Anticipating scope creep in the design phase of infrastructure projects

A case study on scope creep and its effects

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March 29th, 2018

Delft University of Technology
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Report:

Type:	Graduation Thesis
Document title:	Anticipating scope creep in the design phase of infrastructure projects
Sub title:	A case study on scope creep and its effects
Place:	Delft
Date:	29-03-2018

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Master:	Construction Management & Engineering
Course:	CME 2000 – Graduation Thesis

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Preface

This thesis contains the result of my graduation research to complete the master's degree of the Msc programme Construction Management and Engineering at the Technical University in Delft. The research is conducted at the engineering company Sweco Nederland. This thesis contributes to anticipating scope creep that occurs in every infrastructure project. The causes of scope creep are explored and four factors with high potential to control scope creep are recommended for implementation.

This research contains five different parts. Part A contains the introduction, problem and research structure. Part B gives the demarcation of this research. The analysis of the literature is placed in part C1, and the analysis of the case study is placed in part C2. Fourth, part D contains the results of the analysis. Finally in part E the conclusion and recommendation are given.

Writing my thesis could not have been completed without the help of others. I would like to use this opportunity to thank everybody who helped me.

Firstly I would like to thank my colleagues from Sweco who made this graduation experience one accompanied by jokes and laughter. Special thanks goes to my daily supervisor Gijsbert van Eck. He helped me gaining interesting insights, always made time to speak to me, but also helped me through times of insecurity. I would also like to thank my supervisor Freerk Hoeksma for his academical guidance and the many metaphors he used to make me rethink my statements. Special thanks also goes to Marco Janssen, who was not my official supervisor, but helped me on a regular basis with the problems I encountered. Without the help of Marco this would be have been a more difficult journey. Also thanks go out to Herman Treurniet, who was always willing to listen to my complains or joyful insights and helped me more than once through the day.

Special thanks goes to my graduation committee who provided guidance during my research process. Without the guidance and critical notes of Rogier Wolfert, Sander van Nederveen, Ruud Binnekamp and Mark de Bruijne, this research would have been of less quality.

I would like to thank Marcel de Coo and Robin de Rooy for their time, help and advice while conducting my case study. Furthermore, special thanks goes to Jan Heijmans, Wim van Rijswijk, Herman Paas, Guido van Bennekom, Lennart van Dijk, Han de Kreij, Dominique Pankow, Joren Prinsen, Kim Klappe and Ariaan van Heiningnen. They gave guidance, helped me or gave me knowledge I needed to conduct my research. The survey was filled in by many participants who I would also like to thank.

Last but not least I would like to thank my family for their support, but especially my mother and Martijn for their confidence and for always believing in me.

Bernice Hofland
Delft, March 2018

Summary

Introduction, problem and goal of research

Infrastructural projects are complex. This follows from their dynamic and multi-disciplinary character and the high amount of interconnected parts. To deal with this, system engineering is seen as a suitable approach. The complexity in projects leads to high risks of unavoidable changes. Project changes are found to be one of the most frequent and largest concerns and occur in every stage of the life-cycle. The scope is found to be an important factor that affects the success of project implementation. Very few projects exist that do not change in some way during their life cycle. Additionally, very few changes occur that are not of influence on time, cost and quality.

Changes in an early phase of the project are easier to incorporate, are accompanied by lower costs and have a large effect on having a fit for purpose system, see figure 0.1. Scope changes in the design phase can thus be seen as desirable. But even though some changes may be justified, many are caused by never analyzing or underestimating the consequences while the claimed benefits are overestimated. When changes are not formalized and managed correctly, it is a risk contributing to project failure.

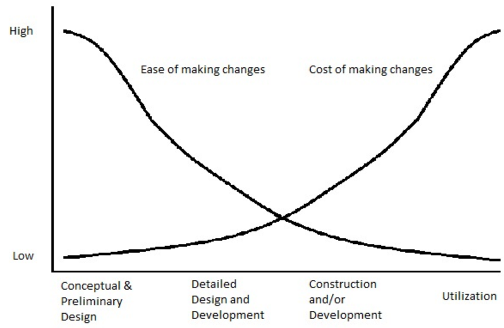

Figure 0.1.: Ease and cost of changes for the life cycle (Faulconbridge and Ryan, 2014)

A change that is not formalized and managed correctly, is scope creep. Scope creep consists of many minor changes that seem to have a minor impact, but when accumulated can have a large impact a project. Some project changes may be justified, but too many sneak into a project because the consequences are either never analyzed or drastically underestimated and the claimed benefits are unrealistically overestimated. Scope management is needed to decrease scope creep and its negative impact before it becomes a large influence or cancels a project. Scope creep is defined as:

Non-formalized scope changes whereof the impact is negative and not researched.

There is an interesting contradiction between wanting scope changes in the design phase and not wanting scope creep. Scope creep causes ignorance about the impact and therefore the project team is unable to anticipate this. This will lead to a negative influence on the integrity of the design and on the costs, planning and quality of a project. Scope management only controls scope when changes are formally identified, but cannot control change in this situation. It is a feared thing that can happen to any project, wastes money, reduces satisfaction, and leads to not meeting the expected project value. The problem statement can be defined as:

Projects cannot anticipate scope creep because the change is not formalized and the impact not researched which results in negative effects on the planning, the budget, and the quality of the end product.

The research objective will try to improve the problem situation. As such, this research will lead to characterizing scope creep initiated in the design phase and gain insight into anticipating its causes and effects. This will be done by following the objective of this research:

To make recommendations by trying to compare approaches for scope management to practice and merge this into factors with high potential for better anticipating scope creep and its effect.

Method

The sub-research questions together will gain enough knowledge to answer the main research question: **Which course of action is recommended to improve the ability to anticipate scope creep and its effect, having System Engineering as a framework in the design phase?**

Sub-research question 1:	*Which causes and effects of scope changes and scope creep can be found in literature?*
Sub-research question 2:	*Which causes of scope creep can be found in practice?*
Sub-research question 3:	*Which scope management approaches to improve the anticipation of scope creep can be found in literature for projects using System Engineering?*
Sub-research question 4:	*How are the scope management approaches from theory executed in practice and is this done as intended?*
Sub-research question 5:	*What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?*
Sub-research question 6:	*Which parts of the approaches are best to anticipate scope creep, considering both literature and practice?*
Sub-research question 7:	*Can the parts based on theory be implemented realistically in practice?*

This research will be an exploratory research and a case study is used to gather information for the analysis. For the case study document research and in-depth interviews are used. The case study projects are chosen based on certain aspects. For this research it is intended that the results must be applicable to all kind of infrastructural projects and the selection must be as similar as possible to an average infrastructural project. Different rail projects are examined based on the problem of scope creep and using System Engineering as framework. The rail sector is found suitable as context for a case study and to translate to a generic advise for infrastructure projects. The projects are also chosen based on additional criteria, for instance the type of assignment, the complexity, the client-contractor relation, large cost overruns and many scope changes. The chosen cases are shown in figure 0.2.

This research followed a certain structure where both literature and practice are combined to find the factors with the highest potential to control scope creep, see figure 0.2. The analysis is structured by the use of four criteria, namely costs, integrity, quality and planning. Causes for scope creep are found in literature and in practice for question 1 and 2, and are appointed to the different criteria to analyze the case study on the basis of the scope management approaches that can improve anticipating scope creep. This analysis results in the most promising factors and are validated on their realistic character before a recommendation is made to anticipate scope creep.

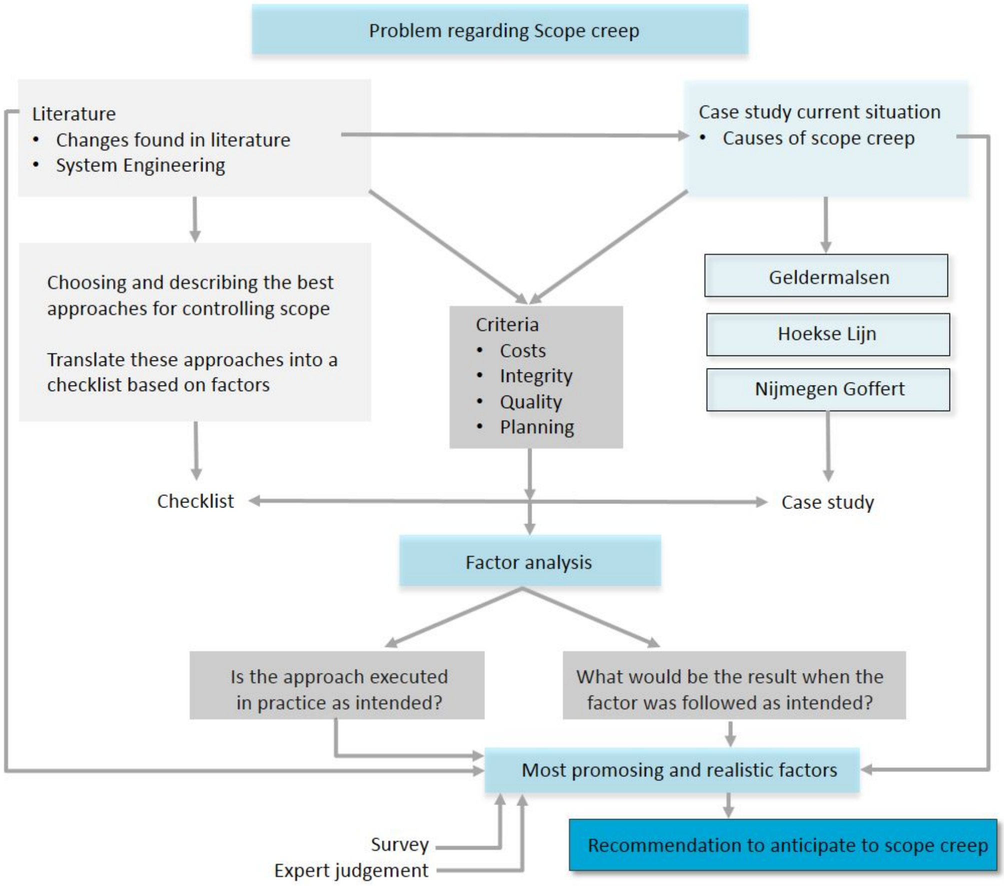

Figure 0.2.: Structure of the research

Analysis

Scope Creep can occur in multiple forms. The causes found in practice can be merged into seven main causes which are also in line with what is found in literature:

1. Start of the project
2. Process of an EOW
3. Time pressure
4. Scope management process
5. Team composition
6. Process of the project
7. Human Factors

Scope changes can have effects like rework, time loss, and reorganization of schedule and work methods. Indirect effects include, among others, loss of productivity, disputes and blame among project partners, loss of float and therefore increased sensitivity to further delays.

Three scope management approaches were found that are the most promising to manage the scope and anticipate scope creep. These approaches were analyzed by looking at the case study projects. It was questioned how they were executed in practice and if this was done as intended. Furthermore it was questioned what the result would be if they would have been followed correctly as stated by theory. Each approach was divided into factors that are all essential parts. This resulted in eleven factors that were analyzed based on four criteria. These are costs, integrity, quality and planning.

(1) Configuration Change Management can be divided into eight factors:

1. Set up the configuration and the Configuration Management Plan
2. Identifying Configuration Items
3. Accurate data and clarity on version and status of documents
4. Configuration Control Board
5. The establishment of baselines
6. The processing of changes
7. Distinction between types of changes
8. EOW approvals done.

(2) Information management can be divided into two factors:

1. Information management
2. Check documents on accuracy, consistency and completeness

(3) Partnering is analyzed as one factor.

Results

The factors with highest potential follow from comparing the eleven factors to each other. For each criteria the most promising factors can be derived:

- Costs: EOW approval, Partnering and Check on accuracy, consistency and completeness
- Integrity: Information management system, Configuration Control Board and Identifying Configuration Items
- Quality: Baselines, Configuration Control Board and Establishing the configuration and the Configuration Management Plan
- Planning: Baselines, Information management system, Partnering

The four criteria can be prioritized for the client and the engineering company. Both parties are important to consider when finding the most realistic factor to anticipate scope creep.

Prioritizing criteria results in the factors with highest potential for both parties. This lead to the four factors that best improve the ability to anticipate scope changes, shown in figure 0.3.

Figure 0.3.: Most important factors from the left to the right

The realistic character of the factors is analyzed in five steps and this gives input for the recommendations.

1. First the factors are again related to the case study analysis. During the analysis some interesting points were raised considering the realistic character of the factors.
2. Second the factors are related to the seven scope creep causes found in the case studies. It is analyzed how many of these causes that are found in practice could be solved when implemented. A Configuration Control Board was the most effective, but an information management

system influenced the most frequent causes. It is also analyzed if the factors could be combined. Combining partnering and an information management system would be the most effective.

3. Third the factors are analyzed by the use of a survey (N=33). This survey shows how many projects used the factors and if the participants would find them realistic to implement and if they think the factor could be of value for keeping control of the scope. Information management system was seen as most realistic and giving most value. The scores were also accompanied by explanations of the participants which showed interesting insights.
4. Fourth two experts from the work-field were asked if they would see the four factors realistically being implemented in projects. Most factors would be realistic under certain circumstances.
5. Finally the factors are related to literature to give the factors more guidance for implementation and see if literature also state the factors as realistic.

Recommendations for practice

Three recommendations for practice are established:

(1) It is recommended to introduce a Configuration Control Board together with baseline management. These two factors are seen as complementary and crucial for maintaining the scope. The first one is scoring high on the analysis with the four criteria, the latter is scoring high in maintaining scope in practice and is more realistic. Together they ensure a good basis for scope management and anticipating the impact of changes. It would require that sufficient room is given and capacity is made available to make a thorough assessment and impact determination of changes and to manage the baselines.

(2) It is recommended that projects are structured on the basis of an information management system. Such a system would make scope management and maintaining the integrity easier and reduces scope creep. A system that focuses on managing requirements, that is already used within the company and that employees already work with, is recommended. Someone must be responsible for maintaining the system, but it is essential that employees see that it is everyone's responsibility to work with the system and thus the ignorance with the system must be taken away.

(3) It is recommended to introduce partnering. Partnering ensures that projects focus on mutual benefits, trust and good cooperation which would improve scope management and take away causes of scope creep. This can be reached by open consultation, transparency, mutual respect, a fixed agenda with regular meetings and actions like team building exercises, joint goal formulation, and periodic assessment. However, focus must also remain on setting up good scope management.

Relevance

The academic relevance can be found first in enriching the theory of the scope management approaches with the practical application in a certain demarcated sector and the problems that are found there. Second, it is shown that scope creep is a problem that happens to each project and is related to fact that following the approaches as intended could result in an unworkable situation. Third, this research shows which causes of scope creep are disturbing the use-ability of the scope management approaches. Finally, theory is embedded with knowledge on improving the anticipation of scope creep.

The practical relevance can be found in the recommended factors that came forth as best factors to anticipate scope creep and on how to realistically implement these to ensure the best possible situatione. Also problems were found by the performance of the scope management approaches and a focus can be established on improving these.

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Part A - Introduction

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1. Introduction

Infrastructural projects in the construction industry are complex. The complexity follows from the dynamic and multi-disciplinary character of projects and the high amount of interconnecting parts. The dynamic character on its turn follows from the increase in uncertainty in technology, budget, and development processes (Chan, Scott & Chan, 2004). Highest in complexity are projects with a high degree of interaction and inter-dependency and which are continuously changing or evolving. The main components of complexity are bad communication and poor generation and use of information. Whilst technical complexity is a definite factor, it is in fact the organizational aspects which contribute the most to project complexity (Wood & Gidado, 2008).

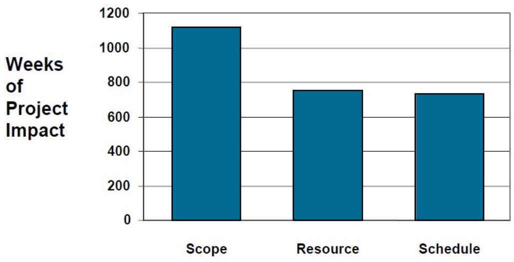
The dynamic character results in increasing complexity, but also in more difficult projects and a project team that faces unprecedented changes throughout the process (Chan, Scott & Chan, 2004). The complexity and related uncertainty results in unforeseen events, unavoidable changes (Boggelen, 2011) and in circumstances high of risk and uncertainty. Currently, the construction industry has developed difficulty in managing the increasing complexity (Wood & Gidado, 2008).

For developing complex systems and working systematic, a suitable approach is needed. The rise of complexity at any given time and cost frame and the missing interdisciplinary collaboration can be approached with System Engineering (SE) (Werkgroep Leidraad, 2013) and is defined as:

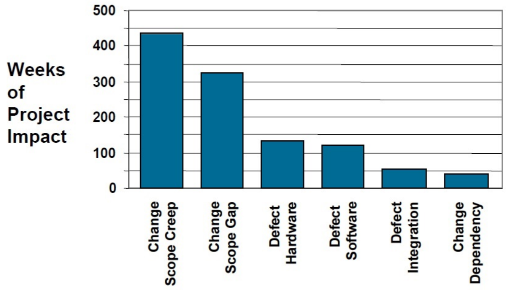
"System Engineering are systematic efforts to (1) translate an operational need into system performance and configuration specifications, (2) incorporate all physical and functional requirements to achieve an optimal design, and (3) integrate factors such as maintainability, reliability, safety, and security to meet cost, performance, and schedule objectives" (Business Dictionary, 2017).

System Engineering is in the construction industry often prescribed as a framework to work with when facing highly complex projects. It ensures that the developed product meets the requirements of all stakeholders more completely and helps establishing interdisciplinary collaboration (Gräßler & Yang, 2016). SE results in a quality system where quality is measured by the ability to meet the documented requirements, so being fit for purpose. Furthermore it has as benefit the saving of money in all phases of the system life cycle (Faulconbridge & Ryan, 2014). Due to the dynamic environment in the construction industry, a project is never static and sensitive to a lot of changes. SE helps to map the scope and anticipate these dynamics. This helps the involved parties having a clear view on the impact of changes (Werkgroep Leidraad, 2013).

However, projects in the construction industry are still characterized by cost overruns and delays in almost every case. Over the time span between the initiation and completion, many factors may influence the final project costs (Flyvbjerg, Holm & Buhl, 2008). The project process is subject to many variables and unpredictable factors resulting from many sources causing delay (Assaf & Al-Hejji, 2006) (Al Hammadi & Nawab, 2016). Changes are due to various causes from different sources and have considerable impacts. Changes are defined as *"any additions, deletions or modifications of the scope of the project"* (Hwang & Low, 2012). Various researchers say that project scope is found to be an important project related factor that affects the success of project implementation (Chan, Scott & Chan, 2004). In line with this is that project changes is found to be one of the most frequent and largest concerns and occur on every stage of the life-cycle. Risks related to this are dominant in frequency and damage, see figure 1.1a (Kendrick, 2008).



(a) Pareto of risk categories



(b) Pareto of scope risk

Figure 1.1.: Pareto of risk (Kendrick, 2003)

The scope of a project is the basis of the design, however, what actually includes the scope will vary by type of project. When the design phase continues, the project scope becomes more detailed, but will remain between the defined boundaries (Kuprenas & Nasr, 2003). Scope can be divided into project and product scope. This research will look only at product scope, defined as "*the attributes and characteristics of the deliverables in the project creation which are measured against requirements*" (Mirza, Pourzolfaghar & Shahnazari, 2013)).

Scope changes can occur through a fundamental change of design or through small changes called scope creep (Kuprenas & Nasr, 2003). Scope creep shows the most impact on projects in terms of scope, see figure 1.1b (Kendrick, 2003). How scope creep is related to scope changes and how this follow from the different characteristics of a project is shown in figure 1.2.

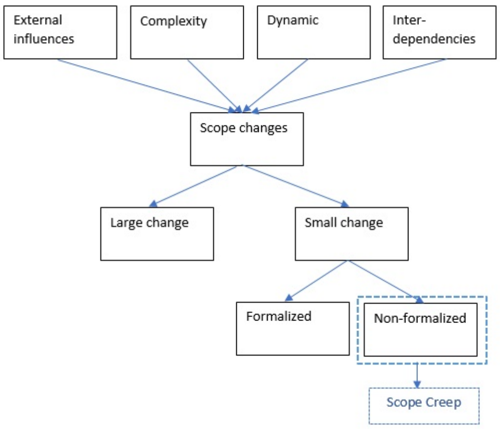


Figure 1.2.: Demarcation into scope creep (Own figure)

Scope creep is described as the adding of features and functionality without having insight on the effects on time, costs and resources, or without customer approval (PMI, 2008). Scope creep therefore is a term for unauthorized changes (Khan, 2006). It influences a project without approval and/or insight into its impact. Good management of the scope is important to decrease scope creep and its negative impact, as it can become a very large influence and may even cancel a project (Khan, 2006). However, with good scope control and the use of a method like SE, scope creep can still occur, and therefore it is important to research this phenomenon. Scope creep will be defined as:

"non-formalized scope changes whereof the impact is negative and not researched".

2. Problem Description

In this chapter the problem will be defined. The problem will first be introduced in section 2.1 followed by the problem statement in 2.2 and the problem demarcation in 2.3.

2.1. Problem Introduction

The most significant and common risk on each project is losing overall control of project scope (Massey, 2011). In addition it can be said, that there are very few projects that do not change in some way during their life cycle and that there are very few changes without influence on time, cost or quality aspects (Lester, 2006). Each day in a construction process, decisions are made based on incomplete information, personal experience, and assumptions and therefore, project changes are to be found in all stages of a project life-cycle (Hao, Shen, Neelamkavil & Thomas, 2008). Changes are thus very common in construction projects and occur from different sources, by various causes, at every stage of the project, and may have a negative impact on the costs, schedule and quality (Hao et al., 2008). Managing changes effectively is thus crucial to the success of a project (Hao et al., 2008).

Project changes are found to be one of the most frequent and largest concerns for projects (Hwang & Low, 2012). However, the impact of changes is not the same throughout the project, see figure 2.1 (Faulconbridge & Ryan, 2014). Changes in later phases of the project have larger impact in general (Hao et al., 2008). Regarding this fact, using SE in the design phase could help leading to cost savings in the construction phase. SE focuses on accurately reflecting the requirements in the design which helps to minimize these costly and time-consuming changes later in the life cycle. The design decisions made can be traced back to the requirements and reduces the risk of failure later (Faulconbridge & Ryan, 2014). In the conceptual and preliminary design phase, changes can be made the most easiest for the lowest costs. It is important that the end result of the design is sufficient enough to minimize changes later in the project. Therefore, changes in the design phase could have a positive impact and are even, in some extent, desirable.

