality Management level 2

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	50,40	13,84	-2,50	-0,679378
Level 3	97,93	3,45	-0,02	0,17165247
Level 4				

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	59,40	20,22	-1,27	-0,6081661
Level 3	69,04	12,80	-1,25	-0,0152932
Level 4				



	Timely processed					Deliverd mitigation measures			
	LIM >98%	%	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean	LIM >90%	%	Z-score KPI2 (x-u)/σ	Z-limit K
1	2015-5	67	1,20	-2,50	0,00	2015-5	73	0,67	-1,27
2	2015-6	58	0,55	-2,50	0,00	2015-6	77	0,87	-1,27
3	2015-7	58	0,55	-2,50	0,00	2015-7	77	0,87	-1,27
4	2015-8	40	-0,75	-2,50	0,00	2015-8	40	-0,96	-1,27
5	2015-9	29	-1,55	-2,50	0,00	2015-9	30	-1,45	-1,27
6	2015-10	95	-0,85	-0,02	0,00	2015-10	60	-0,71	-1,25
7	2015-11	90	-2,30	-0,02	0,00	2015-11	89	1,56	-1,25
8	2015-12	90	-2,30	-0,02	0,00	2015-12	89	1,56	-1,25
9	2016-1	97	-0,27	-0,02	0,00	2016-1	75	0,47	-1,25
10	2016-2	97	-0,27	-0,02	0,00	2016-2	75	0,47	-1,25
11	2016-3	100	0,60	-0,02	0,00	2016-3	45	-1,88	-1,25
12	2016-4	100	0,60	-0,02	0,00	2016-4	47	-1,72	-1,25
13	2016-5	100	0,60	-0,02	0,00	2016-5	66	-0,24	-1,25
14	2016-6	100	0,60	-0,02	0,00	2016-6	70	0,08	-1,25
15	2016-7	100	0,60	-0,02	0,00	2016-7	63	-0,47	-1,25
16	2016-8	100	0,60	-0,02	0,00	2016-8	66,7	-0,18	-1,25
17	2016-9	100	0,60	-0,02	0,00	2016-9	74,4	0,42	-1,25
18	2016-10	100	0,60	-0,02	0,00	2016-10	57,1	-0,93	-1,25
19	2016-11	100	0,60	-0,02	0,00	2016-11	81,8	1,00	-1,25
20	2016-12	100	0,60	-0,02	0,00	2016-12	76,6	0,59	-1,25

PRJ.3 Project assessment and control process

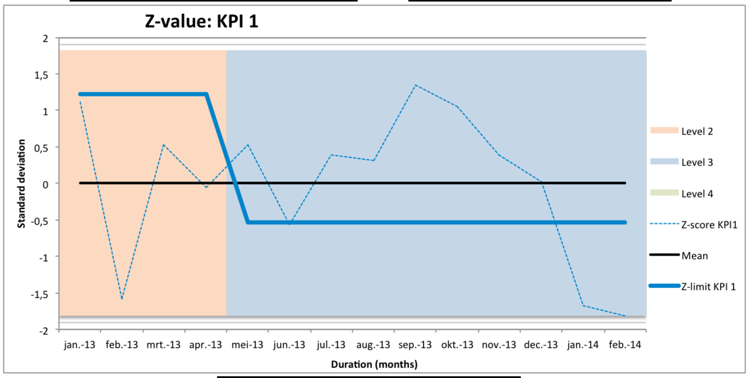
Project 1 — **PRJ. 3 Project assessment and control** — Level 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	19,50	8,56	1,23	-0,140
Level 3	37,30	13,61	-0,54	-0,187
Level 4				

KPI 2

Capability	u	σ	Δ (gem - lim)
Level 2			
Level 3			
Level 4			



duration active work orders

	LIM < 30Days	Days	Z-score KPI1 (x-u)/σ		Z-limit KPI 1	Mean
1	jan-13	10	1,11	-1,11	1,23	0,00
2	feb-13	33	-1,577	1,58	1,23	0,00
3	mrt-13	15	0,526	-0,53	1,23	0,00
4	apr-13	20	-0,058	0,06	1,23	0,00
5	mei-13	30	0,536	-0,54	-0,54	0,00
6	jun-13	45	-0,566	0,57	-0,54	0,00
7	jul-13	32	0,389	-0,39	-0,54	0,00
8	aug-13	33	0,316	-0,32	-0,54	0,00
9	sep-13	19	1,345	-1,34	-0,54	0,00
10	okt-13	23	1,051	-1,05	-0,54	0,00
11	nov-13	32	0,389	-0,39	-0,54	0,00
12	dec-13	37	0,022	-0,02	-0,54	0,00
13	jan-14	60	-1,668	1,67	-0,54	0,00
14	feb-14	62	-1,815	1,81	-0,54	0,00

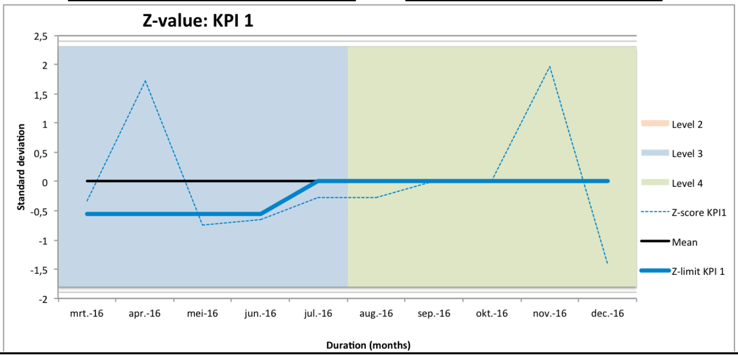
Project 3 — **PRJ. 3 Project assessment and control** — Level 4

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	37,75	22,05	-0,56	-0,340
Level 4	60,00	14,80	0,00	0,027

KPI 2

Capability	u	σ	Δ (gem - lim)
Level 2			
Level 3			
Level 4			



Delivery of planning information

	LIM < 50/60 days	Days	Z-score KPI1 (x-u)/σ		Z-limit KPI 1	Mean
	jan-16		1,712	-1,71	-0,56	0,00
	feb-16		1,712	-1,71	-0,56	0,00
1	mrt-16	45	-0,329	0,33	-0,56	0,00
2	apr-16	0	1,712	-1,71	-0,56	0,00
3	mei-16	54	-0,737	0,74	-0,56	0,00
4	jun-16	52	-0,646	0,65	-0,56	0,00
5	jul-16	64	-0,27	0,27	0,00	0,00
6	aug-16	64	-0,27	0,27	0,00	0,00
7	sep-16	60	0	0,00	0,00	0,00
8	okt-16	60	0	0,00	0,00	0,00
9	nov-16	31	1,96	-1,96	0,00	0,00
10	dec-16	81	-1,419	1,42	0,00	0,00

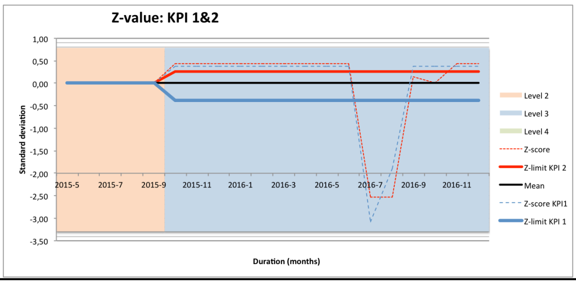
Project 5 — **PRJ. 3 Project assessment and control** — Level 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0,00	0,00	0,00	0,000
Level 3	0,35	0,92	-0,38	-0,049
Level 4				

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	0,00	0,00	0,00	0,000
Level 3	3,19	7,16	0,25	-0,065
Level 4				