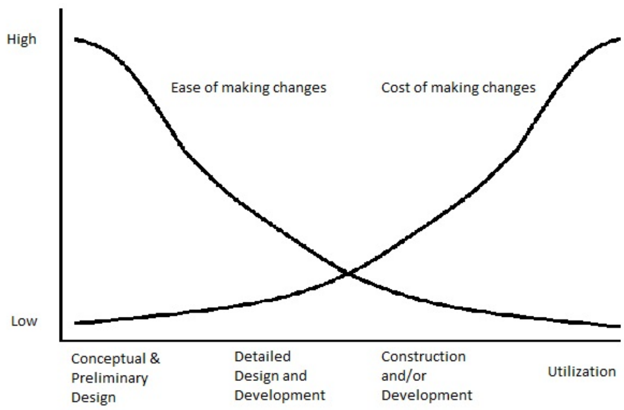


Figure 2.1.: Ease and cost of changes for the life cycle (Faulconbridge and Ryan, 2014)

Scope change is thus an inevitable reality for any project and nothing to be afraid of (Khan, 2006). However, when changes are not formalized and managed correctly, it is a risk contributing to project failure (Hao et al., 2008). A change that is not formalized and managed correctly, is scope creep. Scope creep consists of many minor changes that seem to have individual impact, but can largely impact a project (Shane, Molenaar, Anderson & Schexnayder, 2009). Some project changes may be justified, but too many sneak into a project because the consequences are either never analyzed or drastically underestimated and the claimed benefits are unrealistically overestimated (Kendrick, 2015). So, good management of the scope is needed to decrease scope creep and its negative impact before it becomes a large influence or even cancels a project (Khan, 2006).

The difference between the impact of normal scope changes and scope creep can be seen in figure 2.2. Scope changes are noticed and, based on their impact, approved or not by the client and contractor. These changes are then formalized and scope management makes sure that the scope is still in control.

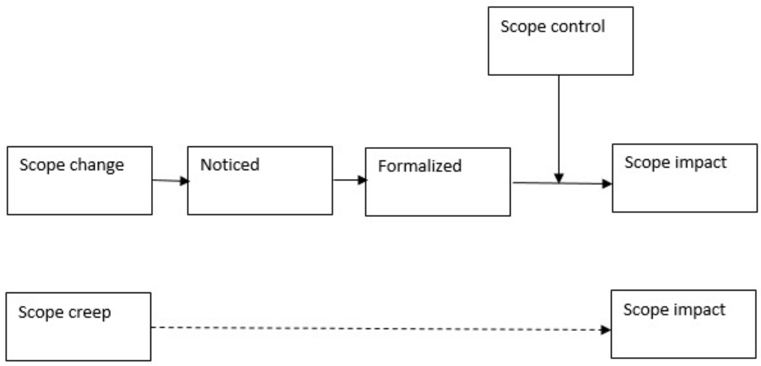


Figure 2.2.: Differences between Scope Change and Scope Creep (Own image)

If a change of scope is not formalized, it can be named scope creep (R. Larson & Larson, 2009). Change management only applies when scope changes are formally noticed and documented, scope creep however is not formalized and therefore not controlled. Therefore, the impact is unknown and scope creep can influence the project negatively without having the project anticipating it. Scope creep increases the project costs by many minor scope changes and always influences the project budget and schedule (Kuprenas & Nasr, 2003). So, scope creep are non-formalized scope changes whereof the impact is negative and not researched, see figure 2.3.

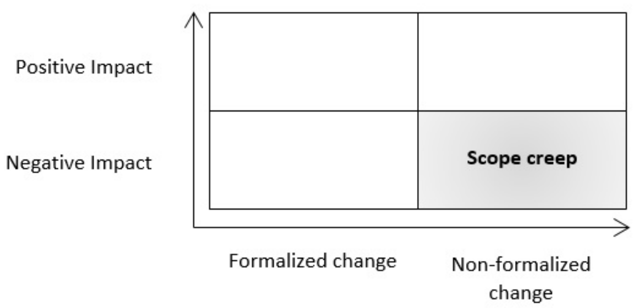


Figure 2.3.: Scope creep defined in terms of impact and formalization (Own image)

It can happen that scope changes are of such small impact that they are chosen not to be formalized as it turns out that in some projects only changes with financial consequences are formalized. These scope changes become floating requirements that are not part of the scope and scope management. These changes can be seen as scope creep because they influence negatively the integrity of the project and ensures that the product is less fit for purpose. All requirements must be verified and validated as part of SE. These floating requirements can cause problems during this validation process. Sometimes they become part of the scope afterwards to recover the validation starting points. However, then they are still seen as scope creep as they influenced the project negatively when they were introduced in the project.

In line with this are scope changes without formalization were afterwards the financial consequences are made insightful with back reasoning. This process follows from an underestimation of the impact of a scope change, and based on this it was chosen to not formalize the change. However, afterwards the (financial) impact turned out to be larger than expected. Also these scope changes are seen as scope creep. The changes meet the characteristics of scope creep at the time of introducing even when they are written down afterwards.

2.2. Problem Statement

There is an interesting contradiction between wanting scope changes in the design phase and not wanting scope creep. Scope creep causes ignorance about the impact and therefore the project team is unable to anticipate this. Furthermore, if changes are not documented, some team members could be not aware of the proposed scope change and would not introduce the change. This influences the iterative character and the integrity of the design negatively. Furthermore it influence the design being fit for purpose when changes do not become part of the scope but are still introduced.

The problem for projects follows from not formalizing scope creep. This results in ignorance about its impact and therefore a project is unable to anticipate this. This will lead to a negative influence on the integrity of the design and on the costs, planning and quality of a project. Scope management only controls scope when changes are formally identified, but cannot control change in this situation. Scope creep is a feared thing that can happen to any project, wastes money, reduces satisfaction, and leads to not meeting the expected project value (R. Larson & Larson, 2009).

The problem statement can be defined as:
Projects cannot anticipate scope creep because the change is not formalized and the impact not researched which results in negative effects on the planning, the budget, and the quality of the end product.

2.3. Problem Demarcation

- **Infrastructural projects of the construction industry** are the main focus of this research. The generalization into this sector will come from Rail projects which are part of this sector.
- **Scope** is demarcated into product scope. A product scope is the attributes and characteristics of the deliverables in the project creation (Mirza et al., 2013).
- **Scope changes** are any additions, deletions or modifications of the scope (Hwang & Low, 2012).
- **Scope creep** are non-formalized scope changes whereof the impact is negative and not researched.
- **System Engineering** is the framework used for the case study projects. The research is delineated by choosing only projects that use System Engineering as this framework is mostly used for highly complex projects. It ensures that the product meets the requirements and helps establishing collaboration (Gräßler & Yang, 2016).
- There is an interesting contradiction between wanting scope changes in the design phase and not wanting scope creep. Due to this tension, scope creep that is initiated in the **the design phase** is considered to be the main focus of this research and therefore only changes in this phase will be researched. The impact of these changes can be phase crossing and therefore also the quality of the end product will be taken into consideration
- Scope influences the **planning, the budget and the quality** and is related to project success. Scope change and creep influence these aspects in different ways. Scope changes are only introduced when the impact on quality, budget and planning is weighed. Scope changes need to have a positive impact on the desired end result. The impact on time and budget is subject to the benefits regarding the quality. Scope creep, however, adds little value (Kendrick, 2015). Scope creep has a direct negative impact on the integrity of the project and thus on the quality, because the influence of the change is not manageable.
- **Quality** is defined as having an end result that is fit for purpose. Fit for purpose is defined as being well equipped/suited for its designated role or purpose (Oxford University Press, 2017).
- **The perspective of the contractor** is used as focus in this research. The contractor in the design phase is often an engineering company. The viewpoints of the client are taking into consideration as this makes the outcome of the research more realistic.

3. Research Structure

In this chapter the research structure will be made clear. First the research objectives are stated in 3.2, which are based on the problem that is already stated in chapter 2. The objectives form the basis for the research question in 3.2. The relevance of the research will then be discussed in 3.3. The research will be realized using a certain research method, which will be discussed in 3.4. Finally, the research followed a certain structure which is discussed in 3.4.4.

3.1. Research objectives

In chapter 2 an elaboration is made on the problem that currently is found in infrastructural projects in the construction industry. The defined problem statement was: *Projects cannot anticipate scope creep because the change is not formalized and the impact not researched which results in negative effects on the planning, the budget, and the quality of the end product.*

The research objective will try to improve the problem situation. So, this research will lead to characterizing scope creep initiated in the design phase and gain insight into anticipating its causes and effects. This will be done by following the objective of this research:

To make recommendations by trying to compare approaches for scope management to practice and merge this into factors with high potential for better anticipating scope creep and its effect.

This overall research objective can be split up into three different sub-objectives:

- To get a clear picture of the optimal approach found in literature for the management of scope
- To get a clear picture of the current approach in practice regarding these approaches
- To get a recommendation on implementing factors that will create an environment to be able to anticipate the origin of scope creep and reducing its negative impact on planning, budget and quality

3.2. Research Question

The problem and different objectives that are defined earlier, together demarcate the research. The research is a combination of a part based on literature and a part based on the practice, which will be discussed in 3.4. It is shown in figure 3.1 how the different sub-research questions relate to both practice and literature and to both scope creep and doing an analysis.

The different sub-research questions together will gain enough knowledge to answer the main research question in this paper. This question follows from the research objective. The main research question can be stated as:
Which course of action is recommended to improve the ability to anticipate scope creep and its effect, having System Engineering as a framework in the design phase?

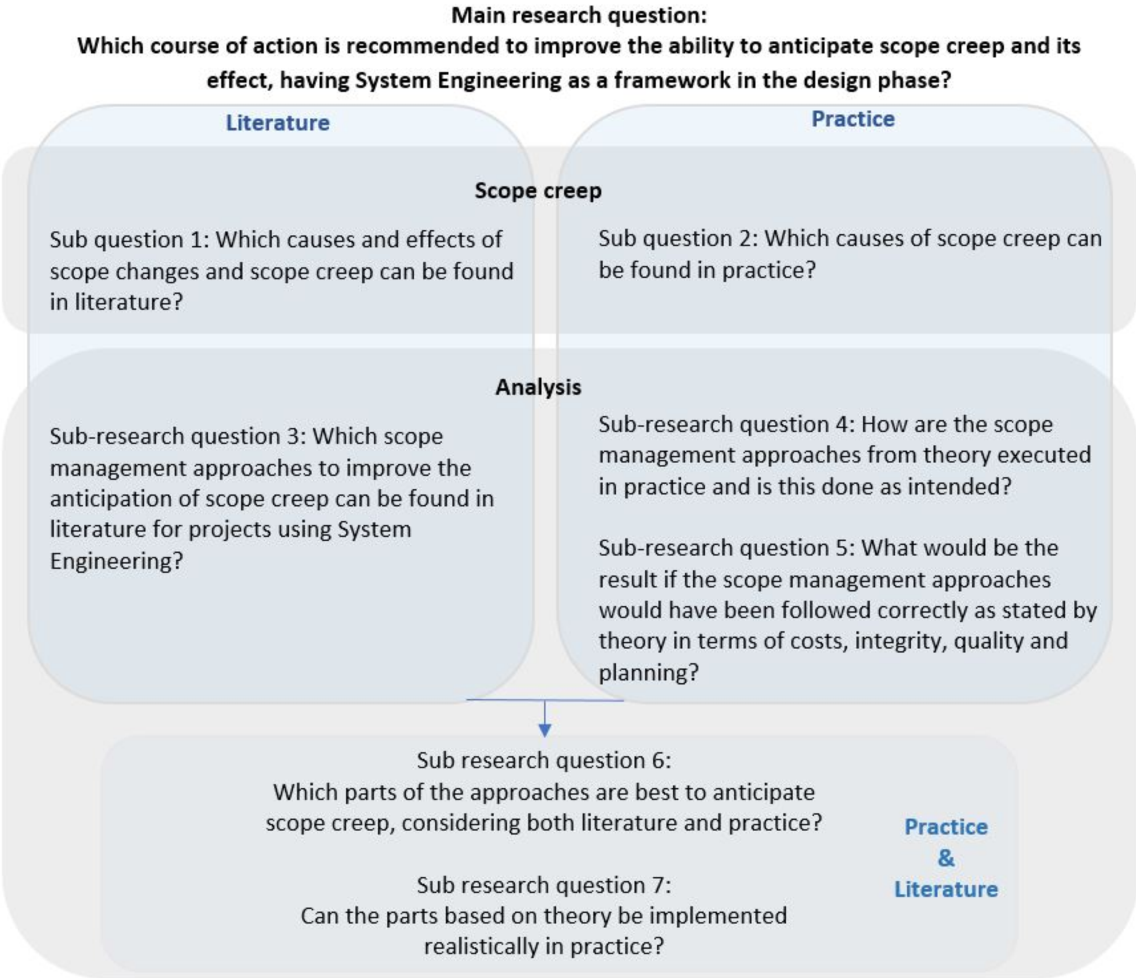


Figure 3.1.: Structure of research questions (Own image)

Sub-research questions regarding Scope creep

These two questions will focus on researching scope creep. Question 1 will give insight into the effects and what can be found as causes for scope creep in the literature. Mostly scope creep is seen as part of scope change and therefore causes and effects for scope change can be the same for scope creep. Question 2 will focus on which causes for scope creep can be found in practice. These questions will be the input for the recommendation.

Sub-research question 1:	*Which causes and effects of scope changes and scope creep can be found in literature?*
Sub-research question 2:	*Which causes of scope creep can be found in practice?*

Sub-research question regarding the analysis of the literature

Question 3 will focus on finding approaches for scope management. These approaches must be suitable to improve the anticipation of scope changes. These approaches are to be translated into a checklist, so this can be used for the analysis of the practice.

Sub-research question 3:	*Which scope management approaches to improve the anticipation of scope creep can be found in literature for projects using System Engineering?*

Sub-research question regarding the analysis of the practice
Question 4 focuses on how the scope management approaches stated in question 3 are executed in practice and it shows whether or not it is done as intended. Question 5 uses the information of question 4 and explains what would have been the result if the approaches would have been followed correctly. This is based on four different criteria, costs, planning, quality and integrity. Why these four criteria are chosen is discussed in section Q.1 in appendix Q.

Sub-research question 4:	*How are the scope management approaches from theory executed in practice and is this done as intended?*
Sub-research question 5:	*What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?*

Sub-research questions regarding the comparing of the analysis of the literature and practice Question 6 focuses on which parts of the scope management approaches seems promising to anticipate scope creep. This is based on the findings of both the literature analysis and the practice analysis. How these theoretical parts can be implemented in practice in a realistic way is asked in question 7.

Sub-research question 6:	*Which parts of the approaches are best to anticipate scope creep, considering both literature and practice?*
Sub-research question 7:	*Can the parts based on theory be implemented realistically in practice?*

3.3. Relevance

As stated in the objective, an analysis of the current situation of scope management approaches for controlling the scope and anticipating scope creep will be executed. The different approaches are split up into factors that are analyzed on their ability to anticipate to scope creep, and the recommendation will focus on the result of this analysis. It is hypothesized that problems will be found both in the current process and in the realistic character of the approaches and how scope creep is embedded in the literature. The recommendation therefore will be twofold and will be both theoretically and practically relevant.

The recommendations regarding the problem in practice will be based on an improving anticipating scope creep by introducing factors of the scope management approaches into projects. The limitations regarding the literature will be improved by embedding scope creep within the approaches and System Engineering, and by putting focus on the realistic character of the factors. This twofold suggestions leads to better results in terms of quality, integrity, budget and planning in practice, which is beneficial for involved parties. Furthermore, the literature will be enriched with knowledge of scope creep.

The recommendations will be generalized for the context of infrastructural project in the construction industry. The case study will be done based on Rail projects. This sector is characterized by complexity, multi-functionality and many interdependence's, and is therefore found suitable as context for a case study and to translate to a generic advise for infrastructure projects. This makes this research relevant for all clients of these projects and for contractors working on the design phase.

3.4. Research Method

This research will be based on gaining knowledge about scope management, the phenomenon scope creep and how to anticipate scope creep. The knowledge will be used to recommend a course of action that is required to improve the general scope management of projects and to improve the ability to anticipate scope creep. It is important to consider that there will not be a ‘one size fits all’ solution that can be applied to all kind of projects. Every project is unique. However, the solution can be in line with a standard approach that is used uniformly and can be adjusted to the each project.

3.4.1. Research Type

The research cube is a format that can type each research. There are three different dimensions, (1) the research question (2) the place where the data is collected, and (3) the number of research units with the categories one few or many cases (van der Zee, 2004), see 3.2.

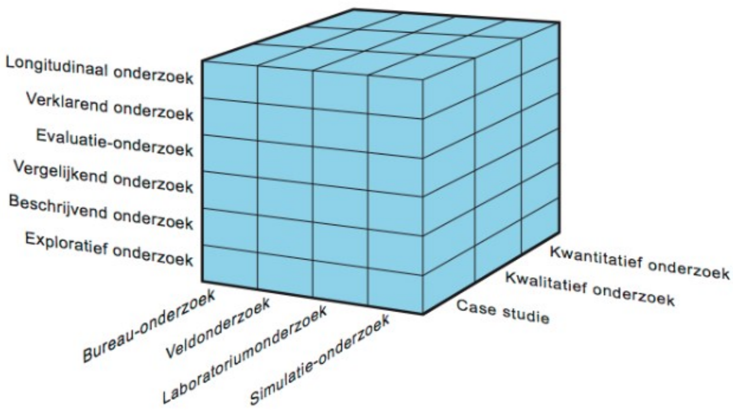


Figure 3.2.: Research cube (van der Zee, 2004)

This research can be seen as an exploratory research. Exploratory research focuses on systematically collecting and analyzing data in wanting to discover new relationships or learning new facts (Hulp bij Onderzoek, 2018). The goal is to better understand the research problem, in this case the phenomenon scope creep (Scribbr, n.d.). Exploratory researcher rather looks for categories to be distinguished and the global scores of 'accidental' units, than to the precise scores of a predefined set of units. Therefore exploratory research will usually be of a qualitative nature (Swanborn, 2004).

A decision was made about how to carry out the research. Relevant data must be gathered and processed into valid answers on the research questions. This research will obtain data by the use of a case study and will be done based on a desk research. This is in line with the fact that exploratory research is often carried out in this form (Scribbr, n.d.). This will be discussed further in 3.4.3.

This choice is based on the five major strategies for research, which are using a survey, an experiment, a case study, a grounded theory approach or a desk research (Verschuren & Doorewaard, 2010). A grounded theory approach is not in line with what this research will accomplish. A case study relates to a social phenomenon in its natural environment, where that phenomenon can not be isolated from its environment or context. The fact that there is no boundary between this is the main reason for a case study. This boundary makes using a survey or experiment problematic (Braster, 2000). The boundary is indeed present at this research. Scope creep is bound to its context, namely a project situation.

A survey is used to research the general opinion on the realistic character of factors and their value for scope management. This will be an online anonymous questionnaire send through e-mail to different employees of Sweco. A questionnaire can generate a large amount of data based on many respondents (Saris & Revilla, 2015). Questionnaires are easy to analyze and easy to process in statistical analysis software like SPSS. Questionnaires are seen as a way of collecting data that is not apprehensive or intrusive for the respondents (Walonick, 1993). In the questionnaire there will be room to explain answers to find more depth in the answers.

3.4.2. Case study

Case study research helps understanding a complex issue and extends and improves the knowledge of what is already known through previous research. A case study is a detailed contextual analysis of a limited number of projects and their relationships. What is needed is a good defined research question and a strong focus (Soy, 1997). A case study is characterized by a broad research question, which means that research remains open to possible innovative insights and iterations (Management Platform, 2015), which is taken into considerations by setting up the research question in 3.2. A literature review is needed to establish what research has been previously conducted and to find insightful questions about the problem (Soy, 1997).

Case study uses different methodologies to study a social phenomenon, such as in-depth interview, participatory observations and document analysis (Management Platform, 2015). The case study in this research will be based on multiple sources of information:

- Document analysis to identify scope creep and how scope changes are managed in the design phase, to characterize different causes, and to substantiate the results of the case study interviews
- In-depth interviews to identify causes for scope creep and how scope changes are managed in the design phase

The first method is document analysis which focuses on the gathering of texts produced by the project team in an effective and systematic way in order to provide a description and explanation of scope creep. The focus during this research is on obtaining detailed interpretations, descriptions and explanations from participants involved. Examples of documents that can be used within the research are minutes of meetings, e-mails, annual reports, websites, articles, and policy reports (Management Platform, 2015). Six criteria have been set for the selection of sources (Management Platform, 2015), stated below. The documents used in this research are shown in appendix H, I, and J, and all documents meet these six criteria.

1. The document is related to and relevant to the subject within the research;
2. The documents have coherence;
3. The document is related to the organization to which the research relates;
4. The document covers the period the research is focused on;
5. It concerns the actors involved;
6. It must relate to the researched phenomenon.

The second method is the in-depth interview. which is a conversation between the researcher and a respondent who is involved in the project and has knowledge of scope control. The purpose of this is to discover experiences, interpretations and experiences in relation to how the project was managed and in relation to scope creep (Management Platform, 2015). These interviews will be performed by asking open questions to the interviewees. The questions will be based on literature research and the theoretical framework of the research. The interview will be send back to the interviewee to verify the statements made during the interview. Only after confirmation of the interviewee, the information will be used in the research.

3.4.3. Choosing cases

Case study research can be single or multiple in scope. The choice for one case study is motivated by the possibility of a critical case study or unique access to sources (van Bueren, Jansen & Verbart, 1999), however this is not the case in this research. Therefore it is chosen for a multiple case study. Even though multiple cases are used, each case is treated as a single case and each case conclusions is used as information contributing to the whole study (Soy, 1997).

The selection of the cases is important (van Bueren et al., 1999) as the sample must be selective and strategically chosen (Verschuren & Doorewaard, 2010). The selection partly depends on the nature of the research, which is in this case exploratory research. For the variety of the selection it is important to pay attention to a balanced distribution of all possible case studies. By choosing cases that are too similar, it is possible that the outcomes will not be justified (van Bueren et al., 1999). In this case it is important that the results must apply to the largest possible group of projects, which is called generalizability. For this research it is intended that the results must be applicable to all kind of infrastructural projects. The sample must covers all relevant differences in the population, but not in the same numerical proportions as in the population. In other words, it is not about being statistically representative, but about being variation-forming representative as a basis for generalizability (Smaling, 2009).

It turns out that many researchers have a temptation to make statistical generalizations based on the results from case study research (van Bueren et al., 1999). However, if a research is entirely qualitative, numbers and frequencies will not play a role in the analysis. The focus must then lie on making the generalizability of the outcomes to the population more plausible (Smaling, 2009). The statements will relate to theoretical and not to statistical generalizations. Theoretical generalization refers to the generalization of results to the underlying theoretical propositions and statements can be tested or refined. In many cases this will happen in the form of refinement of a theory, which is often exploratory research (van Bueren et al., 1999). In this exploratory research the theory of dealing with scope creep will be refined and delivers both theoretical and practical relevance. A case study is extremely relevant for practice-oriented research. This because it revolves around clarifying a problem and thereby formulating a possible recommendation (Management Platform, 2015) which is also the aim in this research.

External validity reflects if the findings can be generalized beyond the cases. Techniques such as cross-case and within-case examination along with literature review helps ensure external validity (Soy, 1997). Each case is in this researched examined in the same way to find scope creep and are analyzed in the same way by the use of the checklist. Furthermore the checklist of the different approaches is tested cross-case in the same way to ensure the validity (Scribbr, n.d.). The different cases are also compared to each other, so examined cross-case, to find the most promising factors to deal with scope creep.