	Delay LIM <0	%	Z-score KPI1 (x-u)/σ	Zscore KPI1	Z-limit KPI 1	Mean	**Buffer** LIM<5	%	Z-score (x-u)/σ	Z-score I	Z-limit KPI 2
1	2015-5	0	0,00	0,00	0,00	0,00	2015-5	0	0,00	0,00	0,00
2	2015-6	0	0,00	0,00	0,00	0,00	2015-6	0	0,00	0,00	0,00
3	2015-7	0	0,00	0,00	0,00	0,00	2015-7	0	0,00	0,00	0,00
4	2015-8	0	0,00	0,00	0,00	0,00	2015-8	0	0,00	0,00	0,00
5	2015-9	0	0,00	0,00	0,00	0,00	2015-9	0	0,00	0,00	0,00
6	2015-10	0	-0,38	0,38	-0,38	0,00	2015-10	0	-0,45	0,45	0,25
7	2015-11	0	-0,38	0,38	-0,38	0,00	2015-11	0	-0,45	0,45	0,25
8	2015-12	0	-0,38	0,38	-0,38	0,00	2015-12	0	-0,45	0,45	0,25
9	2016-1	0	-0,38	0,38	-0,38	0,00	2016-1	0	-0,45	0,45	0,25
10	2016-2	0	-0,38	0,38	-0,38	0,00	2016-2	0	-0,45	0,45	0,25
11	2016-3	0	-0,38	0,38	-0,38	0,00	2016-3	0	-0,45	0,45	0,25
12	2016-4	0	-0,38	0,38	-0,38	0,00	2016-4	0	-0,45	0,45	0,25
13	2016-5	0	-0,38	0,38	-0,38	0,00	2016-5	0	-0,45	0,45	0,25
14	2016-6	0	-0,38	0,38	-0,38	0,00	2016-6	0	-0,45	0,45	0,25
15	2016-7	3,2	3,08	-3,08	-0,38	0,00	2016-7	21,3	2,53	-2,53	0,25
16	2016-8	2,1	1,89	-1,89	-0,38	0,00	2016-8	21,3	2,53	-2,53	0,25
17	2016-9	0	-0,38	0,38	-0,38	0,00	2016-9	2,1	-0,15	0,15	0,25
18	2016-10	0	-0,38	0,38	-0,38	0,00	2016-10	3,1	-0,01	0,01	0,25
19	2016-11	0	-0,38	0,38	-0,38	0,00	2016-11	0	-0,45	0,45	0,25
20	2016-12	0	-0,38	0,38	-0,38	0,00	2016-12	0	-0,45	0,45	0,25

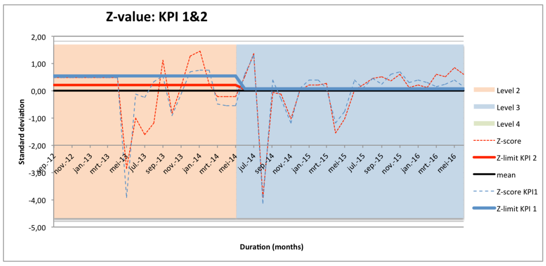
Project 2 **PRJ. 3 Project assessment and control** **Level 3**

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	87,52	13,65	0,55	-0,025
Level 3	80,92	13,26	0,07	0,039
Level 4				

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	82,43	11,36	0,21	-0,011
Level 3	80,64	12,14	0,05	0,051
Level 4				



		Level 2	Level 3	Level 4
background		40	50	
		Level 2	Level 3	Level 4
background			35	65

	Availability						Completion				
	LIM >80	%	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean	Correlation	LIM>80	%	Z-score (x-u)/σ	mean	Z-limit KPI 2
1	sep-12	94	0,47	0,55	0,00	0,886	sep-12	88	0,49	0,00	0,21
2	okt-12	94	0,47	0,55	0,00		okt-12	88	0,49	0,00	0,21
3	nov-12	94	0,47	0,55	0,00		nov-12	88	0,49	0,00	0,21
4	dec-12	94	0,47	0,55	0,00		dec-12	88	0,49	0,00	0,21
5	jan-13	94	0,47	0,55	0,00		jan-13	88	0,49	0,00	0,21
6	feb-13	94	0,47	0,55	0,00		feb-13	88	0,49	0,00	0,21
7	mrt-13	94	0,47	0,55	0,00		mrt-13	88	0,49	0,00	0,21
8	apr-13	94	0,47	0,55	0,00		apr-13	88	0,49	0,00	0,21
9	mei-13	34	-3,92	0,55	0,00		mei-13	50	-2,85	0,00	0,21
10	jun-13	86	-0,11	0,55	0,00		jun-13	71	-1,01	0,00	0,21
11	jul-13	84	-0,26	0,55	0,00		jul-13	64	-1,62	0,00	0,21
12	aug-13	92	0,33	0,55	0,00		aug-13	69	-1,18	0,00	0,21
13	sep-13	95	0,55	0,55	0,00		sep-13	95	1,11	0,00	0,21
14	okt-13	75	-0,92	0,55	0,00		okt-13	73	-0,83	0,00	0,21
15	nov-13	86	-0,11	0,55	0,00		nov-13	84	0,14	0,00	0,21
16	dec-13	97	0,69	0,55	0,00		dec-13	97	1,28	0,00	0,21
17	jan-14	98	0,77	0,55	0,00		jan-14	99	1,46	0,00	0,21
18	feb-14	98	0,77	0,55	0,00		feb-14	85	0,23	0,00	0,21
19	mrt-14	81	-0,48	0,55	0,00		mrt-14	80	-0,21	0,00	0,21
20	apr-14	80	-0,55	0,55	0,00		apr-14	80	-0,21	0,00	0,21
21	mei-14	80	-0,55	0,55	0,00		mei-14	80	-0,21	0,00	0,21
22	jun-14	89	0,61	0,07	0,00		jun-14	87	0,52	0,00	0,05
23	jul-14	98	1,29	0,07	0,00		jul-14	97	1,35	0,00	0,05
24	aug-14	26	-4,14	0,07	0,00		aug-14	33	-3,92	0,00	0,05
25	sep-14	86	0,38	0,07	0,00		sep-14	80	-0,05	0,00	0,05
26	okt-14	77	-0,30	0,07	0,00		okt-14	79	-0,14	0,00	0,05
27	nov-14	65	-1,20	0,07	0,00		nov-14	68	-1,04	0,00	0,05
28	dec-14	82	0,08	0,07	0,00		dec-14	81	0,03	0,00	0,05
29	jan-15	86	0,38	0,07	0,00		jan-15	83	0,19	0,00	0,05
30	feb-15	86	0,38	0,07	0,00		feb-15	83	0,19	0,00	0,05
31	mrt-15	82	0,08	0,07	0,00		mrt-15	84	0,28	0,00	0,05
32	apr-15	65	-1,20	0,07	0,00		apr-15	62	-1,54	0,00	0,05
33	mei-15	71	-0,75	0,07	0,00		mei-15	68	-1,04	0,00	0,05
34	jun-15	86	0,38	0,07	0,00		jun-15	81	0,03	0,00	0,05
35	jul-15	82	0,08	0,07	0,00		jul-15	83	0,19	0,00	0,05
36	aug-15	87	0,46	0,07	0,00		aug-15	86	0,44	0,00	0,05
37	sep-15	84	0,23	0,07	0,00		sep-15	87	0,52	0,00	0,05
38	okt-15	89	0,61	0,07	0,00		okt-15	85	0,36	0,00	0,05
39	nov-15	90	0,68	0,07	0,00		nov-15	88	0,61	0,00	0,05
40	dec-15	85	0,31	0,07	0,00		dec-15	82	0,11	0,00	0,05
41	jan-16	86	0,38	0,07	0,00		jan-16	83	0,19	0,00	0,05
42	feb-16	85	0,31	0,07	0,00		feb-16	82	0,11	0,00	0,05
43	mrt-16	83	0,16	0,07	0,00		mrt-16	88	0,61	0,00	0,05
44	apr-16	84	0,23	0,07	0,00		apr-16	87	0,52	0,00	0,05
45	mei-16	86	0,38	0,07	0,00		mei-16	91	0,85	0,00	0,05
46	jun-16	83	0,16	0,07	0,00		jun-16	88	0,61	0,00	0,05

PRJ.5 Risk Management process

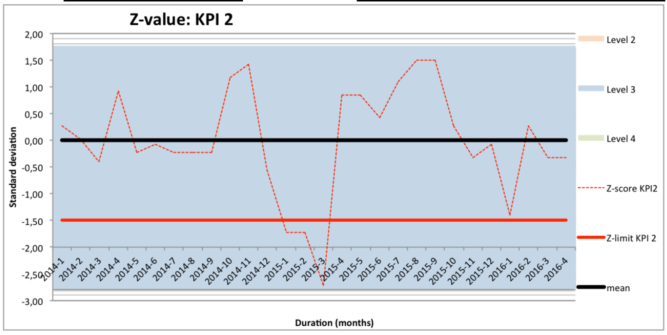
Project 1 — **PRJ. 5 Riskmanagemen Level 3**

KPI 1

Capability	u	σ	Δ (gem - lim)
Level 2			
Level 3			
Level 4			

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	71,82	12,09	-1,50	-0,00088
Level 4				



		Level 2	Level 3	Level 4
background			35	
		Level 2	Level 3	Level 4
background		18	35	50

% mitigation measures in time

	LIM >90	%NBV	Z-score (x-u)/σ	Z-score KPI2 omgekeerd	Z-limit KF	mean
1	2014-1	75	0,26	-0,26	-1,50	0
2	2014-2	72	0,01	-0,01	-1,50	0
3	2014-3	67	-0,40	0,40	-1,50	0
4	2014-4	83	0,92	-0,92	-1,50	0
5	2014-5	69	-0,23	0,23	-1,50	0
6	2014-6	71	-0,07	0,07	-1,50	0
7	2014-7	69	-0,23	0,23	-1,50	0
8	2014-8	69	-0,23	0,23	-1,50	0
9	2014-9	69	-0,23	0,23	-1,50	0
10	2014-10	86	1,17	-1,17	-1,50	0
11	2014-11	89	1,42	-1,42	-1,50	0
12	2014-12	65	-0,56	0,56	-1,50	0
13	2015-1	51	-1,72	1,72	-1,50	0
14	2015-2	51	-1,72	1,72	-1,50	0
15	2015-3	39	-2,71	2,71	-1,50	0
16	2015-4	82	0,84	-0,84	-1,50	0
17	2015-5	82	0,84	-0,84	-1,50	0
18	2015-6	77	0,43	-0,43	-1,50	0
19	2015-7	85	1,09	-1,09	-1,50	0
20	2015-8	90	1,50	-1,50	-1,50	0
21	2015-9	90	1,50	-1,50	-1,50	0
22	2015-10	75	0,26	-0,26	-1,50	0
23	2015-11	68	-0,32	0,32	-1,50	0
24	2015-12	71	-0,07	0,07	-1,50	0
25	2016-1	55	-1,39	1,39	-1,50	0
26	2016-2	75	0,26	-0,26	-1,50	0
27	2016-3	68	-0,32	0,32	-1,50	0
28	2016-4	68	-0,32	0,32	-1,50	0

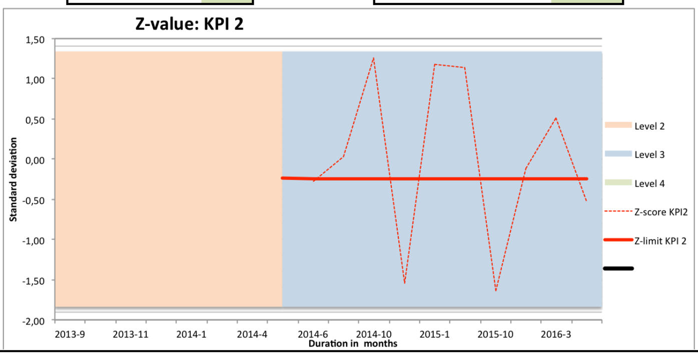
Project 2 — **PRJ. 5 Riskmanagemen Level 3**

KPI 1

Capability	u	σ	Δ (gem - lim)	F-test
Level 2				2&3
Level 3				3&4
Level 4				2&4

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2			0,00	
Level 3	10,85	3,47	-0,24	-0,037
Level 4				



% mitigation measures over 4 week deadline

	LIM <10	%	Z-score (x-u)/σ	Z-score KPI2 omgekeerd	Moving avera	Z-limit KPI 2
	2013-9					
	2013-10					
	2013-11					
	2013-12					
	2014-1					
	2014-2					
	2014-4					
	2014-5					-0,24
1	2014-6	11,818	0,28	-0,28	-0,28	-0,24
2	2014-8	10,741	-0,03	0,03	-0,12	-0,24
3	2014-10	6,4935	-1,25	1,25	0,34	-0,24
4	2014-11	16,216	1,55	-1,55	-0,14	-0,24
5	2015-1	6,7358	-1,18	1,18	0,13	-0,24
6	2015-4	6,875	-1,14	1,14	0,30	-0,24
7	2015-10	16,529	1,64	-1,64	0,07	-0,24
8	2016-2	11,268	0,12	-0,12	0,05	-0,24
9	2016-3	9,0909	-0,51	0,51	-0,08	-0,24
10	2016-4	12,698	0,53	-0,53	0,09	-0,24

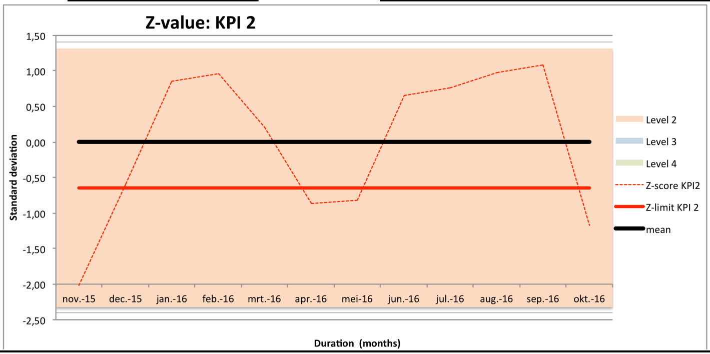
Project 3 — **PRJ. 5 Riskmanagemen Level 2**

KPI 1

Capability	u	σ	Δ (gem - lim)
Level 2			
Level 3			
Level 4			

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	8,99	6,16	-0,65	0,0894
Level 3			0,00	
Level 4			0,00	



Risk concept status

	LIM <5	%	Z-score (x-u)/σ	Z-score KPI2 omgekeerd	Z-limit KF	mean
1	nov-15	21,455	2,02	-2,02	-0,65	0
2	dec-15	12,593	0,58	-0,58	-0,65	0
3	jan-16	3,7736	-0,85	0,85	-0,65	0
4	feb-16	3,0769	-0,96	0,96	-0,65	0
5	mrt-16	7,7519	-0,20	0,20	-0,65	0
6	apr-16	14,341	0,87	-0,87	-0,65	0
7	mei-16	14	0,81	-0,81	-0,65	0
8	jun-16	5	-0,65	0,65	-0,65	0
9	jul-16	4,2969	-0,76	0,76	-0,65	0
10	aug-16	3	-0,97	0,97	-0,65	0
11	sep-16	2,3715	-1,07	1,07	-0,65	0
12	okt-16	16,216	1,17	-1,17	-0,65	0

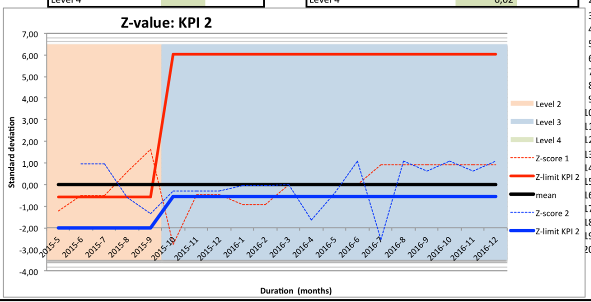
Project 5 — **PRJ. 5 Riskmanagemen Level 3**

KPI 1

Capability	u	σ	Δ (gem -	Slope
Level 2	83,40	2,80	-0,57	0,68
Level 3	98,00	2,16	6,02	0,20
Level 4				