For this research it is intended that the results must be applicable to all kind of infrastructural projects and the selection must be as similar as possible to an average infrastructural project or an average rail project. The rail sector is characterized by complexity, multi-functionality and many interdependence's, and is therefore found suitable as context for a case study and to translate to a generic advise for infrastructure projects. Different rail projects are examined based on the problem of scope creep and using System Engineering as framework. The projects are also chosen on some other criteria. What was seen as most important is that different assignments were basis of the cases together with one project focused on a train track, a light-rail track or/and a station. This to ensure enough differences between the projects. Eventually a integral product and a preparation of a tender dossier, a detailed design, and a reference design are chosen as assignments which all focus on another part of the design phase. In line with this is the complexity of the project. Complexity increases the number of scope changes and a certain amount of complexity must therefore be present in the projects. Another criteria is how leading the project is for the rail sector. This ensures that projects that are cases that are representative for the sector are chosen.

Additionally, the projects were chosen based on client contractor relation. Most rail projects are executed based on a contract with the client, which is often ProRail. However, also a project will be chosen were another client was leading and the organization was differently. Furthermore, in chapter 1 it was stated that most infrastructural projects are characterized by large cost overruns and many scope changes. Therefore projects were chosen with cost overruns due to additional work and where there was an exceeding of the planning. Eventually three projects were chosen, which are further introduced in chapter 8:

1. Project Geldermalsen
   - Client: ProRail
   - Assignment: An integral Functioneel Integraal Systeem Ontwerp (FIS) must be set up, together with an Rail Verkeers Technisch Ontwerp (RVTO) which is the end situation. An implementation decision must be taken for the entire (integral) scope. In addition to this, the request also requires the preparation of the tender dossiers (see H, assignment description). The project focused on the train track and station around emplacement Geldermalsen.
   - Cost overruns: Project Geldermalsen tripled their initial contract sum due to additional work (see H, finance overview).
   - Planning: The project Geldermalsen planned to finish on 1-12-2016, eventually they ended on 28-09-2017, as shown in figure N.1 in appendix K.
   - Complexity and project leadership: This project is a large and complex work that must integrate different projects into one product. The project is on the main corridor of the Dutch rail infrastructure and is an important link for the program of high frequency rail transport of the Dutch government.
2. Project Hoekse Lijn
   - Client: Omexom and RET. The RET was the client who hired Omexom and Omexom hired Sweco as sub-contractor.
   - Assignment: Sweco had to engineer the energy supply of the Hoekse Lijn. This is a project which focuses on converting a rail track into a light rail track for both the track and the stations. Omexom was in charge of the project control.
   - Cost overruns: Project Hoekse Lijn doubled their initial contract sum due to additional work (see I, overview additional work). The project is still not finished, however only one employee is detached at Omexom to carry out the final work.
   - Planning: The project had a deadline on which all documentation had to be approved and delivered to RET. This had to be on 30-06-2017. However, this also includes documents regarding the production and verification. The detailed design had to be finished on 14-03-2016 (see I, contract planning). This eventually became July 2017. The project is still not finished.
   - Complexity and project leadership: This project focused only on the engineering of the energy supply part of the large project of transforming the Hoekse Lijn from rail into light rail. This project is an important Dutch rail project, however also receives many negative media attention due to higher costs and longer project duration.
3. Project Nijmegen Goffert
   - Client: ProRail

- Assignment: This project focused on developing a station hall. The reference design and specifications must be drawn up for this station. For the existing station design, a further deepening has to take place for the reference design (see J, question specification).
- Cost overruns: Nijmegen Goffert almost tripled their initial contract sum due to additional work (see J, Finance overview).
- Planning: The end of the contract was set on 31-12-2012, however, as shown in M.1 the tender documents were finished on 22-05-2013.
- Complexity and project leadership: This project was a pilot project for the use of 3D modeling and therefore there was not many experience with this way of working. Furthermore, there where many disciplines in one box, namely the station itself, which made this project complex. Because the project was a pilot project for 3D modeling, all parties felt the urgency to successfully finish this project. During the festive opening in 2014 this project was successfully finished, delivered according to plan and within budget (ProRail, n.d.-d).

3.4.4. Research Structure

The followed structure of the research followed multiple steps and is shown in figure3.3.

1. Step 1 of this research is the problem analysis, focusing on scope creep and its definition.
2. Step 2 sets up a theoretical framework for scope changes and System Engineering answering sub-research question 1.
3. Step 3 is choosing the different case studies, getting to know the cases and find examples of how scope creep occurs in practice and its causes. Causes for scope creep are derived and clustered into seven causes answering sub-research question 2.
4. Step 4 was linking the found literature on changes to the causes found in practice.
5. Step 5 starts the analysis by looking into the literature of scope management approaches that could improve anticipating scope creep. This results in an answer on sub-research question 3.
6. Step 6 is translating the approaches into checklists. These checklists structures the analysis of the cases. These checklists contain eleven factors derived from the approaches.
7. Step 7 is the description of the case study projects and relating them to the causes of scope creep of step 3.
8. Step 8 is the analysis of the current situations. A post-analysis is made on the basis of logical grounds. With the help of three case studies and the checklist, the design process is followed once more to look at how the approaches were executed. This answers sub-research question 4.
9. Step 9 is to find what the different approaches would change in case of good execution. Here, the analysis is structured by the use of four criteria; costs, integrity, quality and planning. These criteria are divided into causes and effects related to scope creep. These causes and effects follow from the literature on changes of step 2 and the causes of scope creep found in practice from step 3. This results in an answer for sub-research question 5.
10. Step 10 focuses on comparing the factors by a paired comparison that systematically assesses the effects via the four aforementioned criteria. The scores of the criteria are combined and related to the client and engineering company with a multi-criteria analysis. This leads to the factors with the most potential to anticipate scope creep. This answers sub-research question 6.
11. Step 11 focuses on validating the found factors. The highly potential factors are related to the case study results, the causes of scope creep from the practice, the literature, expert judgment and it is statistical substantiated by a survey. Together this shows if and how the factors can be implemented realistically and this answers sub-research question 7.
12. Step 12 is making a recommendation. The analysis so far leads to the needed knowledge to answer the main research question resulting in a recommendation and a conclusion.

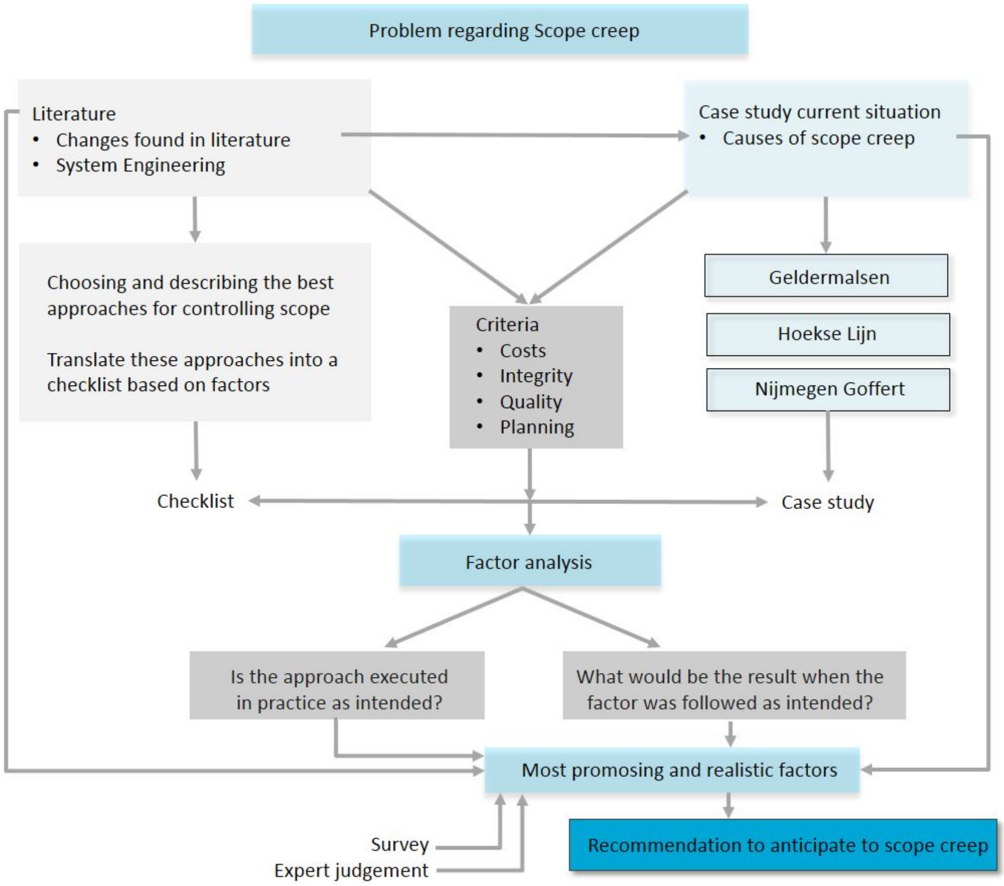


Figure 3.3.: Structure of the research

Appendix Structure

The appendices of this research are structured on the basis of the structure of the report.

- In appendix A, the theory of SE is given in more detail, the summary is given in chapter 4.
- In appendix B, C and D, the three different scope management approaches are given in more detail. The summary of these is given in chapter 7.
- In appendix E, F, and G, the three different scope management approaches are translated into a checklist that is used for the analysis. This is based on the theory in appendix B, C and D.
- In appendix H, I and J, the documents that are used for the analysis of the three case study projects are given. This forms the basis of the analysis of the different projects.
- In appendix K, L, and M, the three projects are analyzed to find scope creep and their causes in the three projects. This forms the basis for chapter 6 and is input for the analysis in chapter 8
- In appendix N, O, P the three scope management approaches are analyzed on basis of the three case studies and the checklistand is input for the analysis in chapter 9, 10, and 11.
- In appendix Q the different factors following from the analysis in chapter 9, 10, and 11 are compared to each other. The analysis in this appendix is input for chapter 12.
- In appendix R the survey results are given. The summary is found in chapter 13.

Part B - Demarcation of the research

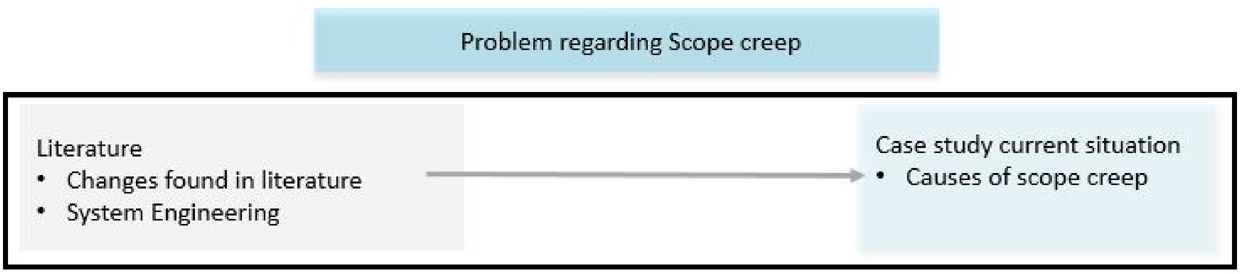
The chapters of this part:

4. System Engineering in the acquisition phase
5. Scope Change
6. Scope Creep causes from practice

Research question that will be answered:

Sub-research question 1: *Which causes and effects of scope changes and scope creep can be found in literature?*

Sub-research question 2: *Which causes of scope creep can be found in practice?*



4. System Engineering in the acquisition phase

This chapter will explain the concept of System Engineering as this is used as basis for this research. This chapter will give only a short description of the concept of System Engineering. The detailed description is given in appendix A.

The increasing rise of complexity at any given time and cost frame and the missing interdisciplinary collaboration in projects can be approached with SE. SE ensures that the developed product meets the requirements of all stakeholders and helps establishing interdisciplinary collaboration (Gräßler & Yang, 2016). Due to the dynamic environment in the construction industry, a project is never static and sensitive to a lot of changes. SE helps to map the scope and anticipate these dynamics. This leads to having a clear view on the impact of change (Werkgroep Leidraad, 2013).

Furthermore, infrastructural projects are increasingly becoming multidisciplinary. Road construction, civil engineering, installation technology, rail and sometimes other disciplines are integrated in all phases. This results in other forms of contracts (BAM, 2008). Clients increasingly get more distance from the technical design and construction process. SE offers the ability to realize control and transparency and to explain to clients what choices are made in the design and realization process and what results are derived from it. This prevents errors, optimizes processes, and prevents errors or fixes in a timely manner which are all reasons for scope creep. More attention is being paid to making choices demonstrable and transparent and capturing them (BAM, 2008).

SE is characterized by four different aspects, namely the interfaces must be managed, the decomposition is important, the work must be divided into work packages and finally the validation and verification is a crucial part of SE (BAM, 2008), all are shown in more detail in appendix A.

The advantages of SE are:

- Demonstrating accountability quality consciousness;
- Reduction of failure costs;
- Efficient use of disciplines;
- Understanding the consequences of changes;
- Interface control;
- Flexibility in commitment.

The basis for the process of SE is laid down in the ISO / IEC 15288 standard. For the Grond Wegen Water (GWW) sector of the Netherlands, the large commissioners ProRail and Rijkswaterstaat developed the “Leidraad Systems Engineering in the GWW sector” which is an industry-specific translation of the ISO standard (BAM, 2008).

SE is a systematic way of working that will be used throughout the entire project process. For this research the process of requirement analyses and design is important to consider. Both will be explained in more detail in A.

5. Scope Change

Projects in the construction industry are characterized by cost overruns and delays in almost every case (Flyvbjerg, Holm & Buhl, 2004). Changes in the design and scope is the main reason and is found to be one of the most frequent, most damaging and largest concerns, as stated in 1. This chapter gives answer to the first sub-research question 1: *Which causes and effects of scope changes and scope creep can be found in literature?*. The changes that will be discussed are changes to the scope of a project.

5.1. Scope change in projects

Projects tend to expand when they move from inception through design to development (Shane et al., 2009). It is therefore inevitable that change happens on a project. INCOSE shows in figure 5.1 that in a project the original requirements are both deleted and changed and new requirements are added (Haskins, 2010). It is key for the success of a project how this process is controlled.

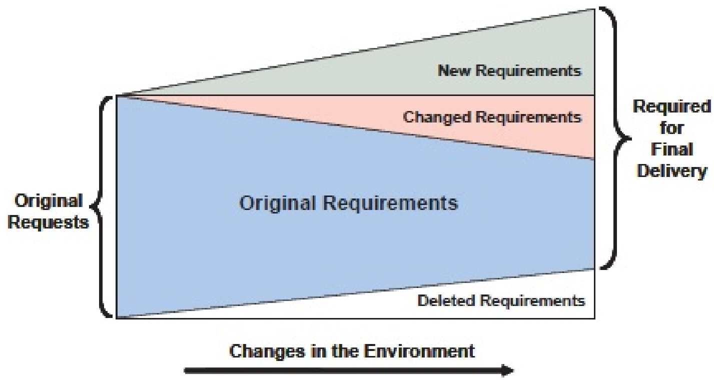


Figure 5.1.: Requirements changes are inevitable (Haskins, 2010)

It is essential for each project to have a clear and defined scope so that the project can be easily coordinated and requirements can be followed. Most of the projects are unsuccessful because they lack a clear definition of both project and product scope and control them insufficiently. A rigorous scope is necessary to meet the needs of the client. Furthermore, scope changes need to be minimized and when occurring controlled, since they have the potential to destroy the entire project (Mirza et al., 2013). Scope creep are unauthorized non-formalized scope changes and can cause extra work or re-engineering. Changes creep into the project scope as result of e-mail -, verbal -, or written instructions that have been issued without realizing the magnitude of the change (Khan, 2006).

An important factor to consider is that large projects have an impact on many territories and stakeholders. Stakeholders want something in return for their cooperation and make demands on plans that mostly result in changes (Giezen, 2012). So, it is important to also identify the stakeholders and include them in the project scope definition. They can contribute with knowledge, which helps to increase buy in and commitment and improves the relationship (Mirza et al., 2013).

5.1.1. Types of changes

There can be made a distinction in the type and sort of a change. Changes can be discretionary or non-discretionary; gradual or radical; anticipated or emergent; elective or required.

First, discretionary changes can result in scope creep, as these changes influence the design directly. Examples are design specification changes or process design developments (Khan, 2006). Second, a gradual change happens slowly over a prolonged period and often occur during the design development stage were decisions are fine-tuned and refined progressively. A radical change happens suddenly and dramatically and has a marked effect. They occur often at a post-design development (Sun, Fleming, Seneratne, Motawa & Yeoh, 2006). Gradual changes are changes that will earlier result in scope creep.

Third, emergent changes will earlier result in scope creep than anticipated changes. The latter is discovered during the project before it actually occurs. However, they still cause changes to the original plan and affect other parts of the project. An emergent change arises spontaneously and is not intended (Sun et al., 2006). Fourth, an elective change can be chosen to be implemented or not. A required change is a change where no option is available than to make the change (Sun et al., 2006). Required changes will probably not always be formalized or their impact will not be researched, therefore these types of changes can earlier result in scope creep.

5.2. Effect of scope changes

Mirza et al. (2013) state that four different problems may arise with the scope of a project: unclear definition of scope; incomplete or partial scope; not finalizing scope documents; and not sharking scope statement. Scope definition is linked to project failure and therefore correlate negatively to project performance. The final project costs tend to be higher when boundaries are not appointed due to changes that interrupt the project process and cause rework, increase project time, and lower the productivity as well as the moral of the field work (Mirza et al., 2013). Other effects of changes can also be determined, starting with increase in project costs which is the most common effect. Other effects can be recruiting of new professionals, increase in overhead expenses, quality degradation, decrease in labour productivity, delay in procurement process, rework and demolition, safety conditions, and delay in completion schedule which is the most frequent effect that can occur (Hwang & Low, 2012).

Changes will affect change management processes as project scope, project organization, control methods, work execution methods, contracts and risk allocation. Direct effects of project change can be rework, time loss, addition of work, revisions to project reports and documents, reorganization of schedule and work methods etc. Indirect effects of project change include loss of productivity as a result of reprogramming, disputes and blame among project partners, loss of rhythm, unbalanced gangs and resource allocation, financial costs, loss of earnings, changes in cash flow, increased risk of coordination failures and errors, lower morale of the work force, loss of float and therefore increased sensitivity to further delays, and so on (Sun et al., 2006).

5.3. Causes of scope changes

Changes can be classified as design development changes or construction changes, only design-generated causes will be considered and include design errors, design changes, omissions and operational improvements (Sun et al., 2006). Other types of design changes can be found like incomplete or inconsistent drawings, design errors or defects, design change, omissions of site conditions and build ability, changes in codes and regulations. This results in different impacts like rework of design and drawing (Hao et al., 2008). Or an option is a positive impact on the quality of the end result.

Changes during the design stage and before the final design that become fixed are less disruptive to the development of the project (Sun et al., 2006). The conflicts about the project changes can be minimized when the problem is found in an earlier stage of the conflict. Change management can be used to plan preventive measures or help to resolve in a timely and systematic manner (Hwang & Low, 2012). It also tries to anticipate possible changes, identify those that have occurred, plan preventive impacts, and coordinate changes across the entire project (Sun et al., 2006). This would prevent scope creep and increase the control of the scope.

Changes in projects usually result from scope changes, difference in work quality and conditions, or uncertainties that make construction dynamic and unstable. These uncertainties and risks follow from the complex and dynamic nature of construction projects (Hwang & Low, 2012). Unattended dynamics in a project represent unexpected events or uncertainties which causes changes to a project system. This can have a potential effect on the performance of a project (Love, Holt, Shen, Li & Irani, 2002). This results in the fact that many decisions during construction projects are made based on uncertain conditions. Designers, engineers and other professionals base their assumptions on existing available information and their previous experience. Sometimes assumptions turn out to be incorrect and decisions need to be revised and changes must be made to certain aspects of already done work. The lack of good pre-design is the most common cause for scope creep and has the greatest impact on design cost. This required rework during the design phase. However, formalization of pre-design procedures, guidelines, responsibilities and deliverables turns out to be the most difficult improvement (Kuprenas & Nasr, 2003).

Internal or External factors

Changes can be caused by internal or external factors. Each change can have a different effect or consequence (Sun et al., 2006). Internal factors include organizational, project and stakeholder related aspects. Organizational aspects involve change in management, lack of integration between sections, and lack of effective and timely communication. Project aspects involve the uncertainties of the project, inaccurate cost estimation, increasing project complexity, change of financial status of any party involved, and shortage of resources available. Finally, stakeholder aspects involve design errors, modifications to the drawings leading to ineffective design, omissions, poor project definition by the owners, inadequate project change management, inadequate pre-project planning, constructability that is ignored in the design process, and poor communication among owners, designers and constructors (Hwang & Low, 2012). Love, et al. (2002) state that internal uncertainties can be found in five different areas, see table 5.1. External factors include natural unforeseeable circumstances, government intervention, economy or legal issues (Hwang & Low, 2012). Love, Holt, Shen, Li and Irani (2002) state that external uncertainties can be found in eight different areas, see table 5.2.

Table 5.1.: Internal factors of change (Love, Holt, Shen, Li and Irani, 2002)

Internal Factor	**Description**
Project-related uncertainties	Location conditions, uncertainties in contract, uncertain duration's for activities, uncertain costs, uncertain technical complexities, resources availability and limitations
Organization-related uncertainties	Different skills needed, different contributors and other resources, project participants that vary trough the construction process

Finance-related uncertainties	Company's financial capability/policies that change, changed financial situation of stakeholders that affect or jeopardize the expected outcome
Interest-related uncertainties	Interactive constraints and interest between disciplines can cause conflict and hinder co-operation in dealing with changes and affect performance
Human-related uncertainties	Effectiveness is affected by individual traits, religious beliefs, social background, customs, education level, life style, work conditions etc.

Table 5.2.: External factors of change (Love, Holt, Shen, Li and Irani, 2002)

External Factor	**Description**
Government-related uncertainties	Acts passed by government may be very costly to a client, change in regulation can affect a contractor´s profitability, changes in taxation and interest rates can affect the financial viability, planning or execution
Economy-related uncertainties	Uncertain inflation and interest rate and changing exchange rates can affect a project in terms of cash flow, costs of materials and salaries, etc.
Social-related uncertainties	The public can influence a project outcome, the changing social environment can affect an individual´s attitude and behaviour (Love et al., 2002). Changes in customers' expectations and tastes or changes in competitors' activities can affect the project (Sun et al., 2006).
Legal-related uncertainties	Changes in legislation can affect a client´s objectives or contractual relationships between parties
Technological-related uncertainties	New technology can influence the design and construction. Uncertainties include changes in using materials, techniques, etc. It can result in redesign and the use of new-alternative materials
Institutional-related uncertainties	Professional institutions can affect the conduct of their members through conditions of engagement, fee scales etc. Professional codes of conduct and education regulations can affect an organization and decision-making
Physical-related uncertainties	Factors are infrastructure/transportation, degree of saturation, district development plans, site access/egress for material and labour transport
Acts of force majeure	Uncertain weather and other natural forces like flooding

5.4. Conclusion

This chapter gave answer to sub-research question 1: *Which causes and effects of scope changes and scope creep can be found in literature?*. First it is said that changes that most easily result in scope creep are discretionary, gradual, emergent or required. Changes can be caused by internal or external factors. Design-generated causes of scope change include design errors, design changes, incomplete or inconsistent drawings, and changes in codes and regulations. The lack of good pre-design is the most common cause for scope creep. The complex and dynamic nature of infrastructure projects result in uncertainties which result in many decisions based on uncertain conditions and assumptions. These can turn out to be incorrect leading to revising decisions and rework.

Direct effects of project changes include among others rework, time loss, and revision of project documents. Indirect effects include among others loss of productivity, loss of rhythm, and increased risk of coordination failures and errors. In order to improve the anticipation of scope creep, these causes and effects are important to considered. Therefore they are input for the further analysis of this research.

6. Scope Creep causes from practice

Scope creep is a problem for projects and can occur in multiple forms. This chapter gives answer to sub-research question 2: *Which causes of scope creep can be found in practice?*. This chapter shows the causes of scope creep that were found in the case study projects. In the appendix the different projects are discussed together with their examples and causes of scope creep. In appendix K project Geldermalsen is discussed, in appendix L project Hoekse Lijn is discussed, and in appendix M project Nijmegen Goffert is discussed. Chapter 3.4.3 gives the overview of what is discussed there and shows how often scope creep causes can be found in each project.

The examples of scope creep and its causes found in the different projects, can be merged into a set of causes for scope creep. This can be clustered into seven main causes, which can be further divided into sub-causes, given in section 6.1. Here also the link to the impact of changes, stated in chapter 5, will be made.

6.1. Explanation of different Scope creep causes

Seven causes are found, that can be divided into sub-causes. The seven causes are: (1) Start of the project; (2) Process of an EOW; (3) Time pressure; (4) Scope management process; (5) Team composition; (6) Process of the project; (7) Human factors.

6.1.1. Start of the project

Defining the starting points for the project process at the start of the project is crucial. When certain things are unclear at the start, they can have negative influence throughout the project and result in scope creep. These causes are mostly related to project related uncertainties, which is an internal factor as seen in 5.3.

Wrong interpretations
When goals, starting points and assumptions are not made clear between the different parties involved, it could turn out that there are wrong interpretations. This could lead to work not meeting the initial wishes, work that is carried out what wasn't part of the scope, or work that was underestimated in scope. An effect of this is re-engineering. Scope creep follows from the negative influence that are a result of wrong anticipation to the scope. This is an internal factor due to project related uncertainties, as can be seen in 5.3.

Moving scope while tendered as fixed scope
During the design phase and preparation of a FIS product, it is normal that the scope of the project is still moving. This is due to the fact that during the development of the design and the FIS product, a optimization takes place and a adjustment and sharpening of the Client Requirement Specification (CRS) and System Requirement Specification (SRS). It often appears during the iterative process that

some wishes are not possible, do not fit into the design, are not feasible or cost too much. It also happens that wishes or requirements are changed throughout the process. It must be recognized that during this process the scope is not fixed and subject to changes. However, these products are often tendered under a fixed scope. As stated in 5.3, this can be seen as a stakeholder aspect based on poor project definition by the owners. The client here made the wrong tender starting point decision.

During the project of Geldermalsen and also in other cases, it happens that ProRail puts projects on the market whereof the desired end result is not known yet. ProRail is involved during the design phase with changing wishes and requirements. They use the project to determine the scope for the final design. However, they approach the project in the field of finance and planning as a fixed process that is not subject to ambiguities. The contractors tendered on a project with a fixed scope, while the scope is often not clear. This tension is often present in projects and can result in discussion on scope and result in scope creep.

Tendered with missing input
It happens that projects are tendered without input of certain stakeholders. For example Bureau Spoorbouwmeester is an important stakeholder in projects, but is sometimes forgotten to ask for input. When the project starts, these stakeholders have many input and like to see requirements changed. This gives reason for discussion. When these wishes are immediately carried out, without formalizing and researching the consequences, this can have negative influence. As is also stated in 5.1, It is important to identify stakeholders and include them in the project scope definition.

Rationality
At the start of a project it is important to make agreements on what is seen as rational during the project. There are unpredictable factors that must be discussed. For example during the tender the contractor makes an estimation of the number of workshops needed with the architect, however this can be exceeded drastically in some cases. The client sees this as rationally needed for the design, however, the extra workshops are not compensated. This results in changing wishes and extra effort without being reimbursed for the work. Also the planning and integrity consequences are unknown.

Complexity
Some complexity cannot be anticipated. There is a tendency of wanting to control everything in the project. However, some complexity is simply not known. Good anticipation and a flexible open mindset of the involved parties is needed for this to avoid discussions or mistakes.

6.1.2. Process of an EOW

Changes must be formalized and correctly managed, to keep control of the scope. Difficulties regarding this process can hinder scope management and have scope creep as result. This can follow from not formalizing changes with small impact or implementing changes before approval, and correcting changes afterwards.

High costs involved
High overhead costs are involved with the process of formalizing changes. The process on both the contractor and the clients side is costly, which can result in not formalizing small changes through an Engineering Opdracht Wijziging (EOW) process. This results in floating changes and an unclear scope which are ingredients for scope creep. Furthermore, drawing up an EOW, which takes much effort, is mostly not reimbursed by the client. Therefore effort is cut in making the EOW complete which results in negative results for the clarity around the impact and consequences of a change.

Discussions take long and are arduous
The discussions regarding the formalization of scope changes can take a long time. This puts pressure on the project. The discussions are also arduous which puts pressure on the relations between the parties involved. This can result in choosing not to formalize changes or in already implementing changes when the discussion is not finished yet. Effect are integrity problems, not being reimbursed for the effort, or re-engineering. EOWs focusing on these effects will often be submitted after the change is introduced in the project. By doing this they take a risk, but also know for certain the consequences of the change. This cause is related to the internal factor of human related uncertainties. The effectiveness is affected by the work conditions and individuals, as seen in 5.3.

Long waiting times
The approval of EOWs can take very long. This result in choosing to stop or continue working on the design. When they continue they can choose two things. First, they can take the risk of not getting a change approved and implement the change already. Second, they can choose to not introduce the change but continue the design work. This results in the risk of needing to do re-engineering when the change is accepted.

Starting before having an official approval
Due to multiple reasons, contractors will choose to already start introducing a change before having an official formal approval. This can be due to trust in the other party, having time pressure, having EOW with large time consequences, or the easiness to immediately implement a change in the design.

Trust is often based on thinking that the additional work will be paid afterward and this can follow from different things. First, the contractor can be tempted by the client into starting the work by assuring them that they will be paid. Second, time pressure is a motive that the client and contractor have in common and can be reason to trust each other and work towards a common goal. Third, contractors can trust the client in getting paid when otherwise they would receive a fair, which is a threat for the process. Finally, personality of project members can result in social pressure.

6.1.3. Time pressure

Time pressure was already mentioned as reason for not setting up an EOW process or starting to work without approval. When the impact of a change seems small, and when time pressure is present, changes will not always be formalized, resulting in floating requirements and an uncertain scope. Furthermore, the construction phase that still has to start, also puts pressure on the design phase. Rail projects are often bounded by certain milestones like having time frames were rail traffic is stopped and certain work can be done.

6.1.4. Scope management process

The scope management process is not always perfectly set up. This can result in working with wrong starting points, working without consistency between documents, much effort to remain the integrity, and many late changes. This are causes that can result in scope creep. To have a decrease in scope creep, correct scope management is essential.

Not formalizing changes

The most important reason for scope creep is not formalizing changes. This is due to not correctly following the process of managing changes which has a large impact on the integrity of the design and can result in many 'floating' requirements.

Consistency

Consistency must be found between different documents. Sometimes there is overlap between different documents which can result in having requirements or assumptions that do not match each other. This is also subject to time pressure and interpretation differences, which can be reason for difference in starting points resulting in mistakes and on its turn in scope creep.

Furthermore, there can be a lack of consistency between different requirements set by the client. It occurs that requirements contradict each other. This give reason for discussion when noticed, but can also lead to mistakes or lack of integrity. This can result on its turn in scope creep. As stated in 5.1, one of the reasons for scope creep is a lack of a good pre-design. This requires re-work during the design and can be due to lack of consistency.

Too much detail

Scope management is made difficult when there is a tendency of wanting to design in much detail. This can result in an uncertain scope and possibly scope creep.

Changes till the last moment

When scope management is too lose, changes can be introduced till the last moment. This makes the design process difficult and can result in integrity difficulties an re-engineering. Changes are part of the process, but must be introduced and managed as early as possible. These uncertainties related to the scope are project related and internal, see 5.3. It can also be seen as a stakeholder aspect based on modifications to the drawings leading to ineffective design, as stated in 5.3.

Not anticipating changes

It could happen that changes are expected but there is no acting on them. Anticipating these changes is lacking and this can result in mistakes, time pressures or unnecessary re-engineering.

Wrong process of reacting on reviews and changes

The process is not always followed as should, as shown in figure 6.1 which is an example of project Hoekse Lijn. It shows that the requirements and verification is written down at the start. After the product validation and verification a review is given, which results in new wishes and requirements and mistakes that the client want to see solved. However, this is not looped back to the requirement set as should, see option 1 in figure 6.1. What happens is that they implement the changes into the product, like option 2. The wishes and requirements are not updated, changes are not written down, and there is not a new product set up to validate. The verification is fixed with reasoning backwards. As stated in 5.3, this can be seen as a stakeholder aspect based on poor project change management.

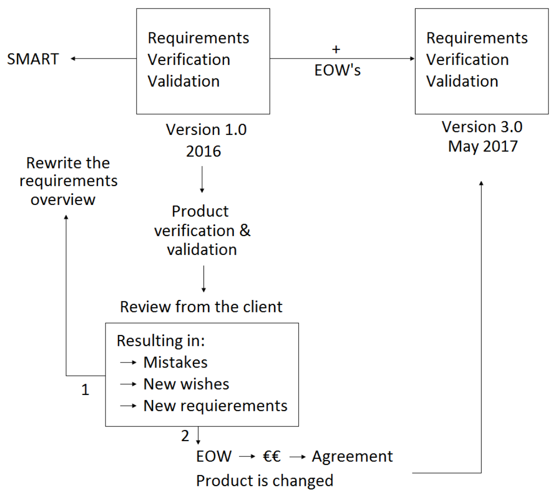


Figure 6.1.: Example of a wrong process

6.1.5. Team composition

The team composition influence the project outcome
and the process of the design. The process of demarcating the scope, is influenced by both the scope management and the team. Even with good scope management, the team can negatively influence the design process. Men are not perfect and the process is therefore sensitive for mistakes. This risk is smaller when the scope management is set up correctly and the team has enough capacity and knowledge. This factor is mostly due to organization related uncertainties and human related uncertainties and is an internal factor, see 5.3

Wrong people on the wrong spot

It could happen that a project does not have employees with the right knowledge or experience on the right tasks. This can result in a design process that faces many challenges. It could also lead to a design lower in quality.

A project must be set up according to the pyramid shown in figure 6.2. The contract is managed by the project manager, the technical parts by the Lead engineer and the project process by the process coordinator. A team must always have these persons in place, the provide a strong basis for managing the project and scope.

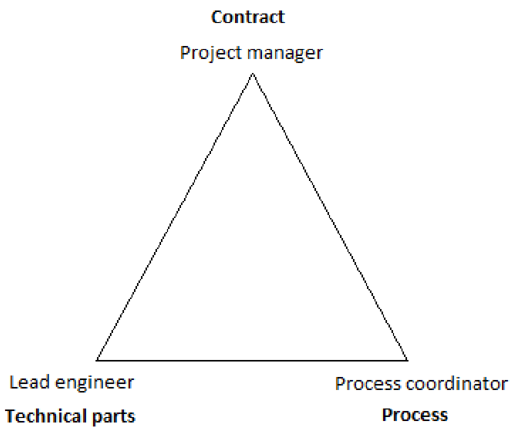


Figure 6.2.: Pyramid or roles and responsibilities (Own Image)

Not enough capacity

When there is not enough capacity on the team, this threatens the entire process of a project. This can result in large consequences for the planning and the reaching of milestones. It can also result in a lack of optimization of the design because there is a continuous time pressure. This can be seen as a project aspects, as stated in 5.3, focusing on a shortage of resources available.

Project is not correctly managed at the other stakeholders

It can happen that the client or another linked stakeholder does not have a correct project management system set up. This endangers the process for the contractor. There is a possibility that wrong or inaccurate information is exchanged, or information is not communicated. These can be reasons for mistakes and scope creep. The management of scope is the responsibility of multiple stakeholders, and can be endangered by this. As stated in 5.3, this can be seen as a stakeholder aspect based on inadequate project change management.

Missing links

In a project certain links between persons must be established to have a good project. The two project managers must manage the contract. Each change must be discussed with the project manager, because he is responsible for the EOWs as they are on contract level. The lead engineer of the client and contractor can exchange technical wishes and requirements. However, it happens that these changing wishes and requirements are not communicated to the project manager. These then will not be formalized in a formal EOW. This process is seen in 6.3 and is reason for unclear scope. It can also happens that one of the engineers does not report back to the project manager.

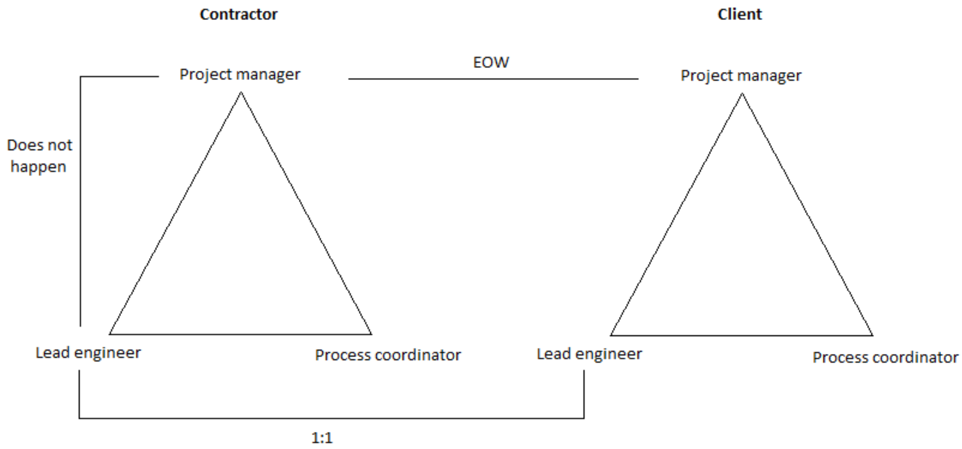


Figure 6.3.: Links between employees (Own Image)

Parties involved with strong opinions

Bureau Spoorbouwmeester and architects are examples of stakeholders with a strong opinion. They often have changing wishes which makes the process subject to many changes and a changing scope.

Working too good

It is recognized in projects that engineers have a tendency to be a perfectionist. It therefore happens that they focus on finishing tasks at a high level of detail and correctness, even though this is not always needed. They also have a tendency of fixing mistakes or optimizing parts that are not part of their scope. This leads to extra work and can affect the integrity when not written down in the scope and looped back to the project manager.

6.1.6. Process of the project

The process of the project can influence the outcome. For example the process of giving reviews can be a difficult aspect, just as not following a certain order of setting up documents and having many disciplines. These can endanger the process and the integrity. The process of a project is sometimes seen as a game which is not always beneficial for the project.

Reviews that take too long

When reviews on the design take too long, this can have a negative influence. Designs will continue even when reviews are not given yet. This results in reviews on old designs. Furthermore, reviews can contain certain changes or assumptions that need to be submitted into the design, which can result in re-engineering and changing of assumptions. The design process becomes subject to a negative influence on the integrity. As stated in 5.3, this can be seen as a stakeholder aspect based on inadequate project change management and poor communication among the client and the designers. The lack of effective and timely communication can also be seen as an organizational aspect.

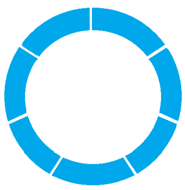
Reviews without integrity
It can happen that the review comments are not integral. Comments are given by different persons and these can be contradictory. The contractor then must find these contradictory comments and must ask the client which comments are leading, which cost many effort. Furthermore, it can happen that these contradictions are not noticed and this can lead to mistakes, wrong assumptions or re-engineering, which are all ingredients for scope creep. This can be seen as organizational aspects involving lack of integration between sections, see 5.3.

Setting up products in a wrong order
It can happen that certain documents are set up based on the output of other documents, when these actually should have been the input of these documents. For example the SRS can be set up based on the FIS, while the FIS actually must be based on the SRS and must be validated against this document.

Many disciplines at one place
Sometimes the integrity becomes threatened when many disciplines come together at a certain bottleneck. This is a difficult process and puts pressure on the design and must be correctly managed to maintain the integrity and get the needed quality. The uncertain situation it can result in, can be reason for scope creep.

Game-like interaction
The engineering of a design is sometimes seen as a game between the parties involved. Strategic decisions can be result of this and can have as result that not all changes are formalized. This is then based on certain reasons, where costs are mostly a main influence. Pressure on the collaboration and trust within a project is a result, just as pressure on the scope management.

6.1.7. Human factors



Human factors can influence scope management, the EOW process and the anticipation of changes. Employees can be too scared to say no to the client or for example the architect. By not saying no, the employees accept a change even when not part of scope, which can result in many wishes or changing requirements that are introduced. A result is floating requirements and changes without formalization. Another human aspect can be, being too control-freak. This is related to the internal human related uncertainties as stated in 5.3

6.2. Conclusion

This chapter gave answer to sub-research question 2: *Which causes of scope creep can be found in practice?*. The different scope creep causes that are discussed in this chapter followed from the analysis of scope creep in the different case studies. The seven main causes with their sub-causes that are found, are:

1. Start of the project
    - Wrong interpretations
    - Moving scope while tendered as fixed scope
    - Tendered with missing input
    - Rationality
    - Complexity
2. Process of an EOW
    - High costs involved
    - Discussions take long and are arduous
    - Long waiting times
    - Starting before having an official approval
3. Time pressure
4. Scope management process
    - Not formalizing changes
    - Consistency
    - Too much detail
    - Changes till the last moment
    - Not anticipating changes
    - Wrong process of reacting on reviews and changes
5. Team composition
    - Wrong people on the wrong spot
    - Not enough capacity
    - Project is not correctly managed at the other stakeholders
    - Missing links
    - Parties involved with strong opinions
    - Working too good
6. Process of the project
    - Reviews that take too long
    - Reviews without integrity
    - Setting up products in a wrong order
    - Many disciplines at one place
    - Game-like interaction
7. Human Factors

Important to know is that there is a difference between cluster 2 and 4. Cluster 4, scope management process, focuses on the process of keeping control of the scope. Changes must be identified and controlled. After a change is identified and formalized, it will influence cluster 2. This is focused on the process of the formalization of a scope change, an EOW.

The different causes are scope creep causes actually found in practice and therefore can be used as input for the further analysis of this research. When a scope management approach can influence one of these scope creep causes, the approach is very effective for anticipating scope creep.

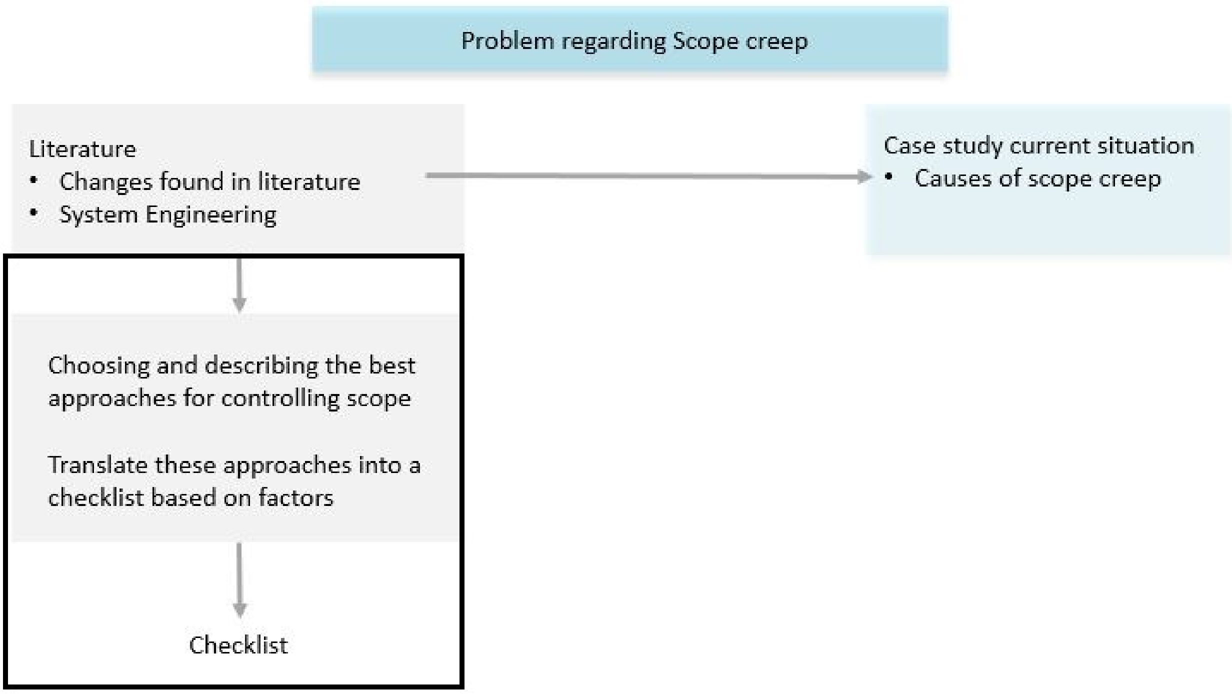
Part C1 - Analysis of the literature

The chapters of this part:

7. Choosing the most optimal scope control approaches

Research question that will be answered:

Sub-research question 3: *Which scope management approaches to improve the anticipation of scope creep can be found in literature for projects using System Engineering?*



7. Choosing the most optimal scope control approaches

In order to come to a recommendation on coping with scope creep, multiple approaches will be analyzed on how they can improve the anticipation of scope creep. Literature already provides ways to deal with the scope of a project, however, how this in practice works will be researched. This chapter starts the analysis and gives answer to the sub-research question 3: *Which scope management approaches to improve the anticipation of scope creep can be found in literature for projects using System Engineering?*. The relation between control and trust will be discussed in section 7.1. This forms the framework to choose the scope management approaches that will be analyzed, which are:

1. Configuration Change Management (section 7.2)
2. Information Management (section 7.3)
3. Partnering (section 7.4)

7.1. Relation between control and trust

In practice there is a continuous tension between trusting the other stakeholders of the project and wanting to control the scope by scope management. Contracts are always incomplete as it seems impossible to negotiate and explain every single future contingency in a formal document. Furthermore, the managers have a desire to feel in control and the clinging to this may be interpreted by the other party as a signal of distrust. However, in an environment of incomplete contracts, trust between parties is essential to help overcome control problems (Pinto, Sleving & English, 2009).