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	58,00	13,47	-2,00	-0,8462
Level 3	70,27	27,60	-0,53	0,0920
Level 4			6,02	



	quantified risks					mitigated risks			
	LIM >85	%	Z-score 1 (x-u)/σ	Z-limit KF	mean	LIM >85	%	Z-score 2 (x-u)/σ	Z-limit KPI 2
1	2015-5	80	-1,21	-0,57	0	2015-5			-2,00
2	2015-6	82	-0,50	-0,57	0	2015-6	71	0,96	-2,00
3	2015-7	82	-0,50	-0,57	0	2015-7	71	0,96	-2,00
4	2015-8	85	0,57	-0,57	0	2015-8	50	-0,59	-2,00
5	2015-9	88	1,64	-0,57	0	2015-9	40	-1,34	-2,00
6	2015-10	92	-2,78	6,02	0	2015-10	62	-0,30	-0,53
7	2015-11	97	-0,46	6,02	0	2015-11	62	-0,30	-0,53
8	2015-12	97	-0,46	6,02	0	2015-12	62	-0,30	-0,53
9	2016-1	96	-0,93	6,02	0	2016-1	69	-0,05	-0,53
10	2016-2	96	-0,93	6,02	0	2016-2	69	-0,05	-0,53
11	2016-3	98	0,00	6,02	0	2016-3	70	-0,01	-0,53
12	2016-4	98	0,00	6,02	0	2016-4	25	-1,64	-0,53
13	2016-5	98	0,00	6,02	0	2016-5	60	-0,37	-0,53
14	2016-6	98	0,00	6,02	0	2016-6	100	1,08	-0,53
15	2016-7	100	0,93	6,02	0	2016-7	0	-2,55	-0,53
16	2016-8	100	0,93	6,02	0	2016-8	100	1,08	-0,53
17	2016-9	100	0,93	6,02	0	2016-9	87,5	0,62	-0,53
18	2016-10	100	0,93	6,02	0	2016-10	100	1,08	-0,53
19	2016-11	100	0,93	6,02	0	2016-11	87,5	0,62	-0,53
20	2016-12	100	0,93	6,02	0	2016-12	100	1,08	-0,53

PRJ.7 Information Management processs

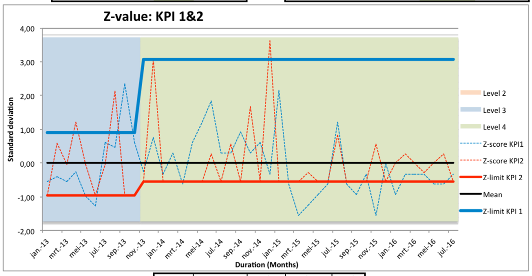
Project 1 PRJ.7 Information Management level 4

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	8,80	6,87	0,90	0,226
Level 4	5,03	3,24	3,07	-0,040

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	96,90	3,24	-0,96	0,0281
Level 4	98,00	3,58	-0,56	0,0111



		Level 2	Level 3	Level 4
background			20	65
		Level 2	Level 3	Level 4
background		18	35	50

	Failure input PMS						Registration within 5 working days				
	LIM < 15%	%	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean	Correlation	LIM >100%	%	Z-score (x-u)/σ	Z-score KPI2 omgekeerd	Z-limit KPI 2
1	jan-13	5	-0,55	0,90	0,00	-0,173	jan-13	100	0,96	-0,96	-0,96
2	feb-13	6	-0,41	0,90	0,00		feb-13	95	-0,59	0,59	-0,96
3	mrt-13	5	-0,55	0,90	0,00		mrt-13	97	0,03	-0,03	-0,96
4	apr-13	7	-0,26	0,90	0,00		apr-13	93	-1,20	1,20	-0,96
5	mei-13	2	-0,99	0,90	0,00		mei-13	97	0,03	-0,03	-0,96
6	jun-13	0	-1,28	0,90	0,00		jun-13	100	0,96	-0,96	-0,96
7	jul-13	13	0,61	0,90	0,00		jul-13	97	0,03	-0,03	-0,96
8	aug-13	12	0,47	0,90	0,00		aug-13	90	-2,13	2,13	-0,96
9	sep-13	25	2,36	0,90	0,00		sep-13	100	0,96	-0,96	-0,96
10	okt-13	13	0,61	0,90	0,00		okt-13	100	0,96	-0,96	-0,96
11	nov-13	7	-0,26	3,07	0,00		nov-13	100	0,56	-0,56	-0,56
12	dec-13	14	0,76	3,07	0,00		dec-13	87	-3,07	3,07	-0,56
13	jan-14	4	-0,32	3,07	0,00		jan-14	100	0,56	-0,56	-0,56
14	feb-14	6	0,30	3,07	0,00		feb-14	100	0,56	-0,56	-0,56
15	mrt-14	3	-0,63	3,07	0,00		mrt-14	100	0,56	-0,56	-0,56
16	apr-14	7	0,61	3,07	0,00		apr-14	100	0,56	-0,56	-0,56
17	mei-14	9	1,22	3,07	0,00		mei-14	100	0,56	-0,56	-0,56
18	jun-14	11	1,84	3,07	0,00		jun-14	97	-0,28	0,28	-0,56
19	jul-14	6	0,30	3,07	0,00		jul-14	100	0,56	-0,56	-0,56
20	aug-14	6	0,30	3,07	0,00		aug-14	96	-0,56	0,56	-0,56
21	sep-14	8	0,92	3,07	0,00		sep-14	100	0,56	-0,56	-0,56
22	okt-14	6	0,30	3,07	0,00		okt-14	92	-1,67	1,67	-0,56
23	nov-14	7	0,61	3,07	0,00		nov-14	100	0,56	-0,56	-0,56
24	dec-14	4	-0,32	3,07	0,00		dec-14	85	-3,63	3,63	-0,56
25	jan-15	12	2,15	3,07	0,00		jan-15	100	0,56	-0,56	-0,56
26	feb-15	3	-0,63	3,07	0,00		feb-15	100	0,56	-0,56	-0,56
27	mrt-15	0	-1,55	3,07	0,00		mrt-15	100	0,56	-0,56	-0,56
28	apr-15	1	-1,24	3,07	0,00		apr-15	99	0,28	-0,28	-0,56
29	mei-15	2	-0,93	3,07	0,00		mei-15	100	0,56	-0,56	-0,56
30	jun-15	3	-0,63	3,07	0,00		jun-15	100	0,56	-0,56	-0,56
31	jul-15	9	1,22	3,07	0,00		jul-15	95	-0,84	0,84	-0,56
32	aug-15	3	-0,63	3,07	0,00		aug-15	100	0,56	-0,56	-0,56
33	sep-15	2	-0,93	3,07	0,00		sep-15	100	0,56	-0,56	-0,56
34	okt-15	4	-0,32	3,07	0,00		okt-15	100	0,56	-0,56	-0,56
35	nov-15	0	-1,55	3,07	0,00		nov-15	96	-0,56	0,56	-0,56
36	dec-15	5	-0,01	3,07	0,00		dec-15	100	0,56	-0,56	-0,56
37	jan-16	2	-0,93	3,07	0,00		jan-16	98	0,00	0,00	-0,56
38	feb-16	4	-0,32	3,07	0,00		feb-16	97	-0,28	0,28	-0,56
39	mrt-16	4	-0,32	3,07	0,00		mrt-16	98	0,00	0,00	-0,56
40	apr-16	4	-0,32	3,07	0,00		apr-16	99	0,28	-0,28	-0,56
41	mei-16	3	-0,63	3,07	0,00		mei-16	98	0,00	0,00	-0,56
42	jun-16	3	-0,63	3,07	0,00		jun-16	97	-0,28	0,28	-0,56
43	jul-16	4	-0,32	3,07	0,00		jul-16	100	0,56	-0,56	-0,56

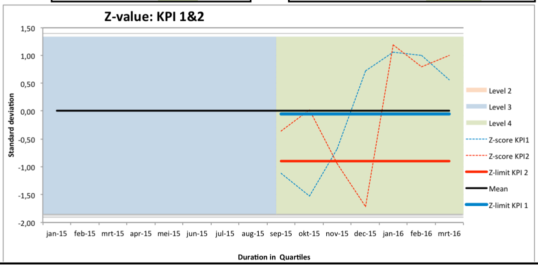
Project 2 PRJ. 7 Information Management level 4

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3				
Level 4	68,43	29,8	-0,05	0,422

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3				
Level 4	70,71	10,33	-0,90	0,277