There is need for a minimum level of both trust and control in order to have confidence in the other party. Therefore trust and scope control play different roles in the relationship. Trust in a contractual relationship can facilitate the exchange of information and bring about a reduction in control and its associated costs since parties do not have to fear any manifestations of opportunism. Establishing trust is desirable since it reduces the costs of monitoring and controlling, while making the working relationship more efficient. Therefore it can be said that the relationship between trust and control is a complex one, where control does not operate in opposition to trust but as a necessary complementary means of governance (Pinto et al., 2009).

So, these two aspects are in practice related. When parties do not trust each other fully, they have the tendency to regain control and record more. When parties work more on mutual trust, they feel less urgency to record all scope changes that occur. Furthermore, the contractor in practice feels that they cannot write down every detail and therefore do not reach full control. In practice this results in the situation shown by the * in figure 7.1. This situation is based on a fixed price contract between client and contractor.

For the contractor to anticipate scope creep better, both trust and control of the scope is necessary. This follows from the causes for scope creep, found in the case study and stated in chapter 6. The causes related to the start of the project, to the process of an EOW and both the process of

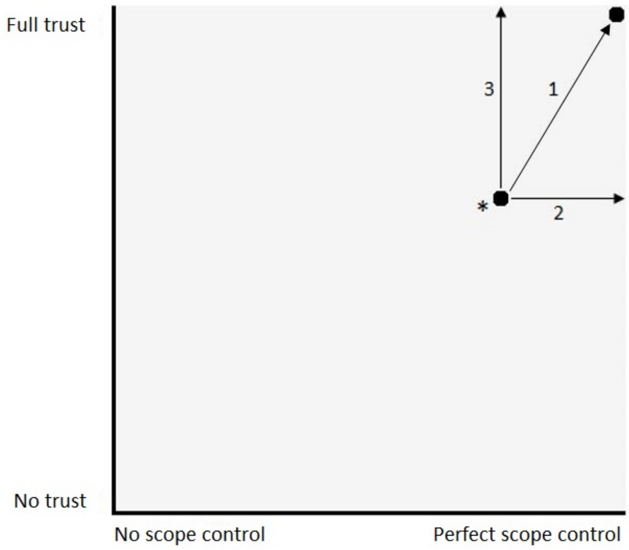


Figure 7.1.: Axial system having trust and recording as axes (Own Image)

scope control and of the project in general, are all related to keeping control over the scope of the project. Time pressure, human factors and the team composition are both related to maintaining control and to the relation between the parties. Therefore the scope management approaches that are seen as optimal to control scope creep, and which must be related to the found scope creep causes, must also be related to both control and trust.

The first approach will focus on improving the scope control in projects while remaining trust at the same time, shown with arrow 1 in figure 7.1. The second approach will focus only on maintaining control over the project and the scope, shown with arrow 2 in figure 7.1. The third approach focuses on improving trust in a project and is shown with arrow 3 in figure 7.1. Three approaches are thus chosen to improve the anticipation of scope creep. The first two approaches provide tools for scope management. The third approach is not a tool but a mindset, and becomes a outlier of the other two approaches. However, it is seen as an important approach to improve anticipating scope creep.

7.2. Scope management approach 1 - Configuration (change) management

Looking at the literature and SE, Configuration Change Management (CCM) is introduced to cope with the scope of a project and changes in projects. CCM is part of SE and will be chosen as the first scope management approach for dealing with scope changes. CCM focuses on having complete control of the scope which can cause a decrease in scope creep. It also ensures that changes can easily be managed between client and contractor. This keeps the relationship good. It also ensures that there are agreements on dealing with changes and formalizing the scope in baselines. CCM focuses thus both on trust and control of changes. CCM will be discussed in more detail in appendix B.

7.2.1. Description of Configuration Change Management

Projects using SE analyze the problem and changes in a project, related to the wish of the client (Werkgroep Leidraad, 2013). Configuration Management (CM) is part of SE and is a process of maintaining the integrity of the system while handling changes (Lindkvist, Stasis & Whyte, 2013). CCM is the part of CM that focuses only on changes.

The configuration are all objects which make a system, supplemented with relevant documents, design considerations and cost estimates. The configuration must be known at the start of the project and must be clear and traceable throughout the life-cycle (Werkgroep Leidraad, 2013).

To achieve the project's objective, project tasks are divided into separate work packages and then integrated into the final system (Mirza et al., 2013). The Work Breakdown Structure (WBS) include the necessary products and associated work packages to produce the system (Khan, 2006). The subsystems can be broken down into (Configuration Item (CI)). The WBS contains what is needed for the design, development, integration and testing of the CIs (Faulconbridge & Ryan, 2014).

Configuration management process

CM ensures that product functional, performance, and physical characteristics are properly identified, documented, validated, and verified and with that it establishes product integrity. Changes to these product characteristics are properly identified, reviewed, approved, documented, and implemented (Haskins, 2010). So, CM tries to control changes, CCM helps maintaining the changes in the system design together with the proposed alternatives and reasons for the certain change (Faulconbridge & Ryan, 2014). It ensures that the project staff can effectively use the same, accurate information which will prevent the happening of mistakes (Werkgroep Leidraad, 2013).

Fundamental to ensure effective management of the evolving configuration is the establishment, control, and maintenance of baselines (Haskins, 2010). The baseline gives the formal frozen status of a system and determines the configuration. It results in a complete system documentation at a certain time, determined by the parties involved (Werkgroep Leidraad, 2013). When the contract definition is done, the first baseline arises (ProRail, 2015). When changes occur, it can only change the baseline through a documented change management process (Faulconbridge & Ryan, 2014). In complex projects an iterative process repeats itself and leads to a new specification of the system on each detail level and must be accompanied by a new baseline (Werkgroep Leidraad, 2013).

A clear vision of the configuration helps handling changes in a structural manner when they appear. A proposal for a change is followed by an impact assessment to decide whether changes are acceptable (Werkgroep Leidraad, 2013). It is recommended to establish a Configuration Control Board (CCB) with representation from all stakeholders and engineering disciplines (Haskins, 2010). The CCB is charged with the responsibility to manage the changes that come up during the process (Faulconbridge & Ryan, 2014) How exactly CCM is accomplished is something that must be determined within each project. CCM implies that the following steps must be taken (BAM, 2008):

1. Identify and document the functional and physical characteristics of individual configuration items making them unique and accessible in some form;
2. Establish controls to changes in those characteristics;
3. Ensure consistent products via the creation of baseline products;
4. Maintain enough information to ensure system and product integrity;
5. Record, track, and report change processing and implementation status and collect metrics pertaining to change requests or problems with the baseline;
6. Perform Configuration Audits associated with milestones to validate the baselines.

For a change proposal a formal document is submitted requesting and specifying a corrective action to a baseline document that contains a latent defect. The content of the Engineering Change Proposal, or in Dutch the EOW, must contain sufficient information to evaluate and approve the

EOW. This must contain among others the reason for change, an impact assessment, the changes to the documentation set, and the impact on cost or schedule (Faulconbridge & Ryan, 2014).

There are two sort of changes. Class 1 changes are more major changes and the client must be involved by the approval of these. Class 2 changes are all other minor changes. The client must be involved for information purposes. The client can easily loose visibility into class 2 changes and thus on its impact (Faulconbridge & Ryan, 2014).

7.3. Scope management approach 2 - Information management

The second approach will focus on getting the current situation to maintaining and improving the control of the information, have always up-to-date information, have a accurate scope to work with, and maintain control of the scope. The optimal approach for this is the use of information management. This concept is important to consider and is often related to a information management tool and will be discussed in detail in appendix C. Information management focuses on having control of the information and the establishment of relations between information. The integrity of the design becomes easier due to this. When a change occurs, the relations to other aspects of the design easily becomes clear. Mistakes will be smaller, the impact and consequences of a change become easier insightful, and the design is always based on the most accurate data. The chance of scope creep is smaller when having such a system during a project.

7.3.1. Description of Information management

The need to report and document all changes in a careful way follows from the tensions about change and the fact that changes in the construction industry are inevitable (Hwang & Low, 2012). To minimize the impact of changes, information management is needed. Information is often stored in numerous documents, spreadsheets, drawings and applications. Information is often scattered and inconsistent while relevant document frequently circulate in multiple versions. Significant search efforts, project delays and failure costs are the result of this. Not having the right information might result in a project outcome that does not correspond with the initial idea. So, one of the major challenges these days is to manage all information effectively. In order to make the appropriate decisions, project members need to have relevant and up-to-date and accurate information instantly available. However, this is not always the case. (Relatics, 2017).

A common approach to deal with all information, is organizing all documents. However, this does not organize the information inside these documents. Documents often contain multiple subjects and heterogeneous information and classifying a document ignores its internal information and makes this information untraceable and unmanageable. Information management focuses on managing all information instead of only the documents. Information management provides opportunities to manage the information according to SE and makes projects manageable. Information is managed in a coherent network of explicitly described information, which helps projects to be realized faster, with a better outcome and less failure costs. It will help reduce the lead time and provide an increase in control and improve the quality and compliance. High quality deliverables can be generated such as complete requirement specifications, test plans, risk registers, contract documents and interface reports (Relatics, 2017).

A tool for information management would result in having all relevant information always accessible by following the relations between items. This results in no seek time, no mistakes and no surprises. A tool would be based on four aspects; Having all data in hands, Adapting to the information needs, A tool that is simple and intuitive, and A tool that is collaboration focused, this is also discussed in more detail in C (Relatics, 2017).

Relatics is a web-based semantic database which makes capturing, managing and unlocking information possible in an unambiguous and consistent way. It is a cloud platform that is used by large projects in the construction, infrastructure and civil engineering industry to control information within projects. The tool Relatics is ISO/IEC 27001:2013 certified (Relatics, 2017). The tool Relatics is the most commonly used tool for information management. Therefore examples will be given in appendix C of companies that work with information management in the form of using Relatics.

7.4. Scope management approach 3 - Partnering

The third approach focuses on the trust in projects. A project management approach looking at partnering and trust in co-working will be taken into consideration. This will be explained in more detail in appendix D. When trust is established and co-operation is improved, conflict resolution will become easier. Furthermore there will be more effective communication and efficient coordination which makes the chance on scope creep decrease.

7.4.1. Description of Partnering

The construction industry is a very competitive high-risk business and faces many problems, such as little cooperation, lack of trust, and ineffective communication. This results in adversarial relationships resulting in project delays, difficulty in resolving claims, cost overruns, litigation, and a win-lose climate (Chan, Chan et al., 2004). However, cooperative, strong relationships have proven to be far more beneficial than the competitive, adversarial behaviour characteristic (Chan, Chan et al., 2004). The main reason for the introduction of partnering is the need to move away from the traditional adversarial relationships in construction contracting (Black, Akintoye & Fitzgerald, 2000).

Although partnering may not resolve all the problems encountered in the construction process, it creates an effective framework for conflict resolution, improved communications, reduced litigation, and cost containment on potential overruns. Partnering leads to win-win situations and synergistic teamwork. It aims to generate an environment of trust, open communication and employee involvement. It has evolved as an innovative approach and lowers the risk of cost overruns and delays. Also, it increases the opportunity for innovation due to the open communication and trust (Chan, Chan et al., 2004). Other important benefits are the increased customer satisfaction and increased understanding of parties. Mutual understand will result in the parties working well together to achieve project targets (Black et al., 2000).

The formal contract can be seen as a safeguard against any breakdown of the partnering arrangement. However, it can also be stated that the behaviour is not determined simply by formal structures, but instead is the result of conscious choices and actions. Therefore, economic conditions which encourage clients and contractors to work together towards a common purpose may be essential (Bresnen & Marshall, 2000). A change therefore could be to move with contracts from price to a package of factors with a greater recognition of good behaviour (Black et al., 2000). However, these strategies can be both induced and legitimized (Rousseau, Sitkin, Burt & Camerer, 1998). Therefore, not too much faith must be put in economic incentives, and they must not overshadow or replace means intended to stimulate intrinsic motivation and mutual trust (Kadefors, 2004).

Essential for good partnering

According to (Chan et al., 2004) nine factors are needed for good partnering: Establishment and Communication of Conflict Resolution Strategy, Commitment to Win-Win Attitude, Regular Monitoring of Partnering Process, Clear Definition of Responsibilities, Mutual Trust, Early Implementation of Partnering Process, and Willingness to Share Resources among Project Participants.

Additionally, some factors are essential to have implemented: Adequate Resources, Support from Top Management, Long-Term Commitment, Effective Communication, Efficient Coordination, and Continuous search for improvements (Chan, Chan et al., 2004).

Mechanisms for achieving continuous improvement and conflict resolution are also recommended. These systems formalize, plan and structure the relations (Kadefors, 2004). These mechanisms typically include among others pre-project team building exercises and facilitation workshops, joint goal formulation, and escalation guidelines for resolving disputes in a timely and effective manner (E. Larson, 1995), (Bresnen & Marshall, 2000), (Kadefors, 2004).

Trust

Mutual trust has been found to be one of the most important success factors in maintaining partnering relationship (Wong, Cheung, Yiu & Y, 2008), (Kadefors, 2004), (Black et al., 2000). Trust is developed through communication and leads to a positive state that works encouraging for cooperation. Trust thus has a strong positive influence on relationships between team members and on project success and is important for critical stakeholder relationships. Trust can facilitate the exchange of information and bring a reduction in control in contractual relationships. It reduces the transaction costs of monitoring, controlling and makes the relationships therefore more efficient. When trust expands, the costs associated with maintaining the relationship with a partner should drop appreciably (Pinto et al., 2009). Wong et al (2008) proposed that trust be categorized into system-based, cognition-based and affect-based trust. The three types of trust co-exist and are mutually dependent. A system is as good as its weakest point and a project manager must thus focus on all three (Wong et al., 2008).

7.5. Conclusion

This chapter gives answer to the sub-research question 3: *Which scope management approaches to improve the anticipation of scope creep can be found in literature for projects using System Engineering?*. The three recommended scope management approaches focus on improving trust and control of scope in projects. These aspects are both needed to decrease the appearance of scope creep.

It can be said that Configuration change management, Information management and Partnering combined should make the current situation more optimal in anticipating scope creep and scope changes. It is important to consider that of all three approaches a minimum effort must be established. All approaches can be combined to SE. CCM is part of SE, an information management system can be applied to the ISO/IEC 27001:2013 standards and partnering can be included in each project independent of the framework. Therefore it is expected that all three approaches are easily introduced in projects using SE as framework.

These approaches give input for the analysis of the case study. The first two scope management approaches are a tool for anticipating scope changes. Partnering is a mindset and is therefore different of the other two approaches. However, it is still seen as important to introduce in projects in order to anticipate scope creep.

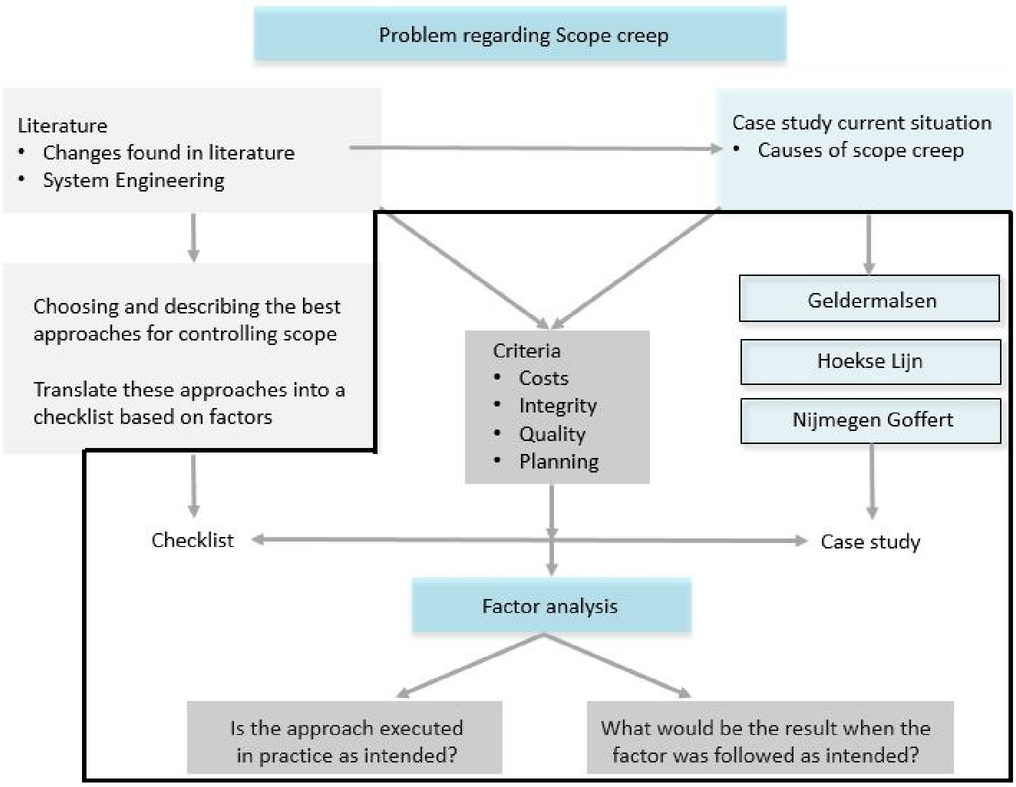
Part C2 - Analysis of the Case Study

The chapters of this part:

Research question that will be answered:

Sub-research question 4: *How are the scope management approaches from theory executed in practice and is this done as intended?*

Sub-research question 5: *What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?*



8. Description of the Case Study Projects

In this chapter the different case studies are introduced which were also already stated in section 8. First project Geldermalsen will be introduced, followed by project Hoekse Lijn and finally by project Nijmegen Goffert. Each project will be introduced. Then it is described how the management of changes is laid down and where scope creep was found in the projects. Finally the final quality is assessed. The information is based on appendix K, L, M. The scope creep found in these projects were translated to the scope creep areas in chapter 6. These also come back in the last section 8.4, where the these causes are linked to the scope creep of the different projects. This is done in a table that gives a good overview of how frequent each scope creep cause appeared in each project. A note that must be made is that Sweco used to be called Grontmij, and therefore both names will be used in the appendix and here for project Hoekse Lijn.

8.1. Project 1, Geldermalsen

8.1.1. Introduction

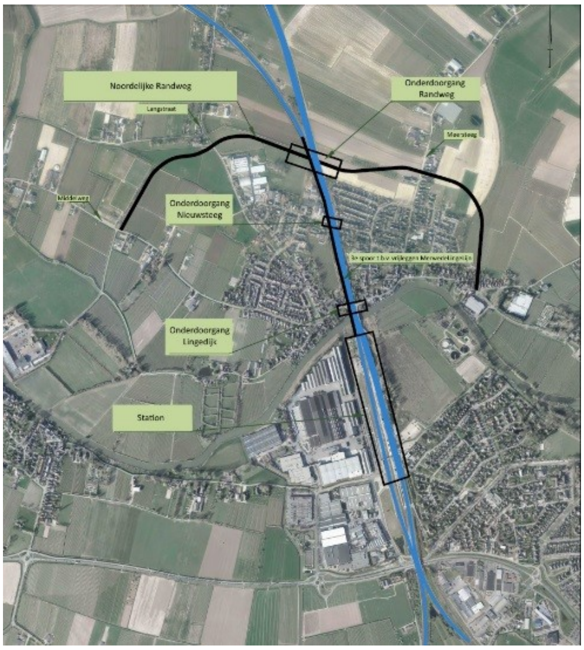


Figure 8.1.: Overview area of project Geldermalsen (ProRail, n.d.-a)

More capacity is needed on the railway between Amsterdam and Eindhoven so that train traffic can increase. This project is part of the Programma Hoogfrequent Spoorvervoer (PHS). In this program, ProRail works together with other carriers on increasing the number of passenger trains on busy routes. Furthermore, they try to accomplish sufficient capacity for freight transport. The ultimate goal is to travel without a timetable (ProRail, n.d.-c). For Geldermalsen the 6/6/2 framework is intended, which means that there must be capacity for six Intercity's, six Sprinters and two freight carriers each hour (See H, Annex 2).

In order to get the capacity between Amsterdam and Eindhoven, or the so called 'A2 corridor', the station and tracks in and around Geldermalsen have to be modified. The MerwerdeLinge Lijn between Dordrecht and Geldermalsen will have its own free track. In two places the level crossings will be removed and there will be an underpass under the track. There will be a third tunnel so that the new ring road can be constructed. At the Geldermalsen station the platforms will have to be extended (ProRail, n.d.-a). In the existing situation, the Lingedijk and Nieuwsteeg are both access routes for residents, but also for (local) companies and industry. As a result, the traffic pressure and nuisance of the traffic is high (See H, Annex 2) The construction will start around 2019. The project of the engineering of the disentanglement of emplacement Geldermalsen is awarded to Grontmij, how Sweco was called back then, on 17-6-2015, the contract is signed at 7-7-2015 and the project is closed at 15-11-2017 (see H, Contract adviseur).

During the engineering trajectory of both the PHS projects and the project Vrijleggen MerwerdeLinge Lijn (VMLL), which means the release of the MerwerdeLinge Lijn by disentanglement, it has been decided to integrate the projects into one project: "Spooromgeving Geldermalsen". The procedures concerning spatial planning mapped the interfaces and dependencies, which makes this integration possible. The contractor is asked to integrate, update and further develop the input products from previous engineering phases of the PHS and VMLL projects to the level that the Implementation Decision can be taken and the tender dossiers for the realization phase can be made. In the 'Elaboration of the Variant' phase, the integral FIS must be set as well as the RVTO (end situation). The transfer solution requires further elaboration such that an Implementation Decision can be taken for the entire (integral) scope (See H, Annex 2).

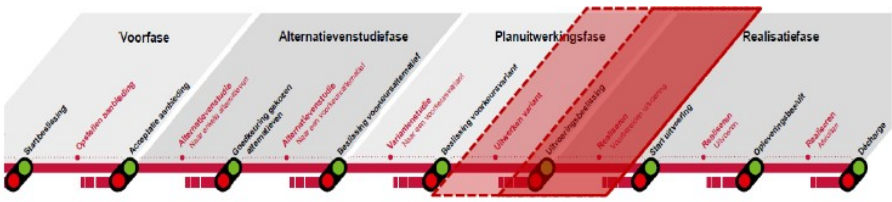


Figure 8.2.: Scope of project Geldermalsen

The emplacement consists of a (partially covered) phased island platform with various station facilities, 12 (head) tracks and a large range of switches. Large-scale changes take place at the emplacement. Track 7 and higher are being cleaned up to create room for MerwerdeLinge Lijn track and the new platform that accompanies this track. The other tracks also change in function and the number of switches is reduced from 38 to 20 (See H, Annex 2).

8.1.2. Changes laid down in the Contract

The contract between ProRail and Grontmij hold a part describing how to deal with changes:

- 5.1 states that if, due to circumstances at the expense and risk of ProRail, changes occur within work packages of the contractor and as a result the work is reduced or increased, the contractor must notify ProRail this in writing.
- 5.2 states that when a situation as described in 5.1, and when financial consequences appear, as soon as possible an additional offer must be submitted to ProRail. The costs that directly

or sideways need to be made for the execution must also be included in this offer. The prices as stated in the budget that was associated with the main offer are leading for the calculation of the additional offers. When the parties do not reach agreement in good consideration on the offer on the basis of 5.1, then they will submit their dispute to an then independent binding adviser, to be appointed by both parties.

- 5.3 states that when a situation as in 5.1 appears, then the contractor will have to indicate to ProRail whether the increase or decrease in work has consequences for the dates referred to and mentioned in Article 3, while maintaining the strict deadlines should be the starting point for the contractor.
- 5.4 states that the contractor before proceeding to the execution of the decrease or increase of work, he first need to receive a written assignment of ProRail. In this assignment any financial consequences must be written down together with any changes to the term (when they need to be submitted for acceptance) and the planning. Executed work of the contractor where no previous written assignment was received by ProRail, are not reimbursed.

8.1.3. Summary of the found Scope Creep areas

Scope creep was found in seven different areas, whereof the analysis is stated in K.

The first area are EOWs that were already partly carried out, but were cancelled eventually. This resulted in non-formalized extra work and non-reimbursed costs. This had extra effort as result and negative effects like re-engineering. The second possible reason for scope creep was time pressure during the entire project. This laid pressure on the design products and resulted in additional work that was not always formalized. There was no time to first research the impact of a change.

The third area were the difficulties concerning the discussions about the EOWs. Sweco start working on changes without having the formal files, because the planning otherwise would suffer. However, ProRail turns out to be reacting slowly. Some works turn out to be carried out already fully, before having a formal approval. Furthermore, performance statements are not returned within ten days. A lot of time and money is lost due to inadequate handling of EOWs and performance statements or the absence of reviews. Furthermore, drawing up an EOW costs many effort and this is not paid by the client. Another difficulty is for what level of detail an EOW must be drawn. When it seems that there is small impact and no financial consequences, a change is not formalized. However this results in floating requirements that result in scope creep.

Another difficult aspect were the SE products. First the SRS was point of discussion due to the fact that this document was not delivered by ProRail. ProRail delivered the SRS after this notion but it was still of insufficient quality for the tender dossier. Sweco started working on this document after a mutual agreement. However, ProRail later states that this was not as intended and takes the responsibility of the document even though Sweco already carried out work for this document and remained doing this for two parts. However, the review comments came very late and the end product came after finishing of the FIS. This resulted in validating against the CRS instead of the SRS. The unclear scope and difficulties for the validation could have been reason for scope creep.

The other product of SE that became difficult is the CRS. The CRS was available for each of the three different projects that were combined, see H. However, an integrated version became available during the project. It seemed that additional requirements and starting points were added to this version. There was a lot of discussion about this point and Sweco did research into the requirements that were added. They submitted an EOW for this, as agreed on. However, ProRail did not approve this EOW. After this, they made a decision on the leading document. Eventually some of these requirements became part of the final validation document of the FIS. This process took a lot of time and resulted in an unclear process and an unclear scope. This resulted in re-engineering, mistakes due to wrong starting points, and discussion on scope, all reason for scope creep.

The fifth area is that of the FISproduct. The assignment regarding the FIS was interpreted as merging the FIS products of the three projects into one product that is of sufficient quality. However, ProRail set up the assignment with a different intention, namely to optimize the FIS. This was not the scope that Sweco tendered on and therefore reason for discussion. Eventually the budget they decided on, was 2/3 of the budget that was needed, due to a large discount given. The entire process was delayed and there was a discussion on the scope and the consequences.

The Spoorbouwmeester and the architect both had a strong opinion during this project. The Spoorbouwmeester was not included in the tender phase and therefore he started giving input when the project started and he became involved. This resulted in many changes that were not always formalized due to their smallness or the easiness to immediately introduce them in the design. Furthermore, there were many workshops with the Spoorbouwmeester and the architect, more than tendered on, and they continued changing their wishes till a very late stage, resulting in scope creep.

Finally, some examples of scope creep are given. First the rail access point, due to requirements that are contradicting to each other. Second, the traveller tunnel is discussed, an example of a design that changed often due to input of the Spoorbouwmeester. Finally, EOW 49 contains a change in scope of a design part and many discussions were based on this part. Furthermore, the bicycle parking location changed many times due to changing wishes of the architect and other stakeholders.

8.1.4. Quality assessment

ProRail started with performance measurements at the end of 2015. An average score is given to each project and this is based on four criteria. It is shown that the project team did not always deliver a good result, however, at the end their score is a 7.8 out of 10 which is largely sufficient.

FIS 1.0 was delivered at 22-01-2016 and FIS 2.0 was delivered at 07-04-2017 (see H). This means that during the 1.0 and 2.0 the work was according to plan. However the process just after the delivering of FIS 1.0 became rated insufficiently on both working according to plan, as expertise and environment and safety. Eventually it seems that the ProRail is content with the result.

Table 8.1.: Performance Measurement for project Geldermalsen by ProRail

Period	Score	Work according to plan	Expertise	Collaboration/ Communication	Environment and safety
Q4 2015	76.39%	-	-	-	-
Q1 2016	78.75%	-	-	-	-
Q2 2016	69.44%	62.5%	65.63%	81.25%	75%
Q3 2016	4.6	4.0	3.7	7.0	4.0
Q4 2016	6.1	5.5	6.0	7.0	4.0
Q1 2017	5.9	7.0	5.0	6.4	7.0
Q2 2017	7.0	7.0	6.7	7.6	7.0
Q3 2017	7.8	7.0	8.3	7.6	7.0

8.2. Project 2, Energy supply of the Hoekse Lijn

8.2.1. Introduction

Figure 8.3.: Overview area of project the Hoekse Lijn (Rotterdam, n.d.)

The railway section between Schiedam Centrum and Hoek van Holland is called the Hoekse Lijn, see figure 8.3. The Hoekse Lijn will be converted from heavy rail to a metro line (Gemeente Rotterdam, n.d.). This high-quality metro line will include two new and seven renovated stations. Travelers can then go directly from the city center to the beach via high-frequency transport. This will lead to an economic boost for the region. The route is now 23 kilometers long and will be extended by one kilometer so that it continues to the beach of Hoek van Holland. The seven current stations will be modernized by raising the platforms (ProRail, n.d.-b). The conversion of the Hoekse Lijn means (Gemeente Rotterdam, n.d.):

- A direct metro connection to the centre of Rotterdam.
- More direct connections with city centres by linking with the Metronet of Rotterdam region.
- During the day a higher frequency to Steendijkpolder (Maassluis): every 10 minutes.
- New stops and a connection with Hoek van Holland beach.
- Stops become more accessible and socially safer.
- An increase in the number of travellers by fourthy percent.
- Travel with new and comfortable equipment.
- Freight transport remains possible.

Many preparations were required for this conversion. The substation of Schiedam had to be adjusted. Furthermore, new cables will be laid on the complete route for the change in security systems, electrical supply and control cables. Finally, a pre-load must be deposited, so that the ground can settle in order to later carry the track. This pre-load will also be placed on the spot where the connecting arch comes. This track will contain a single-track train track (heavy rail) for goods only. This is a unique set-up in the Netherlands (ProRail, n.d.-b).

The conversion of the line involves many parties working on the project. One of the systems that will be built is the energy supply. This case study project focuses on the energy supply of the Hoekse Lijn (see I, Aanbestedingsdossier). The client of the project is RET. Sweco, called Grontmij Nederland B.V. together with Omexom made a declaration of intent for the purpose of this project. Omexom will use for the part of the engineering the knowledge and experience of Grontmij. Grontmij will work as subcontractor for Omexom for the project of the energy supply of the Hoekse Lijn (see I, Intentieverklaring). Omexom is a company that supports its customers to realize an energy transition. They offer a range of services and expertise for the generation, transmission, transformation and distribution of electricity (Omexom, 2016).

The contract for the engineering of the energy supply between Omexom and Grontmij is signed at 21 October 2015 (see I, Getekend contract).

The engineering assignment includes the engineering of all required parts in accordance with the delivered plan of requirements in respect of the Energy Supply System, including all connected requirements and their interfaces with other system components, both in and outside the contract (see I, Aanbestedingsdossier). The work was offered together with four added options. This was the GR HHS, adding an extra inverter, carrying out the redundant of the low voltage installation, and a temporary technical installation (metro). These four added options were also tendered (see, I, Aanbiedingsbrief)

8.2.2. Changes laid down in the Contract

The contract between Omexom and Grontmij, signed at 26-10-2015 hold a part describing how to deal with changes:

11.1 states that Omexom is entitled to desire changes in design, construction or specifications, according to the plan of requirements. Grontmij will as fast as possible, but at the latest after five workdays of the request of Omexom, make a written statement of the consequences of the change for the price and the delivery term and other relevant factors. At the request of Omexom, Grontmij will provide insight into the structure and calculation of the possible price adjustment. The price for the change will be reasonable and in line with market conditions. Only changes to the contract, including the appendices, may lead to a change in price and planning.

11.2 states that a difference of opinion as to whether there is a change to the costs or if the change has other consequences, does not absolve Grontmij from the obligation to carry out the assigned work instantly.

Finally 11.3 states that changes can only be agreed in the form of a change form which is included in the appendix of the contract, and apply only if this is included in the list of agreements. Article 13 applies in full. The payment of additional and less work is coordinated in the relevant change form.

8.2.3. Summary of the found Scope Creep areas

The analysis of scope creep during the project of the energy supply of the Hoekse Lijn is stated in L. The summary of the findings is described here.

The organization of the project Hoekse Lijn was set up in such a way that Grontmij had to send their documents to Omexom, who would pass them further to RET. In this way Grontmij was not in direct contact with the client RET and Omexom was responsible for managing the project and the quality. All three parties started with a capacity that was too small for the scope of the work. Therefore this resulted in difficulties at the start of the project. During the project this was improved by both Omexom and Grontmij.

Due to insufficient project management at both the side of Omexom and Grontmij, the start of the project was characterized by many changing wishes without formalization of changes. This resulted in a bad financial prognosis for Grontmij. In February the project manager at Grontmij changed and after this many EOWs were submitted. This to get reimbursed for already done work.

Scope creep eventually came forth out of four areas. The first one were cancelled EOWs. However, due to the contract, Grontmij was always obliged to carry out the work, even when there was no agreement found. This resulted in not having extra scope formalized, but still carried out.

The second area were all the EOWs that were submitted afterwards. This has as result that changes were introduced without formalizing the changes and researching the impact. Afterwards it turned out that this had many consequences and the financial consequences were submitted in an EOW. However, the consequences already took place and the control of the scope therefore became hard to maintain. All changes were basically scope creep.

The third area is based on reviews that came in late. Instead of the agreed ten days it took on average more than a month and sometimes even a few months to receive a review. It also happened that reviews were first accepted and a month later the same review was not accepted. This resulted in many re-engineering and unanticipated changes. The design or plan already continued and the review was still based on the old versions. Furthermore, many documents ended with many reviews and thus many versions. The review process seemed to never stop and the changing wishes and requirements was a continuous input. This resulted in a scope that was changing much throughout the entire project. These reviews often were not formalized, only after the financial consequences seemed large. Finally, reviews were often based on design versions that were not accurate anymore, which resulted in re-engineering and integrity problems, which is reason for scope creep.

The last area of scope creep came forth out of the grey area of additional wishes and requirements. There were many changing wishes and requirements, but so much detail in formalizing changes was not made. Therefore there were many 'floating' requirements. These can have large negative impact on the quality and integrity of the design. This resulted in some examples of scope creep, like the one of the material of the transformers.

The discussion on the component choices was one large example that influenced the entire project. Omexom would choose the ten different installations and their suppliers. This was input for the design, however, Omexom in March 2017 still hadn't chose all suppliers. This resulted in many discussions, additional work, changing of assumptions and mistakes in the design. This was one of the main causes for scope creep.

8.2.4. Quality assessment

The project of the Hoekse Lijn is still not finished. Sweco stopped with the project after delivering their end products. However, RET and Omexom are still engineering. Sweco has on employee with certain expertise posted at Omexom to still help with the engineering. the development of the Hoekse Lijn is dependent on many different stakeholders and the project itself was also split up into different projects.

Hoekse lijn reported on 14-12-2017 that due to existing and new setbacks in the planning of the conversion work of the Hoekse Lijn to metro line, the Metropolitan Region Rotterdam The Hague (MRDH) has decided to postpone the start of the metro operation on the route of the Hoekse Lijn until the autumn of 2018. The construction of the stations and the runway will be completed by the end of 2017, but then there will be a long period of testing and test driving (Gemeente Rotterdam, 2017).

8.3. Project 3, station Nijmegen Goffert

8.3.1. Introduction

Project Nijmegen Goffert is a project that focuses on the development of station Nijmegen Goffert, see figure 8.4

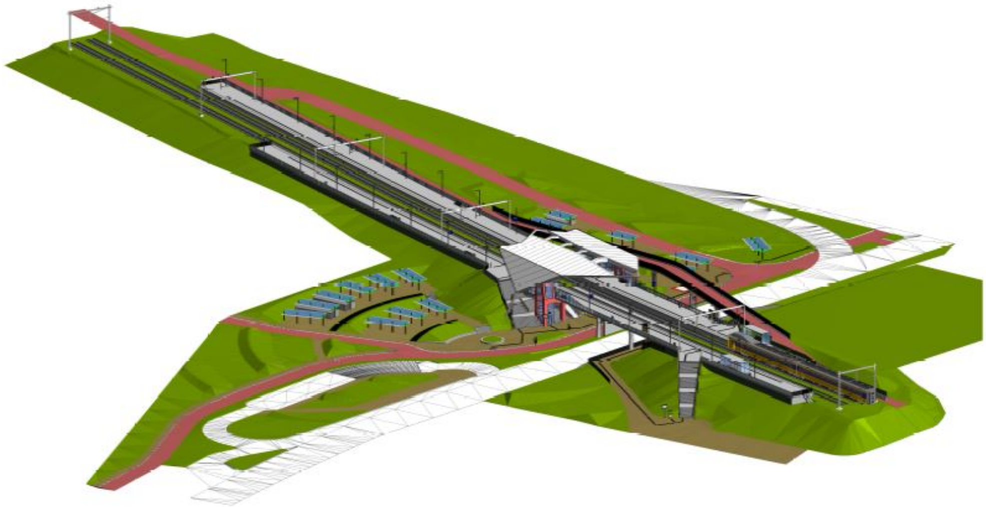


Figure 8.4.: Nijmegen Goffert, see J situatietekening

Station Goffert is located in the district de Goffert, near the Goffert park and Goffert stadium. The station is situated on the existing artwork on the western leg of the Neerbosscheweg. The new station will be located along the double-track train connections Hertogenbosch - Nijmegen (see J, Eisenspecificatie).

The station of Nijmegen Goffert is build for two reasons. To make more space for business in the surroundings of the Goffertpark and to gain better accessibility of the park and stadium De Goffert. The station needs to grow into a public transport hub, serving many commuters and managing peak times during events in the stadium (Sweco, n.d.).

Nijmegen Goffert station is an assignment commissioned by the Arnhem Nijmegen City Region and is part of the development of one of the six nodes that are included in the regional and municipal policy. The station is initially used as a (rail) access point for passenger transport for the surrounding residential areas and the nearby industry. Train, bus, car and bicycle must come together at these nodes (see J, Annex 2). The expectation is that the stop, after full fulfillment of the environment, has 3,500 entrants and exits per average working day, assuming an operation of 4x per hour per direction (see J, Eisenspecificatie).

The design had to fit in with the urban development of the area. Through the use of new materials and a futuristic appearance, the new station exudes the ambition of pulling knowledge institutes and high-tech companies to this area (Sweco, n.d.).

A train and bicycle viaduct must be build together with the track and bearing structure. The platforms must be developed and the bicycle parking. The roads and pavements must be developed together with the waterways and drainage. Another aspect is the energy supply, the cables and pipes and other objects and systems like noise-reducing measures (see J, Annex 2).

Sweco carried out the planning study on behalf of ProRail and was responsible for the pre-engineering of the constructive feasibility and the demand specification based on the requirements. In the realization phase, Sweco supported the ProRail Construction Manager with regard to back office, testing and supervision (Sweco, n.d.).

8.3.2. Changes laid down in the Contract

In the contract that is signed, see J, there is not a certain section based on how to deal with changes during the project. The only time that this is mentioned is in section 4.4 part of the section named "Price". Here it is stated that: Changes, reduction and extension of the Agreement as referred to in Article 6.2. Purchase conditions are settled at the rates and amounts as they are included in the budget associated with the Offer. This article is found in the Purchasing conditions, see J, and focuses mostly on the cost consequences that occur during the project. It therefore does not cover the full load of having changes during the design.

6.1 states that a modification of the Agreement, including the applicable to it terms and conditions or the agreed price, is only possible in case of a subsequent change or addition by ProRail of the description of its obligations under the Agreement, or the applicable assumptions or for those cases that the Agreement provide a facility for this.

6.2 states that when there is an expansion or reduction of the obligations under the Agreement, then Seller ProRail must be immediately informed in writing. The Seller then must submit an additional quotation to ProRail expeditiously. As far as the Agreement was at a fixed price, the supplementary offer is also at a fixed price, unless in view of the content of the expansion or the reduction this cannot in reasonableness be required of the Seller. In other cases - where applicable - an estimated maximum amount is offered, at what amount the expansion or reduction in any case can be carried out. In the supplementary offer are also all necessary costs shown, needed directly or indirectly for the execution. When calculating the financial consequences of the expansion or the reduction, the Seller is obliged, if applicable, to retain the in the Agreement stated unit prices, costs and surcharges and volume discounts.

6.3 states that in his supplementary offer, the Seller must also provide a substantiated statement of whether, and if so, in which extent the change has consequences for the planning of the Delivery, for which, if necessary, the deadlines set in the Agreement must be the starting point.

6.4 states that the Seller must proceed to the implementation of the amendment of the Agreement, to do so, first a written supplementary order from ProRail must be received. In there not only the possible price consequences are recorded, but also the possible changes regarding payment terms and planning.

There is also a work package in Annex 1, see J, based on managing changes. The goal of this work package is controlling the Agreement in response to changes of the Agreement. Changes must be be drawn up using the format of changes.

8.3.3. Summary of the found Scope Creep areas

The analysis of scope creep during the project of Nijmegen Goffert is stated in M. The summary of the findings is described here.

It was decided to split the delivery of products into two parts. Part A was the entire station without the hood and part B was focusing on the hood. The architect would only test the part B, however it turned out that they also reviewed part A. this resulted in involvement of the architect in the design of the entire station. This resulted in a cyclical and iterative design process were design parts received repeatedly multiple changes. From that moment the baseline is not followed anymore.

The architect eventually came up with a changed design for the hood and this needed to be calculated constructively, resulting in a new iterative process. ProRail decided after a few months to freeze the design and start working at carrying out the remaining changes and to complete the work. However, the design was not at rest and therefore the design process was not yet finished. Therefore more changes were added.

Furthermore, the architect continuous with making changes to the hood. The model of the architect was no longer in accordance with the structural model. This resulted in many re-engineering and calculations and a delay in delivering. This puts time pressure on the project.

Another disturbing factor was the agreement on rationality. Not everything can be foreseen, however there is a tender based on fixed sum and an estimation of hours. During the design there is a discussion in what is rational for the design. For example, how many workshops with the architect are needed. Time is subject to the design, however there is a continuous process of optimization and thus changes to the technical scope.

Not everything can be controlled for. For example, extra hours are not always formalized and the small changes coming forth out of meetings are not written always down. This is partly the result of the close collaboration. However, it has consequences for the control of the scope. Furthermore, the work of the employee is not always under full control. Engineers are perfectionists and want to deliver the best quality, even when this amount of detail is not always part of the scope. This can result in additional work or optimization's which result in an unclear scope.

The process of EOWs take time, with as result that work is already carried out without approval, or additional work that is not formalized. The process of an EOW is accompanied by high overhead costs. The project manager of Nijmegen Goffert therefore made with an EOW a reservation of a certain amount. Each time a work was small in size and financial consequence, this became part of this EOW. This was based on mutual trust and worked well.

The project of developing station Nijmegen Goffert took place all around the station. This resulted in many disciplines linked to each other in a small geographical area. When something needed changing, this resulted in many additional disciplines that also needed change. Therefore there was a large pressure on the integrity of the design. Mistakes in the managing of the integrity would fast result in scope creep.

There are also some examples of scope creep that caused bottle necks for the project. Some parts needed many changing or had a larger impact than was expected. One example is the unforeseen translation of the 2D image of the Municipality into the 3D model. Another example is the continuous changing of the hood. Furthermore, an example is the fence that changed many times from fence to glass and back. Finally some design aspects at the elevator caused trouble.

8.3.4. Quality assessment

In a satisfaction statement (see J) the project manager of ProRail states that Grontmij has the project 'Realization Nijmegen Goffert' carried out to the satisfaction of the client. The work carried out by Grontmij have made it possible that the project has been successfully completed.

This focuses mainly on the management and control of the implementation of the project. The station was officially opened on 14 December 2014 according to schedule. The planning was estimated to be 14 months for Grontmij but became 14/16 months. This was due a delay in contracting activities of the contractor Dura Vermeer and due to longer support of the ProRail Construction Management Team in connection with BackOffice and processing of changes (see J).

It can be said that the eventual quality of the project was in line with what was intended. The design became better optimized than expected and this resulted in the station having received a substantial upgrade and has therefore become a very pleasant and socially safe environment for the traveler (see J, Motivation).

8.4. Scope creep found in the different projects

After the analysis of the different case study projects, knowledge is gained about which forms of scope creep appeared in which project. The different causes of scope creep that were introduced in chapter 6 are also based on the scope creep that appeared in the projects. Therefore the link between the causes and different projects can be made. Table 8.2 shows how often a certain cause took place during the three different projects.