	On time analysis on quality of documents						Quality check of cleared documents				
	LIM > 70%	%	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean	Correlation	LIM >80%	%	Z-score (x-u)/σ	Z-score KPI2 omgekeerd	Z-limit KPI 2
	jan-15				0,00	0,339	jan-15				
	feb-15				0,00		feb-15				
	mrt-15				0,00		mrt-15				
	apr-15				0,00		apr-15				
	mei-15				0,00		mei-15				
	jun-15				0,00		jun-15				
	jul-15				0,00		jul-15				
	aug-15				0,00		aug-15				
	sep-15				0,00		sep-15				
	okt-15				0,00		okt-15				
	nov-15				0,00		nov-15				
	dec-15				0,00		dec-15				
1	jan-16	35	-1,12	-0,05	0,00		jan-16	67	-0,36	0,36	-0,90
2	feb-16	23	-1,53	-0,05	0,00		feb-16	71	0,03	-0,03	-0,90
3	mrt-16	48	-0,69	-0,05	0,00		mrt-16	61	-0,94	0,94	-0,90
4	apr-16	90	0,72	-0,05	0,00		apr-16	53	-1,71	1,71	-0,90
5	mei-16	100	1,06	-0,05	0,00		mei-16	83	1,19	-1,19	-0,90
6	jun-16	98	0,99	-0,05	0,00		jun-16	79	0,80	-0,80	-0,90
7	jul-16	85	0,56	-0,05	0,00		jul-16	81	1,00	-1,00	-0,90

TEC.10 Maintenance process

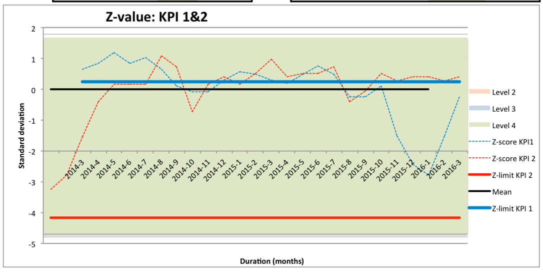
Project 1 TEC 10 Maintenance process level 4

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3				
Level 4	91,34	5,52	0,24	-0,10

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3				
Level 4	38,44	8,77	-4,17	0,0695



		Level 2	Level 3	Level 4
background				40
		Level 2	Level 3	Level 4

Planned maintenance finished / **Maintenance with identified cause**

	LIM >90%	Percent	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean	Correlation	LIM >75%	%with	Z-score KPI2 (x-u)/σ	Z-score KPI2 omgekeerd	Z-limit KPI 2
1						-0,076	2014-1	10	-3,24	3,24	-4,17
2							2014-2	14	-2,79	2,79	-4,17
3	2014-3	95	0,66	0,24	0,00		2014-3	25	-1,53	1,53	-4,17
4	2014-4	96	0,84	0,24	0,00		2014-4	35	-0,39	0,39	-4,17
5	2014-5	98	1,21	0,24	0,00		2014-5	40	0,18	-0,18	-4,17
6	2014-6	96	0,84	0,24	0,00		2014-6	40	0,18	-0,18	-4,17
7	2014-7	97	1,03	0,24	0,00		2014-7	40	0,18	-0,18	-4,17
8	2014-8	95	0,66	0,24	0,00		2014-8	48	1,09	-1,09	-4,17
9	2014-9	92	0,12	0,24	0,00		2014-9	45	0,75	-0,75	-4,17
10	2014-10	91	-0,06	0,24	0,00		2014-10	32	-0,74	0,74	-4,17
11	2014-11	91	-0,06	0,24	0,00		2014-11	40	0,18	-0,18	-4,17
12	2014-12	93	0,30	0,24	0,00		2014-12	42	0,41	-0,41	-4,17
13	2015-1	94,5	0,57	0,24	0,00		2015-1	40	0,18	-0,18	-4,17
14	2015-2	94	0,48	0,24	0,00		2015-2	43	0,52	-0,52	-4,17
15	2015-3	93	0,30	0,24	0,00		2015-3	47	0,98	-0,98	-4,17
16	2015-4	92,5	0,21	0,24	0,00		2015-4	42	0,41	-0,41	-4,17
17	2015-5	94	0,48	0,24	0,00		2015-5	43	0,52	-0,52	-4,17
18	2015-6	95,5	0,75	0,24	0,00		2015-6	43	0,52	-0,52	-4,17
19	2015-7	94	0,48	0,24	0,00		2015-7	45	0,75	-0,75	-4,17
20	2015-8	90	-0,24	0,24	0,00		2015-8	35	-0,39	0,39	-4,17
21	2015-9	90	-0,24	0,24	0,00		2015-9	38	-0,05	0,05	-4,17
22	2015-10	92	0,12	0,24	0,00		2015-10	43	0,52	-0,52	-4,17
23	2015-11	83	-1,51	0,24	0,00		2015-11	41	0,29	-0,29	-4,17
24	2015-12	78	-2,42	0,24	0,00		2015-12	42	0,41	-0,41	-4,17
25	2016-1	76	-2,78	0,24	0,00		2016-1	42	0,41	-0,41	-4,17
26	2016-2	83	-1,51	0,24	0,00		2016-2	41	0,29	-0,29	-4,17
27	2016-3	90	-0,24	0,24	0,00		2016-3	42	0,41	-0,41	-4,17

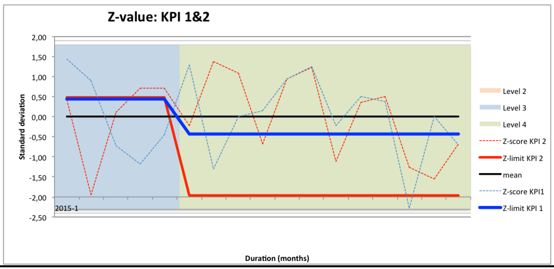
Project 2 Tec.10 Maintenance process level 4

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	80,93	13,21	0,45	-0,5863001
Level 4	67,80	16,37	-0,44	-0,0971643

KPI 2

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	23,40	3,38	0,47	0,32522182
Level 4	38,42	6,84	-1,96	-0,0971643



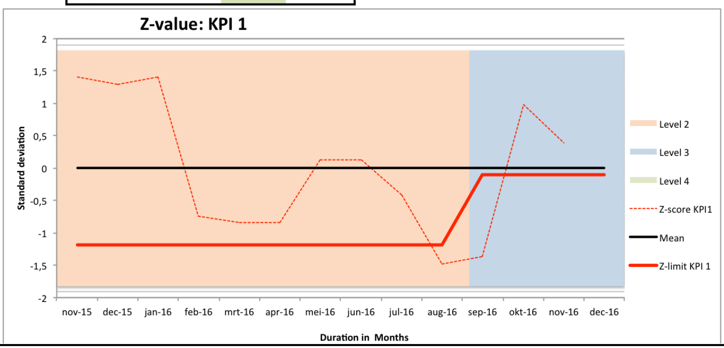
Finised planned maintenance / **Complains**

	LIM >75%	Percent	Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean	Correlation	LIM <25	#		Z-score KPI 2 (x-u)/σ	mean	Z-limit KPI 2
1	2015-1	100,00	1,44	0,45	0,00	-0,410	2015-1	22	0,41	-0,41	0,00	0,47
2	2015-2	92,86	0,90	0,45	0,00		2015-2	30	-1,95	1,95	0,00	0,47
3	2015-3	71,43	-0,72	0,45	0,00		2015-3	23	0,12	-0,12	0,00	0,47
4	2015-4	65,38	-1,18	0,45	0,00		2015-4	21	0,71	-0,71	0,00	0,47
5	2015-5	75,00	-0,45	0,45	0,00		2015-5	21	0,71	-0,71	0,00	0,47
6	2015-6	88,89	1,29	-0,44	0,00		2015-6	40	-0,23	0,23	0,00	-1,96
7	2015-7	46,43	-1,31	-0,44	0,00		2015-7	29	1,38	-1,38	0,00	-1,96
8	2015-8	67,74	0,00	-0,44	0,00		2015-8	31	1,08	-1,08	0,00	-1,96
9	2015-9	70,37	0,16	-0,44	0,00		2015-9	43	-0,67	0,67	0,00	-1,96
#	2015-10	83,33	0,95	-0,44	0,00		2015-10	32	0,94	-0,94	0,00	-1,96
#	2015-11	88,24	1,25	-0,44	0,00		2015-11	30	1,23	-1,23	0,00	-1,96
#	2015-12	64,00	-0,23	-0,44	0,00		2015-12	46	-1,11	1,11	0,00	-1,96
#	2016-1	76,00	0,50	-0,44	0,00		2016-1	36	0,35	-0,35	0,00	-1,96
#	2016-2	74,07	0,38	-0,44	0,00		2016-2	35	0,50	-0,50	0,00	-1,96
#	2016-3	30,43	-2,28	-0,44	0,00		2016-3	47	-1,26	1,26	0,00	-1,96
#	2016-4	67,86	0,00	-0,44	0,00		2016-4	49	-1,55	1,55	0,00	-1,96
#	2016-5	56,25	-0,71	-0,44	0,00		2016-5	43	-0,67	0,67	0,00	-1,96