Table 8.2.: Scope Creep found in the different projects

Scope Creep causes	**Geldermalsen**	**Hoekse Lijn**	**Nijmegen Goffert**	**Total**
Start of the project	**Frequently**	**Occasionally**	**Occasionally**	**Occasionally**
Wrong interpretations	Frequently	Occasionally	Never	Occasionally
Moving scope while tendered as fixed scope	Frequently	Frequently	Frequently	Frequently
Tendered with missing input	Frequently	Frequently	Occasionally	Frequently
Rationality	Occasionally	Never	Occasionally	Occasionally
Complexity	Occasionally	Occasionally	Occasionally	Occasionally
Process of an EOW	**Frequently**	**Frequently**	**Occasionally**	**Frequently**
High costs involved	Frequently	Frequently	Occasionally	Frequently
Discussions take long and are arduous	Frequently	Frequently	Never	Occasionally
Long waiting times	Frequently	Frequently	Never	Occasionally
Starting before having an official approval	Frequently	Never	Occasionally	Occasionally
Time pressure	**Frequently**	**Frequently**	**Occasionally**	**Frequently**
Scope management process	**Occasionally**	**Occasionally**	**Occasionally**	**Occasionally**
Not formalizing changes	Occasionally	Occasionally	Occasionally	Occasionally
Consistency	Frequently	Never	Never	Never
Too much detail	Occasionally	Occasionally	Occasionally	Occasionally

Changes till the last moment	Occasionally	Frequently	Frequently	Frequently
Not anticipating changes	Occasionally	Occasionally	Occasionally	Occasionally
Wrong process of reacting on reviews and changes	Occasionally	Occasionally	Never	Occasionally
Team composition	**Occasionally**	**Frequently**	**Occasionally**	**Occasionally**
Wrong people on the wrong spot	Never	Occasionally	Never	Never
Not enough capacity	Never	Frequently	Never	Never
Project is not correctly managed at the other stakeholders	Occasionally	Frequently	Never	Occasionally
Missing links	Occasionally	Occasionally	Occasionally	Occasionally
Parties involved with strong opinions	Frequently	Frequently	Frequently	Frequently
Working too good	Frequently	Occasionally	Frequently	Frequently
Process of the project	**Occasionally**	**Frequently**	**Never**	**Occasionally**
Reviews that take too long	Frequently	Frequently	Never	Occasionally
Reviews without integrity	Never	Frequently	Never	Never
Setting up products in a wrong order	Occasionally	Occasionally	Never	Occasionally
Many disciplines at one place	Frequently	Occasionally	Frequently	Frequently
Game-like interaction	Occasionally	Frequently	Never	Occasionally
Human Factors	**Frequently**	**Occasionally**	**Frequently**	**Frequently**

This table shows that in total there are 26 sub-causes to be found and 7 main causes. Of the seven main causes, process of an EOW, time pressure and human factors are important causes to consider, as there sub-causes make this appear frequently in practice. The other four causes appear occasionally and thus are also important. Only four causes 'never' appeared. This results in the fact that there is much room for improvement in projects.

9. Analysis Configuration (Change) Management

In order to conduct the research regarding the practical execution of Configuration Change Management, a checklist is set up which can be found in appendix E and gives a guideline for the conducting of the research.

CCM is for this analysis divided into eight different factors. These factors are all crucial parts that need to be implemented to have good CCM. The factors are: (1) Set up the configuration and the Configuration Management plan, (2) Identifying Configuration Items, (3) Accurate data and clarity on version and status of documents, (4) Configuration Control Board, (5) The establishment of baselines, (6) The processing of changes, (7) Distinction between types of changes, (8) EOW approval.

Each factor will be analyzed individually and starts with a short summary of how the project was executed regarding CCM. This is based on the thorough analysis presented in appendix N and answers sub-research question 4: *How are the scope management approaches from theory executed in practice and is this done as intended?*.

Then an analysis is based on how the situation would have changed if the theory behind the factor would have been followed correctly. This answers the sub-research question 5: *What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?*. This analysis is based on logical grounds and on the opinion of the project managers and lead engineers of the projects. The four criteria costs, quality, integrity and planning are used to give structure to the analysis. Each criteria is analyzed based on cause or effect that would result from or be taken away by a factor. These causes and effects are stated in appendix Q. Only the causes and effects that will change are named. The number of causes and effects that are changed are input for the analysis in chapter 13.

1. Set up the configuration and the Configuration Management plan

This is a crucial factor for getting the right mindset in a project. In the project of Geldermalsen, the project team did set up a project management plan, but didn't set up a Configuration Management Plan (CMP) and they therefore did not manage the configuration process as intended by literature. For the project Hoekse Lijn Omexom was responsible for setting up a project management plan and a CMP. However, these were never communicated to Sweco and they therefore did not manage the configuration process as intended. Nijmegen Goffert also did not set up a CMP because this was not asked of them in the project requirements.
The integrity of the project is found in setting up a WBS and following the CRS for validation. Both products are set up by the client in the projects and are mostly of good quality. Therefore for Sweco this will have no consequences.

Costs

Investment and maintaining costs are needed to set up the system, however making sure that the CMPis maintained will be the hardest. For Geldermalsen an estimation of 80 hours is said to be

enough to set up a CMP and the basis for the configuration. An employee of scale 6 will be needed and this results in an investment of €8,400,- to set up the basis for the executing of CM. For Nijmegen Goffert the estimation is comparable to that of Geldermalsen. However the project is smaller and parts of the plan can be copied from other projects, resulting in 40 hours and thus €4.200,-. To maintain the configuration would costs a few hours each weak resulting in €400,- each week. In project Hoekse Lijn only a small investment should have been made, because Omexom was responsible for setting up the CMP. Setting up all agreements and the entire project management plan took them 3,5 week work with 1,5 man, which resulted in an investment of €15.000,-. Only a part of this was for the CMP. The configuration must be maintained and this would lead to a small investment of Sweco to assure that Omexom would do this.
Two causes are positively influenced and one negatively. The final projects costs will be smaller due to the fact that changes will less interrupt the project process when the configuration is maintained. There will be less room for uncertainties at the start of the project because the configuration is set at the start and more agreements will be made than in the current situation. The overhead expenses will increase because maintaining the promises stated in the CMP will result in more time for processing and documenting.

Integrity

Having a CMP and a clear configuration will decrease the chance on having six causes: An incomplete or partial scope because the scope is made insightful during the configuration set up and can then be made complete. Design changes and design errors will appear less when there is a more clarity on the starting points. Less uncertainties due to setting up and discussing the configuration at the start and thus less assumptions need to be made and probably less decisions then need to be revised. There will be a better plan as part of the CMP for setting up the trace-ability and communication.
Effects are that there will be less rework and re-engineering due to less revised decisions and design errors. This will result in less loss of rhythm and loss of productivity as a result of the rework, which are three effects.

Quality

Setting up a good configuration and CMP will benefit both the product and process quality and benefit from a better integrity. The design will be more fit for purpose by decreasing the chance on six different causes. There will be less rework when the configuration is clearer, and thus more room for optimization. If the scope definition is unclear, this will be made insightful at the start and will be less disruptive during the project. The project team will easier be able to grasp the complexity of the project. There will be less uncertainties and thus less assumptions made, therefore less decisions must be revised.

Planning

Having set up the configuration and the CMP will decrease the chance on having the following two causes of time delays in the planning: Changes in the design and scope will be less disruptive and coordination and communication problems will decrease.
Effects are that there will be less rework or loss of time, this will result in less loss of productivity or rhythm. Furthermore, the planning can better be substantiated and it will save time in the management of the scope, this are four effects.

2. Identifying Configuration Items

This is a crucial part of CM but turn out to be hard to set up. It was not followed in the project Geldermalsen, Hoekse Lijn and Nijmegen Goffert. Geldermalsen and Hoekse Lijn did derive objects from the WBS and Nijmegen Goffert established a System breakdown structure (SBS). The selection of a CI can be based on several factors like complexity, interfaces, use/function, commonality and documentation needs. A decision must be made on what to take as basis for the selection. A functional scheme could be set up which can be based on different things. It can be based on disciplines but also for example on the difference between train stops or free train tracks based on geographical locations. Geo information systems can also be linked to these objects.

Costs

Investment and maintaining costs are needed. For Geldermalsen the investment of identifying CIs is estimated to take 40 hours and this will result in €4,200,-. Keeping these kind of schemes workable, will cost on average 2 hours a week which is around €200,-. For Hoekse Lijn the investment is estimated to be 16 hours, which result in an amount of €1.680,-. Keeping everything up-to-date is estimated to cost 4 hours each week, so €400,-. For Nijmegen Goffert this would cost many time on paper. They used a 3D model so it would be easier and faster to put everything inside the model. The design report is not linked to the model, so it would be hard to understand what is written in the report and would result in many documents. The putting in the model would cost time but would be easier to maintain than on paper. It does not affect any causes.

Integrity

Identifying CIs will decrease the chance on having seven causes: Less design errors because interfaces are easier made insightful and thus consequences are made insightful and can be acted upon, therefore design changes are less disruptive. The communication of changes will be better substantiated. The consistency that can be missing between items and documents can be found easier when mapping the relations between them, this also helps that changes can be easier implemented across many disciplines. The scope control process will be better and thus the anticipation of scope changes, just as that working in too much detail will be less disruptive.
Effects are that there will be less risk for the interfaces, and less rework and there will a smaller risk for coordination failures and errors, which are three effects.

Quality

Identifying CIs does benefit the quality by having a integrity that will be better. The two causes that directly affect the fit for purpose are having less missing consistency in documents and the chance on design errors will be smaller.

Planning

Having identified CIs will not decrease causes of delay.
The effect is less rework and and this will have as result a faster scope control process where interfaces and impact of a change can faster be identified.

3. Accurate data and clarity on version and status of documents

The project team of Geldermalsen, Hoekse Lijn and Nijmegen Goffert did all had access to accurate data, together with a list if design products and documents, however, there was not a document tracing version numbers. The clarity of the versions was therefore lacking. At the start of the project of the Hoekse Lijn, this was established but not maintained by Omexom. In the projects there was no trace-ability matrix which made the tracking even harder.

Costs

To set up a trace-ability matrix and version and status tracking, an investment must be made at the start to set up a good basis by setting up the CMP. After that the set up must be used consistently. Additionally, a tool can be set up, which takes a few hours, so around €400,-. The consistent use and maintaining of this tool or trace-ability matrix will not add extra hours to the project.
One cause is influenced, namely the final project costs will decrease because the costs of failure will decrease. This will probably be one or two percent of the engineering assignment. This can be

€10.000 to €50.000 a year for a project. There will be a small increase in overhead costs because the documentation must happen more completely, but this is negligible.

Integrity

Having accurate data and version control will lead to a decrease of the chance on having four causes: Having design errors due to using the wrong versions will decrease. Implementing changes across multiple disciplines will be easier when knowing what is the most up-to-date version of each document. The trace-ability will be easier and there will be more up-to-date information.

Effects are that there will be less rework, and less revisions to project documents and reports, there will also be less disputes and blames among project partners when document versions are clear and it is clear which versions are already sent or not, this are three effects.

Quality

Having version control does benefit the product and process quality. The two causes that directly affect the fit for purpose are having less chance on missing consistency in the documents, and there will be less design errors.

Planning

Having version control will not take away causes of delay.

It will decrease the amount of rework, loss of productivity and loss of rhythm and will have as result a faster scope control process, these are four effects.

4. Configuration Control Board

In order to deal with changes, a CCB must be established, which was not done in the different projects. The client in all cases took control over the changes and the approval of these. However, the project and all stakeholders can benefit from such a board.

Costs

Investment and maintaining costs will be present when a CCB will be set up. For Geldermalsen and Nijmegen Goffert, ProRail did control all changes. With a CCB this would be in hands of all stakeholders. Probably two persons will take place in this CCB. Meetings can be estimated to take place twice a month, so two times 4 hours twice a month will result in €1.600,-. For the Hoekse Lijn it is said that the CCB would also be responsible for tuning and communicating. This would be 8 hours twice a month for the project manager probably resulting in €1.200 a month.

One cause is affected, as the final projects costs will be smaller due to the fact that changes will less interrupt the project process because changes are first approached by the different stakeholders. Benefits and negative consequences will be discussed based on all interests instead of just based on that of the client. The overhead expenses will increase because there will be more documenting and processing in the CCB. However, there will also be a decrease in overhead expenses because parties are earlier and more thoroughly informed by the mutual sessions.

Integrity

Having a CCB in place during a project will decrease the chance on having seven causes: There chance on communication flaws will be smaller due to the fact that each party is represented in the CCB and information and decisions of changes will be shared among all parties there. When looking at projects where a model is build, this could especially have benefits for the communication. The focus a few years ago was mostly on the modelling, but in the current situation there is much more experience with this, so the focus shifts to the process and how to walk trough a model structurally. By having a CCB this process could be easier because the model is structurally checked and would increase the depth of the comments and increases the quality of a model.

The following cause that can decrease is that parties with strong opinions or bad project management

will become less disruptive for the design process, because each party can now have a say in which changes or chosen to implement or not. Uncertainties can easier be discussed during these sessions which will lead to a smaller need of making assumptions and thus less decisions have to be revised later on in the project. The chance on having wrong interpretations is thus smaller. The trace-ability of decisions and changes will be larger due to having a CCB.
Effects are that there will be less re-engineering when it can be shown during the CCB meeting that changes are not needed or having to many negative consequences in relation to the positive ones. There will be less disputes and blame among the parties when decisions made during the meetings are substantiated, communicated and can later be traced back to these meetings. There will be a smaller risk of coordination failures and errors. This are four effects.

Quality

Having a CCB does benefit the process quality of changes and seven causes affect the fit for purpose. These are that not formalizing changes will now be a mutual decision and because the scope is controlled by the CCB not formalized changes are easier made insightful, just as when it appear that there is wrong anticipating changes. The chance on a wrong process of reacting on reviews and changes is thus smaller. This would also result in less risks for the interfaces, because more parties can give their opinion on this. Just as stated with the integrity, uncertainties are smaller, there are less assumptions and thus less revised decisions. Together it is easier to find room for optimization which benefits the end result. Finally, the stakeholders opinion is earlier included in the scope definition throughout the project.

Planning

Having set up a CCB will decrease the chance on having two causes of time delays in the planning: Changes in the design and scope will be less disruptive and coordination and communication problems will decrease.
It will decrease the effect of rework and unnecessary addition of work. The planning will be clearer and better substantiated. This are three effects

5. The establishment of baselines

The establishment of baselines is one of the crucial parts of CCM. There was always the intention for baseline management, but it is not done consistently. All projects froze the configuration set at the start but did not maintain baseline management. Therefore there was no establishment of new baselines after an iteration of the design took place or when multiple changes were approved. It can be argued that the products of Geldermalsen and the 3D model versions of Nijmegen Goffert can be seen as baselines.

Costs

Investment and maintaining costs will be present for baseline establishment. For Geldermalsen it is estimated that it will take 40 hours to set up the system of using baselines and having a first baseline. This results in €4.200,-. Furthermore, to remain consistent throughout the project, probably baseline meetings are necessary. 4 hours a week can be the estimation to remain good baseline management, this result in 400,- a week. The estimation for Hoekse Lijn is to invest around 100 hours to put everything into an information management system like Relatics. So this would result in an amount of €15.000,-. For Nijmegen Goffert it is said that maintaining baseline management can be without much effort, when having the tools to do this. It would cost around half an hour a day. So for each week this would also result in around 4 hours. It is important to make agreements about for example the level of detail in the baselines.
The final projects costs will be smaller due to the fact that changes will less interrupt the project process because changes directly insightful.

Integrity

The establishment of baselines will decrease the chance on having six causes: There will insight into the scope with the use of baselines, therefore an incomplete scope is fast recognized and acted upon. Furthermore, it will result in less design errors due to working with the wrong scope. Changing the design into using new starting points will be done on strategic points in time, based on that this will as less as possible disrupt the design process. Communication over the scope will improve and therefore less flaws will appear. The scope control process will benefit from having baselines, and scope will easier be maintained when the level of detail increases. Furthermore, the trace-ability of scope changes is easier and more clear.
Effects are that there will be less rework and re-engineering when the scope is better in control. The revision of documents will be easier and planned at times when the baseline becomes a new version. Therefore there is a smaller chance on loss of rhythm and loss of productivity. The risk on coordination failures will be smaller. This are five effects.

Quality

Having baselines does benefit both the product and process quality. Seven causes directly affect the fit for purpose. Firstly, not needing to work with an incomplete and unclear scope, because the baseline focuses on making this clear and therefore the project is better fit for purpose. There will be a smaller chance on wrong interpretations and the project team will easier be able to grasp the complexity of the project. The amount of rework will decrease just as the design errors due to at all times knowing the scope. This is in line with the fact that not anticipating changes will decrease due to having clear starting points at all times. When working with models then the difference can sometimes not be seen in the model, but by having baselines, the changes are made clear. It would be ideal when the program that is used can establish baselines with additional changes automatically. There will be more room for optimization because it is clear where in the scope there is room for this.

Planning

Having set up a baselines will decrease the chance on having four causes of time delays in the planning: Changes in the design and scope will be less disruptive, coordination and communication problems will decrease, discussions will not have to be long and arduous and the level of detail an be less disruptive. This follows from the fact that there is an interaction between the baseline and the planning. Baselines are based on milestones of the planning.
Effects of this interaction will be that the planning can easier be changed and made insightful due to baseline management. Therefore the planning will be of better quality and the time pressure will be less due to this. The planning will be clearer and better substantiated. This are two effects.

6. The processing of changes

The processing of changes is merely based on submitting EOWs. However, not all changes were followed by this formal process which resulted in scope creep. Furthermore, the formal document did not always contain all needed information like requirement numbers, work package numbers, drawing numbers, and interfaces that would receive impact.

Costs

Setting up a good basis for the processing of changes would result in an investment at the start of the project as part of setting up of the configuration and CMP. The maintaining costs in the current situation, with the lack of a good configuration as starting point, would be high. For each EOW difficulties would arise. For Geldermalsen this would take every time about 20 hours resulting in €2.100,-. For Hoekse Lijn this is estimated to be 6 hours, resulting in €630,-. Also for Nijmegen Goffert this would be around 6 hours, however there were less EOWs in this project. When a good configuration is set up, each week someone must invest around 8 hours for each EOW. This is when

multiple EOWs are proposed. This would result in an estimated cost of €840,- for each week.
Two positive causes are found. The final projects costs will be smaller as changes will less interrupt the project process because the consequences are more completely known and therefore the failure costs will decrease. Second, the project costs will be more in agreement with the made costs.

Integrity
Improving the process of changes will decrease the chance on having five causes: Working with an incomplete scope will happen less when all changes are formalized, just as that there will be less design errors due to this. Interfaces are made insightful in the EOW and therefore the changes that must be implement across multiple disciplines will be easier because the consequences are already shown before implementing. The scope control process will be improve in quality just as the trace-ability of changes.
Effects are that there will be that the risks for the interfaces and for coordination failures will decrease. This are two effects.

Quality
Improving the processing of changes affects the fit for purpose by of the design by taking away the fact that changes are sometimes not formalized and this will result in a more complete scope. Furthermore, how to anticipate a change is stated in the EOW and therefore wrongly or not anticipating changes will happen less often. By investing in a clearer situation for each EOW regarding document numbers, requirements, work package, interfaces and design documents, the EOW will be easier to apply and this will reduce the amount of errors in the design. This are four causes.

Planning
Processing changes differently will not take away causes of delay.
It will decrease the amount of rework, loss of productivity and loss of rhythm and will have as result a faster scope control process. The planning will better be substantiated because planning consequences are made insightful when processing changes. This are five effects.

7. Distinction between types of changes

There was no distinction in all three projects between a Change Request (CR), EOW and contract change proposal resulting in the same process for each type of change. Also no classification took place. Changes of type 2 mostly are 'forgotten' and become floating wishes.

Costs
Investment costs will be found in setting up a process. For changes of type 2 an issue list can be created that takes 2 hours per week, which also keeps track of impact. So, the investment is found in communicating with the client. Hoekse Lijn thinks of all changes as an additional work that must be reimbursed. Therefore they make each change an EOW. However due to the 'game' that is played not all changes are formalized. Doing so would result in much detail and administrative work and this is estimated to be a few hours a week, so €400,-, a week. Nijmegen Goffert says that this could be combined in the monthly formal reports or in the frequent informal conversations, which would be better for the collaboration.
The final projects costs will be smaller due to the fact that changes will less interrupt the project process. There is a a clearer way to handle all different changes and this would result in less difficulties. However, the overhead expenses will increase much because there will be more documenting and processing of the different changes. If, as said by Nijmegen Goffert, this would lead to more e-mail conversations this would exceed its goal. However, when combining with the monthly reports this would be more efficient. This result in positive and one negative cause.

Integrity
Making a distinction between changes will result in a better scope control process. However a negative effect could be that there is a larger risk for coordination failures and errors.

Quality
Making a distinction between changes affects the quality by having less changes that are not formalized, the scope therefore will be more complete and the design more fit for purpose. This are two causes.

Planning
Processing changes differently will decrease the chance on having the two causes of delay relating to having long discussions and long waiting times, because some changes can be processed differently. It will take away the effect of having decisions of the planning of low quality.

8. EOW approval

Finally, an EOW must first be approved before put into effect. This hardly happened and resulted in a risk for Sweco. In Geldermalsen this was due to long and arduous discussions. In Hoekse Lijn they started after a while with waiting on approval because they submitted them all together at certain moments. Still they also played a game of alternating waiting and starting. Nijmegen Goffert started and dared to take the risk, based on the good collaboration and open and transparent process. Additionally, in each project the requirement specifications were not adjusted to changes.

Costs
There are no costs accompanied by this and two causes are affected. First, there is more certainty on the made costs and getting money for the work done. The risk of not getting paid is solved. Second, the final project costs will be lower because the failure costs accompanied by this will decrease. However, starting up a design again when they had to wait till they could start is a negative consequence.

Integrity
Identifying CIs will decrease the chance on having to work with an scope that is not accepted and thus the chance on having communication flaws becomes smaller. However it would result in the cause of having a large time pressure, so no causes are decreased in chance.
The effect would be that there will be more rework and re-engineering, revisions to reports and documents and loss of rhythm. It could also appear that experts are not available anymore when an EOW is approved, and this could result either in delays or having new experts working on the project unfamiliar with the scope. This are four negative effects.

Quality
The quality will not directly be affected by waiting on EOW approval, however, the integrity is negatively influenced and this can have its influence on the end quality.

Planning
Waiting on approval of an EOW before continuing causes five new causes of delay. It will result in delays in the decision making and in delays in approvals of EOWs. It can also result in limited capacity in the project team and a huge amount of time pressure. There are boundaries to a planning like milestones and practical things like decommissioning of the tracks. Therefore there will be a dilemma between choosing to wait for approval and influence the planning negatively by this, or already start working on a certain change without approval. There is also the chance of fines when not reaching certain milestones, so it could result in financial problems.
Effects are time loss, reorganization of schedule and work methods, loss of rhythm and loss of float resulting in increased sensitivity to further delays. This are four negative effects.

9.1. Conclusion

Each of the eighth factors was analyzed based on sub-research question 4: *How are the scope management approaches from theory executed in practice and is this done as intended?*. It was expected that most factors of CCM would been implemented in the case studies, as they all used SE as framework. However, it turns out that most factors aren't correctly in place in the case study projects. The intention of setting up configuration, CMP, baseline management and accurate data and clarity on versions is mostly set up, but not correctly followed throughout the project. The process of changes is followed but not complete as should. Finally there is not a CCB set up in the case study projects, there is no distinction between changes and there is no waiting on approval for each EOW. Therefore it can be said that these factors aren't as easily implemented as expected. The difficulties that were encountered are input for the further analysis

Knowing this, it becomes more important to answer sub-research question 5: *What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?*. It can be said that all factors influence the different criteria and scope creep. The investment costs are high for the CMP, identifying CIs and baseline management. The other factors are based on setting up a good basis and then maintaining the situation. Identifying CIs, setting up a CMP, having a CCB and baseline management are factors that strongly influence the integrity and quality in a positive way when followed as intended by theory. Baseline management and a CMP influence the planning strongly in a positive way. Knowing this, gives input for the further analysis.