Project 3 TEC 10 Maintenance process level 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2	16,61	0,93	-1,19	-0,254
Level 3	15,67	1,70	-0,10	0,883
Level 4				



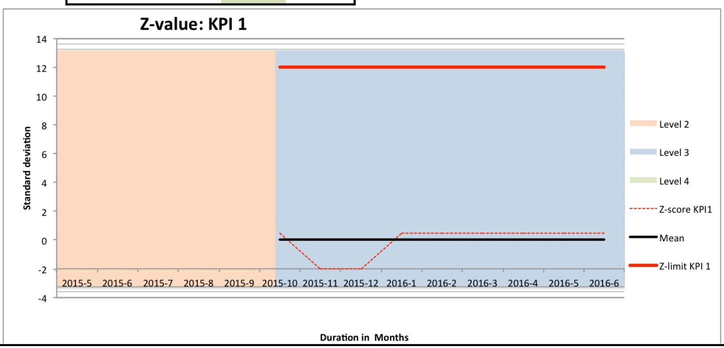
unplannend unavailability

	LIM < 15,5	number		Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean
1	nov-15	15,3	1,402	-1,40	-1,19	0,00
2	dec-15	15,4	1,295	-1,30	-1,19	0,00
3	jan-16	15,3	1,402	-1,40	-1,19	0,00
4	feb-16	17,3	-0,739	0,74	-1,19	0,00
5	mrt-16	17,4	-0,846	0,85	-1,19	0,00
6	apr-16	17,4	-0,846	0,85	-1,19	0,00
7	mei-16	16,5	0,118	-0,12	-1,19	0,00
8	jun-16	16,5	0,118	-0,12	-1,19	0,00
9	jul-16	17	-0,417	0,42	-1,19	0,00
10	aug-16	18	-1,488	1,49	-1,19	0,00
11	sep-16	18	-1,373	1,37	-0,10	0,00
12	okt-16	14	0,981	-0,98	-0,10	0,00
13	nov-16	15	0,392	-0,39	-0,10	0,00
14	dec-16				-0,10	0,00

Project 5 TEC 10 Maintenance process level 3

KPI 1

Capability	u	σ	Δ (gem - lim)	Slope
Level 2				
Level 3	0,20	0,40	12,00	0,054
Level 4				



Changes maintenance strategy

	LIM < 5	number		Z-score KPI1 (x-u)/σ	Z-limit KPI 1	Mean
1	2015-5					
2	2015-6					
3	2015-7					
4	2015-8					
5	2015-9					
6	2015-10	0	0,5	-0,50	12,00	0,00
7	2015-11	1	-2	2,00	12,00	0,00
8	2015-12	1	-2	2,00	12,00	0,00
9	2016-1	0	0,5	-0,50	12,00	0,00
10	2016-2	0	0,5	-0,50	12,00	0,00
11	2016-3	0	0,5	-0,50	12,00	0,00
12	2016-4	0	0,5	-0,50	12,00	0,00
13	2016-5	0	0,5	-0,50	12,00	0,00
14	2016-6	0	0,5	-0,50	12,00	0,00
15	2016-7	0	0,5	-0,50	12,00	0,00
16	2016-8	0	0,5	-0,50	12,00	0,00
17	2016-9	0	0,5	-0,50	12,00	0,00
18	2016-10	1	-2	2,00	12,00	0,00
19	2016-11	0	0,5	-0,50	12,00	0,00
20	2016-12	0	0,5	-0,50	12,00	0,00

Appendix G: Analysis

Project processes				AGR.2 Supply process				ENT.5 Quality Management Process				PRJ.3 Assessment and Control Process			
			#	#	%			#	%			#	%		
	Projects		4	3	75,0			4	100			3	75,0		
	KPI's		31	6	19,4			6	19			4	12,9		
Per level increase			#	Variation	%	Delta	%	Variation	%	Delta	%	Variation	%	Delta	%
		Total		2		2		2		2		3		2	
	Level 2-3	Performance increase		1	50,0	1	50,0	2	100,0	2	100,0	1	50,0	1	50,0
		Similar performance		0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0
		Performance decrease		1	50,0	1	50,0	0	0,0	0	0,0	1	50,0	1	50,0
		Total		6		6		1		1		1		1	
	Level 3-4	Performance increase		3	50,0	3	50,0	1	100,0	1	100,0	1	100,0	1	100,0
		Similar performance		2	33,3	2	33,3	0	0,0	0	0,0	0	0,0	0	0,0
		Performance decrease		1	16,7	1	16,7	0	0,0	0	0,0	0	0,0	0	0,0
Per process					#	average Δ	Achieve goals		#	average Δ	Achieve goals		#	average Δ	Achieve Goals
	Per Process	Average delta per process		Level 2	2	0,0	(1/2	Level 2	3,0	-0,5	(1/3	Level 2	3,0	0,7	(3/3
				Level 3	6	0,3	(3/6	Level 3	3,0	-0,12	(1/3	Level 3	4,0	-0,2	(2/4
				Level 4	6	1,0	(4/6	Level 4	2,0	-2,0	(0/2	Level 4	1,0	0,0	

Per capabilty level		Achieve goals	%	Trend up	%
	Level 2	7/17	41%	5/17	29%
	Level 3	12/27	44%	16/27	59%
	Level 4	7/17	41%	10/17	59%

Improvement of delta	*improvement*	*similar*	*decrease*	Reduction in variation	*improvement*	*similar*	*decrease*	Trend	*Up*	*Down*
level 2 to 3	9/14	2/14	3/14	level 2 to 3	8/14	0/14	6/14	Level 2 to 3	8/14	6/14
level 3 to 4	6/11	2/11	3/11	level 3 to 4	6/11	2/11	3/11	Level 3 to 4	6/11	5/11

PRJ.5 Risk Management Process			
#	%		
1	25,0		
1	3,2		
Variation	%	Delta	%
1		1	
1	100,0	1	100,0
0	0,0	0	0,0
0	0,0	0	0,0
0		0	
0	0,0	0	0,0
0	0,0	0	0,0
0	0,0	0	0,0
	#	average Δ	Achieve Goals
Level 2	1,0	-0,6	0/1
Level 3	2,0	-0,9	(0/2
Level 4			

PRJ.7 Information Management Process			
#	%		
1	25,0		
1	3,2		
Variation	%	Delta	%
0		0	
0	0,0	0	0,0
0	0,000	0	0,0
0	0,0	0	0,0
1		1	
1	100,0	1	100,0
0	0,0	0	0,0
0	0,0	0	0,0
	#	average Δ	Achieve Goals
Level 2	0,0		
Level 3	2,0	0,0	(1/2
Level 4	4,0	0,4	(0/2

TEC.10 Maintenance Process			
#	%		
2	50,0		
3	9,7		
Variation	%	Delta	%
1		1	
0	0,0	0	0,0
0	0,0	1	100,0
1	100,0	0	0,0
2		2	
0	0,0	0	0,0
0	0,0	0	0,0
2	100,0	2	100,0
	#	average Δ	Achieve Goals
Level 2	1,0	-1,2	(0/1
Level 3	3,0	0,3	(2/3
Level 4	4,0	-1,6	(1/4

Safety Process			
#	%		
3	75,0		
4	12,9		
Variation	%	Delta	%
0		0	
0	0,0	0	0,0
0	0,0	0	0,0
0	0,0	0	0,0
3		3	
2	66,7	2	66,7
0	0,0	1	33,3
1	33,3	0	0,0
	#	average Δ	Achieve Goals
Level 2	1,0	0,7	(1/1
Level 3	3,0	0,4	(2/3
Level 4	3,0	0,9	(3/3

Appendix H: Validation

Responses

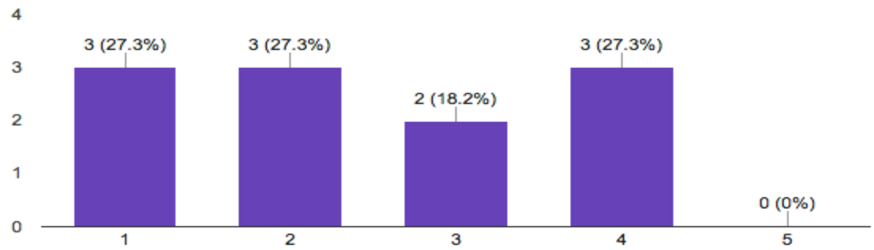
Function:

1. Director exploitation
2. Quality coordinator
3. Quality manager
4. Client: Project manager
5. Process manager
6. Director exploitation
7. Client: Process manager
8. Process manager
9. Process manager
10. Technical manager
11. Quality coordinator

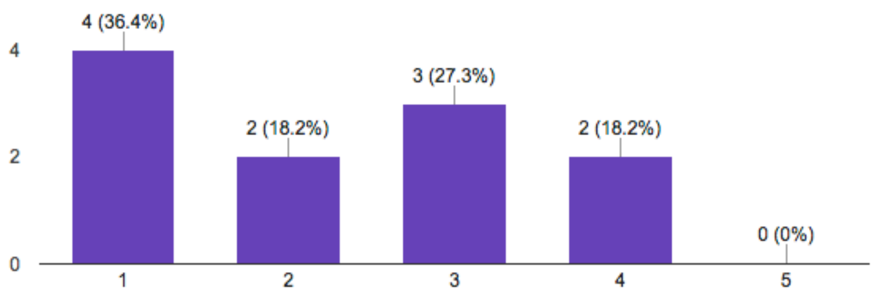
Questions:

Part A: Fit-for-purpose

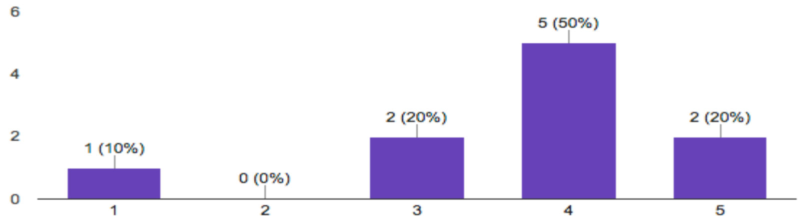
1. For a contractor the main goal to implement ISO15288 and ISO15504 is to reduce failure costs.



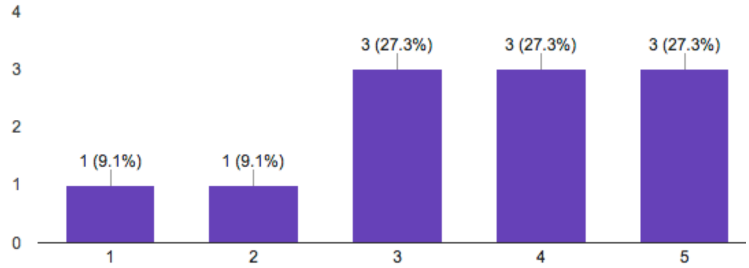
2. Contractors include ISO15288 and ISO15504 to achieve their own goals (not to score EMVI points, Cherry picking)



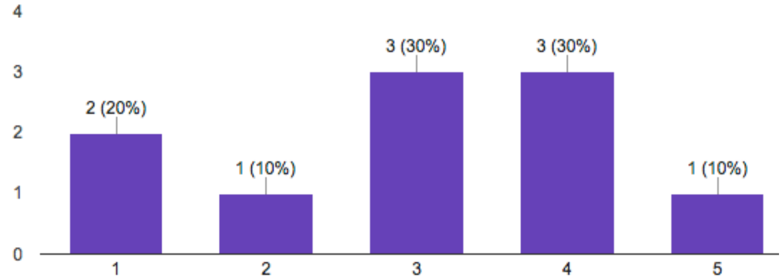
3. With small adjustments the ISO15288 framework fits civil infrastructure projects.



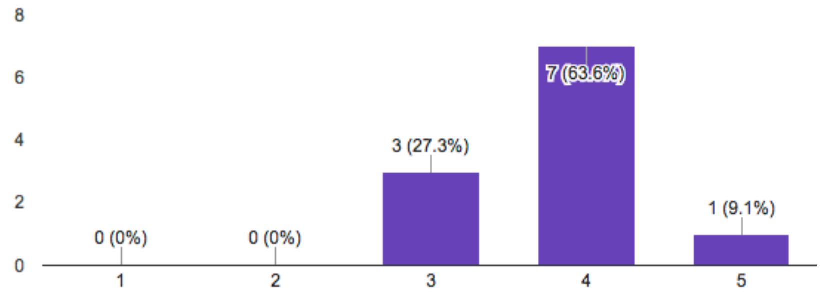
4. Infrastructure project specific processes should be included into the ISO15288 framework and ISO15504 assessment to successfully manage the project.



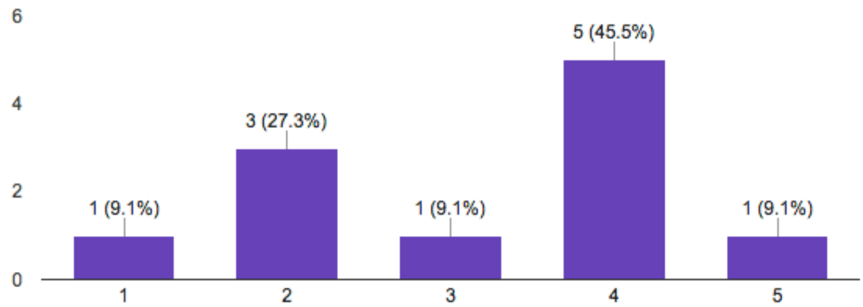
5. Contractors only use the tailoring process to eliminate ISO15288 processes (parts of goals, activities, outcomes)



6. The knowledge and application of the ISO15288 framework is improving over the projects.

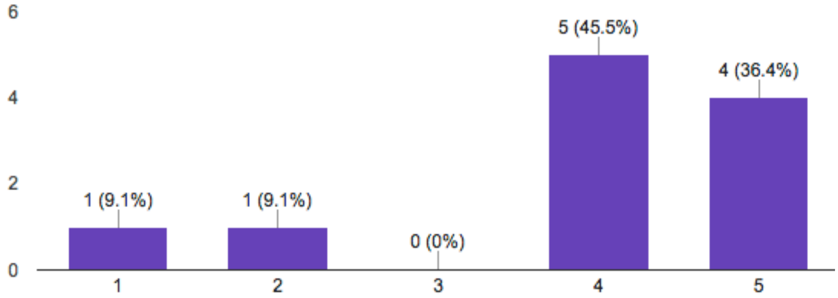


7. The ISO15504 assessment overlaps with other internal and external audits (for example ISO9001, SCB, EDP)

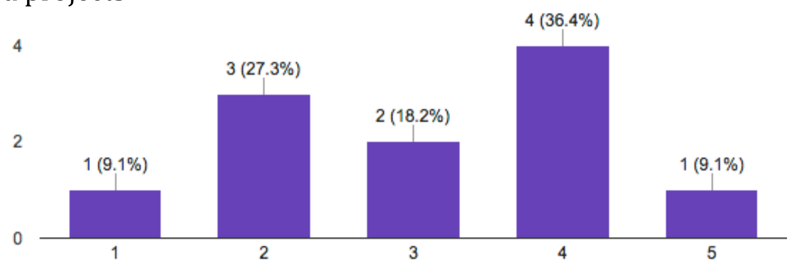


Part B: Capability levels

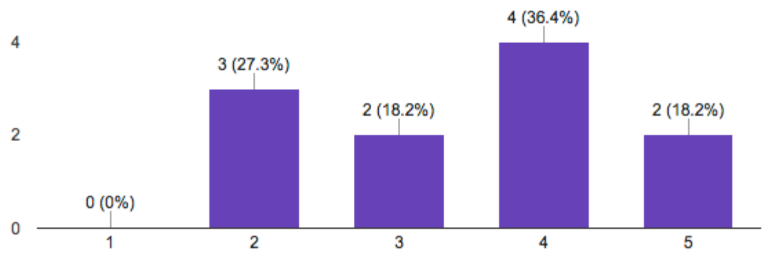
8. In an experienced project organisation, working according to the Project Management System is equal to achieving capability level 3.



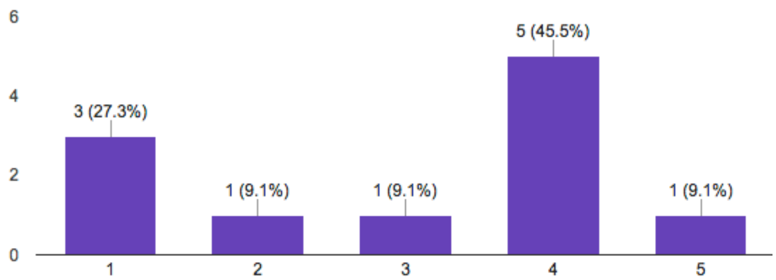
9. It is useful to include the ISO15288 agreement, organizational-enabling and technical management processes (AGR, ENT, PRJ) in the tender phase of major civil infra projects



10. Including AGR, ENT and PRJ processes in the tender phase shortens the duration to achieve capability level 3 after contract date.

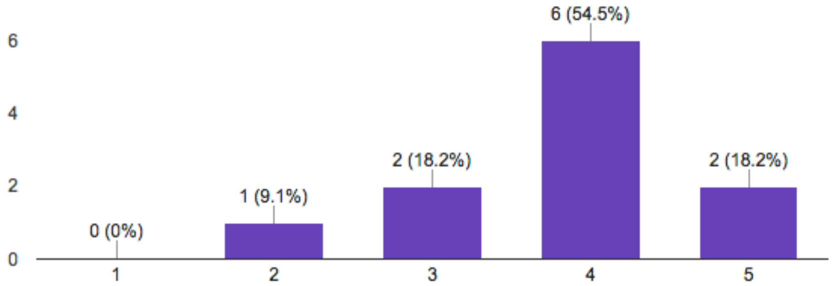


11. During the maintenance phase the design and implementation of maintenance work is included in the maintenance process, resulting in an inactive status of the other technical processes. The other technical processes only become active at a change procedure.

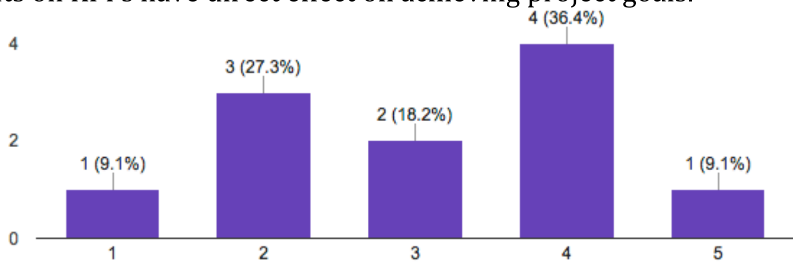


Part C: Analysis

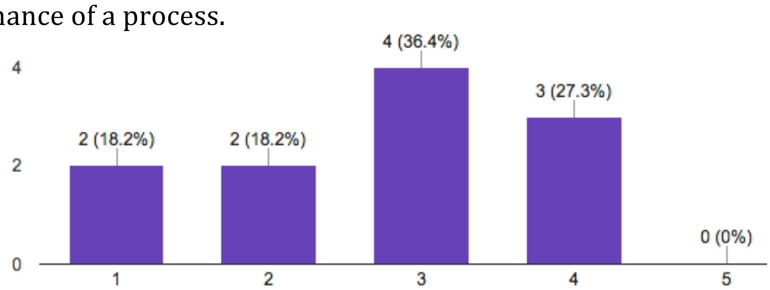
12. Process related KPI's represent the actual performance of a process. (no output KPI's)



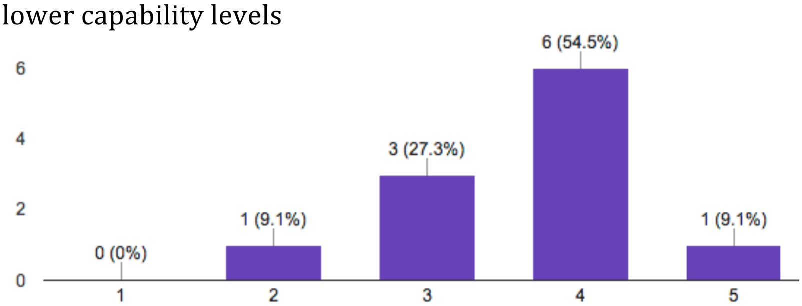
13. The limits on KPI's have direct effect on achieving project goals.



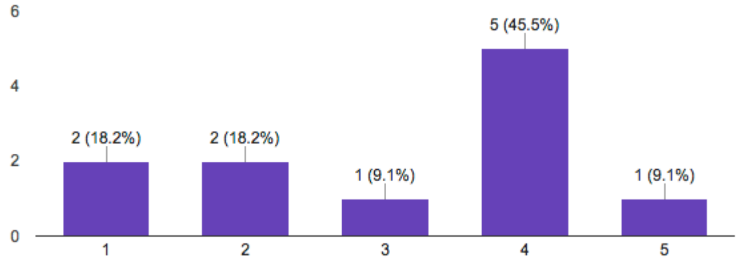
14. The degree of variation and the achievement of business goals indicate the performance of a process.



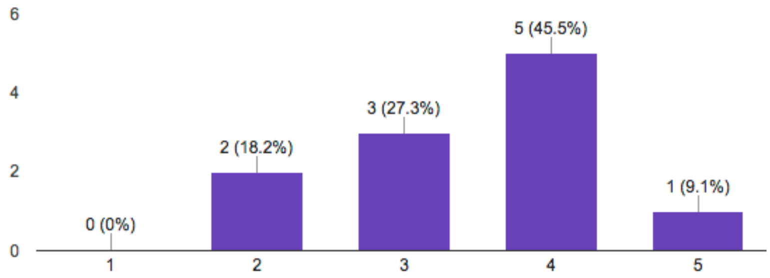
15. Achieving Capability level 4 does not translate to achieving business goals more than at lower capability levels



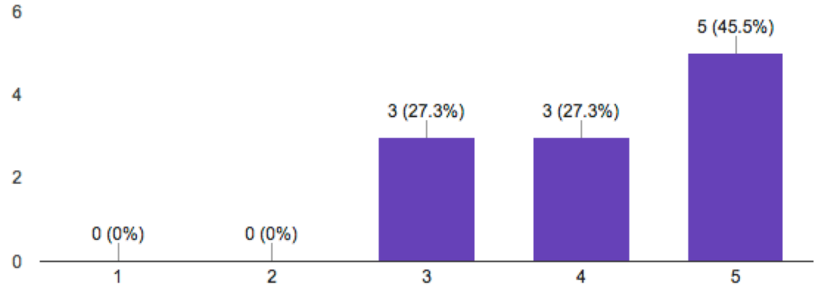
16. Increasing a capability level does not guarantee an increase in process performance. (only in 50% of the processes)



17. A process with on a high capability level is better in adjusting to external influences. (risks, changes)



18. The human factor to achieve performance has more influence than all procedures and standards



19. Correct implementation of the ISO15288 framework and ISO15504-6 assessment contributes to the performance of the contractor.