10. Analysis Information Management

In order to conduct the research regarding the practical execution of Information management, a checklist is set up which can be found in appendix F and gives a guideline for the conducting of the research.

Information management is for this analysis divided into two different factors. These factors are both crucial parts that need to be implemented to have good information management. The factors are: (1) Information management system, (2) Check documents on accuracy, consistency and completeness.

Each factor will be analyzed individually and starts with a short summary of how the project was executed regarding information management. This is based on the thorough analysis presented in O and answers the sub-research question 4: *How are the scope management approaches from theory executed in practice and is this done as intended?*.

Then an analysis is based on how the situation would have changed if the theory behind the factor would have been followed correctly. This answers the sub-research question 5: *What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?*. This analysis is based on logical grounds and on the opinion of the project managers and lead engineers of the projects. The four criteria costs, quality, integrity and planning are used to give structure to the analysis. Each criteria is analyzed based on cause or effect that would result from or be taken away by a factor. These causes and effects are stated in appendix Q. Only the causes and effects that will change are named. The number of causes and effects that are changed are input for the analysis in chapter 13.

1. Information management

The key for information management is not just managing the documents, but also the information in those. This mindset was not followed by Sweco for the project of Geldermalsen and Nijmegen Goffert. It was organized as a rigid data structure and not in a central place. Therefore there was no establishment of relations between information in a system. Project Hoekse Lijn did establish an Information Management System (IMS) at the start of the project. For project Hoekse Lijn and Geldermalsen, the information was not always up-to-date.

An IMS is characterized by four different factors. The first one is having all data in hands. Almost all data was in hands of Sweco but it was not integrated in a structured and traceable way except for the project directory structure. This follows from the lack of a good system and the overload in information. Project changes therefore were not immediately visible. This was also the case for project Hoekse Lijn, regardless of the IMS they set up. The second one is having a system that adapts to the information needs. The structure of information did not adapt to different needs during the project for all three projects. By having a system that can easily be adapted, this could easily be improved. Third, the system must be simple and flexible. All three projects still also used the standard project directory, which is simple to use. However, it was not flexible and made the search for documents not easier. Fourth, the system must be collaboration focused, however it was not web-based or integrated with external systems like Share point. It did not provide a stable platform and did not solve the many spreadsheets used in project Nijmegen Goffert and Geldermalsen. Project Hoekse Lijn did use Share point but also used the project directory.

Costs

Investment and maintaining costs are needed for setting up an IMS. Based on comparison to other projects it can be argued that it would take an average team member to set up a system like Relatics for Geldermalsen two entire weeks and will cost €7.040,-. Sweco does have a standard lay out for the system Relatics which can be used and adapted to the project. After having the Relatics architecture, a team member must keep up the system with the project throughout the life cycle. This will take approximately one day a week and would result therefore in €704,- weekly. The IMSs were not as widely used during the project Nijmegen Goffert as now and therefore the investment would be larger. The current templates would probably take one week to set up, which would be around €4.200,-. After that around 4 hours a week would be necessary to maintain this project, so around €400,-. The system must be opened, changed, and updated for each iteration. Project Hoekse Lijn started with setting up Relatics in October 2015, this took them 23 hours of work and this cost them €2.192. After this they waited for RET to receive their Relatics environment, but they never send this to them. From January till April they spend another 135 hours into setting up Relatics and linking this to Share point. This costed them €10.564 (see I, Oracle export).
Three positive causes are found. The final projects costs will be smaller due to the fact that changes will less interrupt the project process and the failure costs will be reduced due to bad integrity processes. The overhead expenses will decrease because the IMS can easily generate needed information without much effort. There will be less room for uncertainties at the start of the project because the configuration and scope is set at the start.

Integrity

Setting up an IMS will result in information that is clear and visible and insight into the links between requirements, objects, design parts, work packages and other aspects. This results in a decrease in the chance on having eight causes: An incomplete or partial scope will earlier be insightful and can be changed, design changes will be less disruptive, communication and trace-ability will be easier, changes across many disciplines will be easier to implement and it can easy be seen who is responsible for what, the level of detail will be less disruptive, consistency that is lacking is fast found and acted upon, and the information will always be up-to-date.
Effects are that there will be less rework, reorganization of schedule and work methods will be easier, the risk for the interfaces is smaller, there will be less loss of rhythm and productivity, the risk of coordination failures will be smaller. This are six effects

Quality

Setting up a IMS will benefit both the product and process quality. It will also benefit from a better integrity of the design which will result in a design more fit for purpose. This is done by decreasing the chance on five causes. There will be a smaller chance on working with an incomplete scope, missing consistency is made insightful, there will be less rework and more room for optimization and the project team will easier be able to grasp the complexity of the project.

Planning

Having set up an IMS will decrease the chance on having three causes of time delays in the planning: Changes in the design and scope will be less disruptive, coordination and communication problems will decrease, and discussions will not take long.
Effects are that there will be less rework, loss of time, and loss of rhythm and thus less time pressure. Furthermore, the planning can better be substantiated and it will save time in the management of the scope. This are four effects.

2. Check documents on accuracy, consistency and completeness

Documents must be checked on accuracy, consistency and completeness and the project teams of all projects had a strong focus on this at the start of the project, after that, this received less focus.

Costs

The maintaining costs during project Geldermalsen where around 8 hours a month which resulted in €840,-. For Hoekse Lijn this was the job of Omexom, however they did not do this. This made the process difficult because consistency was sometimes lacking. The investment should have been made by Omexom. For Nijmegen Goffert this was not as necessary because they had set up a large part of the documents themselves. Furthermore, they sees this as controlling the control and this would be seen as a waste of time and tooling.
The final project costs will decrease because the failure costs will decrease.

Integrity

Checking documents on accuracy, consistency and completeness will decrease the chance on having two causes: Not having consistency in the products, and there will be less design errors due to working with wrong starting points.
Effects are that there will be less rework and working with wrong documents, less loss of rhythm, and a smaller risk on coordination failures and errors. This are three effects

Quality

Checking documents will benefit the product quality, by influencing two causes. The design will be more fit for purpose when working with the right starting points and by decreasing the chance on different causes. The consistency will easier be maintained and there will be less design errors.

Planning

Checking for accuracy consistency and completeness will not take away causes of delay.
The effect is less rework and and this will have as result a faster scope control process. Furthermore, the planning will be better substantiated. This are two causes.

10.1. Conclusion

The two factors were analyzed based on sub-research question 4: *How are the scope management approaches from theory executed in practice and is this done as intended?*. It was expected that an IMS would already be in place. However, even though Relatics as system is set up within Sweco, only one project used this during their project. Additionally, they did not maintain the system. Therefore it can be said that an IMS is not as widely used in projects as expected and there is still a strong focus on the standard project directories. The checking of documents on accuracy, consistency and completeness receives a large focus at the start of the project. However, there is still room for improvement during the project. The knowledge gained here, is input for the further analysis.

Knowing this, it becomes interesting to answer sub-research question 5: *What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?*. Having an IMS implemented in a project gives great value for both the integrity, quality and planning. However, large investment costs are necessary and maintaining the system requires large efforts of the project team. The checking of documents is followed by substantial lower maintaining costs and no investment costs. However, the benefits for the other criteria are lower. Knowing this gives input for the further analysis.

11. Analysis Partnering

In order to conduct the research regarding the practical execution of partnering, a checklist is set up which can be found in appendix G and gives a guideline for the conducting of the research.

Partnering remains for this analysis one factor. It does contain different crucial parts that need to be implemented to have good partnering in place, but they overlap each other too much to see them as different factors. Partnering will be analyzed and starts with a short summary of how the project was executed regarding partnering and collaboration. This is based on the thorough analysis presented in P and answers the sub-research question 4: *How are the scope management approaches from theory executed in practice and is this done as intended?*.

Then an analysis is based on how the situation would have changed if the theory behind the factor would have been followed correctly. This answers the sub-research question 5: *What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?* This analysis is based on logical grounds and on the opinion of the project managers and lead engineers of the projects. Together with them the different reasoning's are set up for the ideal situation. The four criteria costs, quality, integrity and planning are used to give structure to the analysis. Each criteria is analyzed based on cause or effect that would result or be taken away by a factor. These causes and effects are stated in appendix Q. Only the causes and effects that will change are named. The number of causes and effects that are changed are input for the analysis in chapter 13.

1. Partnering

The mindset for partnering was high for project Nijmegen Goffert. They established good collaboration, strong shared goal, a win-win situation and mutual trust. For project Hoekse Lijn this was not present. There was a sharing of resources and wanting to successfully end the project, but there was no strong collaboration or trust. Project Geldermalsen collaborated but also had many long discussions. In each projects there was cognition based trust in sharing knowledge and resources.

Adequate resources were established in all projects just as support from top management and there was an intention for long term commitment. Effective communication and efficient coordination was in all projects written down in a plan together with made agreements. However in project Hoekse Lijn this was hard to maintain and also in project Geldermalsen there was pressure on this. None of the projects introduced practical sessions apart from a kick off session. They did established joint goals and objectives which mostly focused on successfully finishing the project. There was no economic incentive based on collaboration.

Costs

Investment and maintaining costs are found in the effort of developing a good relationship. Practical sessions can be the basis together with setting up the right mindset. Still trust must evolve during the project. For the practical sessions investments are needed in terms of time and effort to organize and follow these sessions and to jointly start the project with mutual understanding. This could be done in the setting of spending a week together with both project teams. As this is normally

also done there are no additional project costs. Effort must be put in maintaining the made agreements resulting in a few hours each month for setting up the right process, so €400,- a month. Incentives must be determined for each individual project.
Partnering influences four causes positively. First, the final project costs can decrease when the things needed for partnering are in place and effort is put into changing the mindset. Trust can eventually follow. Second, the uncertainties during the project will be smaller and the project costs will benefit from this. Third and fourth, due to collaboration and a win-win situation it will be easier to find agreement on what is seen as rational and the chance is smaller that one of the partners start seeing the project as a game with a focus on costs instead of scope and quality. Uncertainties at the start of the project could encourage this strategic behaviour but can now be suppressed.

Integrity
Having partnering will lead to a decrease of the chance on having five causes: There will be less communication flaws because the collaboration will become better and there will be mutual understandings and mutual goals to accomplish. This improves the productivity of the employees. Parties with strong opinions will need to take the other parties their opinion also in mind to have a win-win situation for all and thus they will be less disruptive. Resources are shared and plans are made for partnering and therefore bad project management of other parties can improve and will have less influence on the project process. Time pressure can still be present but will better be understood by all parties and together a solution can be found to take away the pressure.
Effect is that there will be less disputes and blame among project partners, this will also increase the morale of the work force. This are two effects.

Quality
Having partnering benefits mostly the process quality. Three causes that could lead to a less fit for purpose design are decreased in chance. Namely, there will be less room for not anticipating changes and not formalizing changes which takes away the wrong process of reacting on changes. Due to the win-win mindset there will be a focus of all parties on optimizing the design. Due to the practical sessions and audits there will be room for optimization.

Planning
Having a mindset for partnering will decrease the change on having three causes of delay: communication and coordination problems, delays in the decision making, and discussions that are arduous.
It will decrease the amount of loss of rhythm and will have as result a faster scope control process and less time pressure where parties better understand each others decisions. Decisions based on the planning are better understandable for each party. This are three effects.

11.1. Conclusion

Partnering was analyzed based on sub-research question 4: *How are the scope management approaches from theory executed in practice and is this done as intended?*. It was expected that partnering is easy to implement, but it turned out that in the three projects, different degrees of partnering were found. This shows that it isn't as easy as expected to include a partnering mindset in a project. Knowing which difficulties they encountered are input for the further analysis.

Interesting is having an answer on sub-research question 5: *What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?*. Partnering mostly takes time and effort of both partners to implement. It has a positive result on all four criteria in terms of decreasing the chance on having certain causes or negative effects related to scope creep. This gives input for the further analysis.

Part D - Results

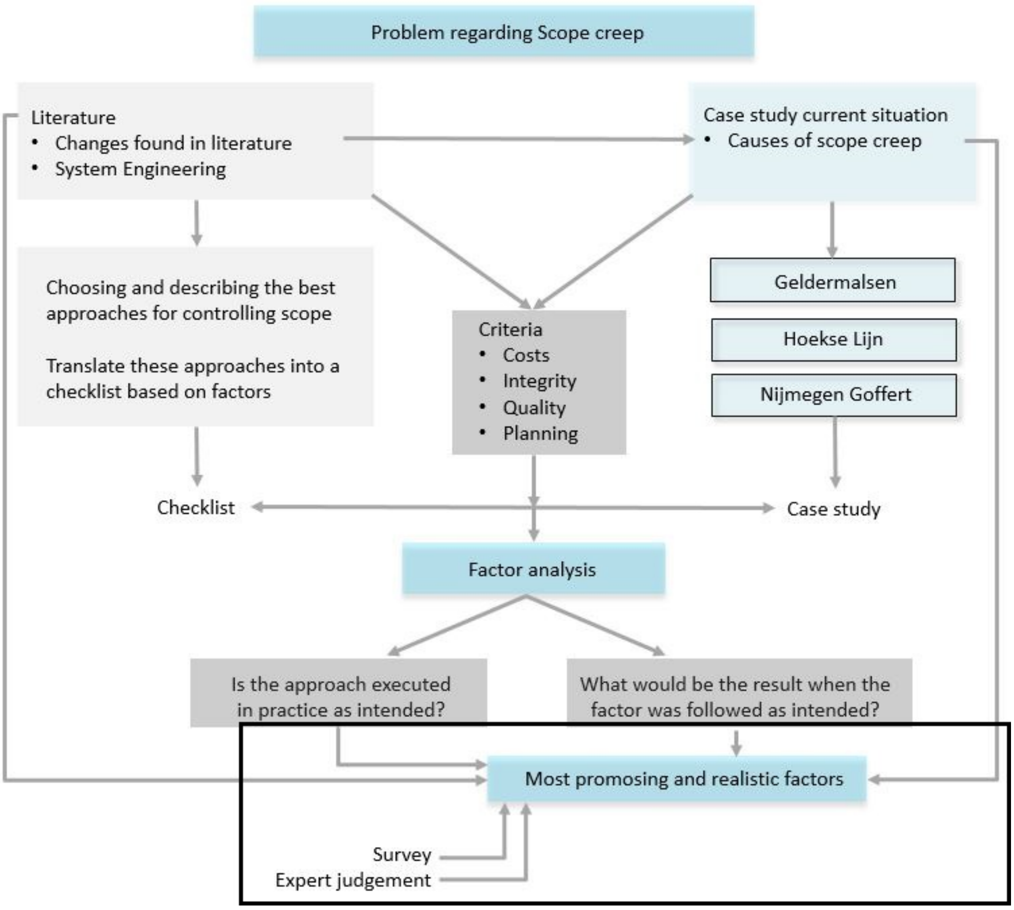
The chapters of this part:

12. Factors with high potential
13. Validating the realistic character of the factors

Research question that will be answered:

Sub-research question 6: *Which parts of the approaches are best to anticipate scope creep, considering both literature and practice?*

Sub-research question 7: *Can the parts based on theory be implemented realistically in practice?*



12. Factors with high potential

This chapter focuses on answering the sub-research question 6: *Which parts of the approaches are best to anticipate scope creep, considering both literature and practice?*. The answering of this question is based on the analysis done in the chapters 9, 10 and 11. In this analysis it is argued what the result would be if the three approaches would have been followed correctly as stated by theory. This was based on four criteria; costs, integrity, quality and planning, introduced in appendix Q.

The highly potential factors follow from comparing the eleven factors to each other, which is done in appendix Q. For each criteria the most promising factors can be derived which are:

- Costs: EOW approval, Partnering and Check on accuracy, consistency and completeness
- Integrity: Information management system, Configuration Control Board and Identifying Configuration Items
- Quality: Baselines, Configuration Control Board and Establishing the configuration and the Configuration Management Plan
- Planning: Baselines, Information management system, Partnering

The four criteria can be prioritized for the client and the engineering company. Both parties are important to consider for finding the highly potential factor for the control of scope and anticipating scope creep. Prioritizing criteria results in the most realistic factors for both parties. Combining these factors for both parties on its turn result in the most realistic and optimal factors to implement in a project, while taking both client and engineering company into consideration.

It is argued in appendix Q that the prioritizing of criteria for the engineering company results in the costs as most important criteria, followed by the integrity, the quality and finally the planning. This results in having the CCB as the most important factor, followed by an information management system, and finally partnering, see figure Q.7 in appendix Q.

For the client it is argued that the end quality of the product is the most important criteria, followed by the costs, the planning and the integrity, explained in appendix Q. This results in having the CCB as most important factor, followed by establishing baselines, and finally by having an information management system, see figure Q.8 in appendix Q.

Combining the best factors for both parties results in highly potential factors, see figure Q.9 appendix Q. Figure 12.1 shows from the left to the right the most promising factors to anticipate scope creep. They will be introduced in the next sections based on earlier mentioned literature, this to show the theoretical content of each

Figure 12.1.: Most important factors from the left to the right

12.0.1. Configuration Control Board

INCOSE recommend to establish a Configuration Control Board (CCB). This must represent all stakeholders and engineering disciplines that participate on the project. Change is inevitable and managing the impact of change on a project is needed. The CCB must check whether the change is necessary, and if the most cost-effective recommendation has been proposed (Haskins, 2010). The CCB is thus charged with the responsibility to manage the changes that come up during the process. The reason for changes varies, ranging from a change to one of the user requirements, to a change in available technology. They CCB investigate the change and decide how big the change is (Faulconbridge & Ryan, 2014). It is important also to ask: "What is the impact of not making the change?". This becomes more important later on in the process because changes made later in the life cycle have an increasing risk of hidden impacts which can have negative consequences for the system cost, schedule, and technical performance of the system (Haskins, 2010).

The CCB should meet regularly to review the process of the changes that are in progress or are proposed. Any party involved can request a change, including the client. These requests must contain sufficient information to decide if the change can be approved. It must show how it impacts the system, especially the impact on other CIs in the design and on the interfaces requirements as described in the baseline documentation. To see the impact, trace-ability across the different levels of design is necessary. Sometimes teams focusing on the interfaces are organized so that they are handled correctly and completely. Sometimes it becomes clear that specifications do not comply with the configuration baseline. These non-conformance's could be accepted by the client without going through the change process. These special cases are called a CR (Faulconbridge & Ryan, 2014). CRs are typically initiated as a result of an investigative analysis triggered by a problem report. CRs are reviewed and approved, rejected, or placed on hold by the CCB. They are normally tracked to completion (Haskins, 2010).

12.0.2. Information management system

Information management must focus on managing all information instead of only the documents and provides opportunities to manage the information according to SE. Information is not stored in a rigid data structure, but as a collection of relationships. The relationships can occur between parts, requirements, tests and responsibilities. An information management tool must be a database which makes it possible to capture, manage and unlock information in an unambiguous and consistent way. All information relevant to a part can be explored by following the relations. This results in no seek time, no mistakes and no surprises (Relatics, 2017).

A tool for information management would be based on four aspects:

1. All data in hands
   It must enable to store all kind of project information and integrate the information in a structured and traceable way. Project changes and requirements are then directly visible, which saves time and ensures that the process is less sensitive to failure.
2. Adapts to information needs
   There must be a flexible architecture that can be tailored in such a way that it fits to the needs of a certain project. The end user has control over the information needs. Simultaneously with working on the project, information can be changed or enriched which makes the information up-to-date.

3. Simple and intuitive
   It must be a simple system what makes it easier to work with and therefore decreases the risk of mistakes. It increases the control of a project and gives more security.
4. Collaboration focused
   The tool increases the collaboration between the project members, by the fact that it can be web based, always accessible from multiple locations and devices, and providing a stable platform. It then frees the project of numerous spreadsheets and individual applications. The collaboration focus is even larger when it is integrated to external systems that are often used, like Sharepoint.

An information management tool would result in organized information in a explicit, coherent network of requirements, design components, functions and other information. Information can be looked at from all possible perspectives, this due to the fact that there is comprehensive traceability. Information can be checked that ensure that the information is always accurate, complete and consistent and this generates high quality deliverable.

12.0.3. Partnering

The construction industry is a very competitive high-risk business and faces many problems which results in adversarial relationships resulting in project delays, difficulty in resolving claims, cost overruns, litigation, and a win-lose climate (Chan, Chan et al., 2004). The main reason for the introduction of partnering is the need to move away from the traditional adversarial relationships (Black et al., 2000).

There must be a change in how projects are managed next to a change in attitude. Instead of treating each other as opponent where the loss of the one is the gain of the other, the parties must work as teammates sharing a common goal. The adversarial relationships must be replaced by open communication, timely decisions, synergy, joint problem solving, and win-win situations. Teamwork, collaboration, trust, openness and mutual respect are important for this (E. Larson, 1995). Partnering can be established by considering nine factors (Chan, Chan et al., 2004):

- **Establishment and Communication of Conflict Resolution Strategy**
  A control and resolution mechanism and strategy must be developed to deal with problems and conflicts. Joint problem solving can help for problematic issues.
- **Commitment to Win-Win Attitude**
  Win-win thinking is essential and equity is important for this. Win-win thinking also means having open airing of problems and a non-defensive manner during arguments. Teams must work cooperatively for finding the causes of problems and their solutions rather than working out the costs of variation. Solutions are worked out by brainstorming and are put into action quickly. There is a sharing of risks, rewards and sharing of ideas.
- **Regular Monitoring of Partnering Process**
  Monitoring methods include the evaluation of team performance, well-defined roles and responsibilities, and determining measurable goals of individual responsibilities. The joint evaluation is an outcome of partnering workshops. Measurable goals should help determining and evaluating individual progress performance.
- **Clear Definition of Responsibilities**
  The parties should develop aligned relationships to support the objectives and they should understand other parties' missions and how this relates to their job. Each team-member could make decisions alone because of clear identification of responsibility and accountability. Furthermore, the extent of decision-making and authority must be known.
- **Mutual Trust**
  Each party should trust, rely on, and understand other parties' decisions.

- **Willingness to Eliminate Non-value Added Activities**
  There must be a willingness to improve processes, reduce duplication, and eliminate barriers.
- **Early Implementation of Partnering Process**
  Multi-project agreements and a list of partner-selection criteria should be developed and started at the design stage.
- **Willingness to Share Resources among Project Participants**
  There must be a willingness to share resources. The sharing can benefit overall organizational goals. A task force can be set up to work closely, using all possible resources available.

Adequate resources that are commonly shared, support from top management, a long-term commitment and a continuous search for improvements are essential to implement these nine factors (Chan, Chan et al., 2004). Furthermore, team building processes and project-wide communication in the early phases of a project influence the behaviour and knowledge of team members. In this way trust-based collaboration is more likely to arise and persist (Kadefors, 2004). So, partnering and trust requires timely, open and direct communication of information. The exchange of ideas, visions, and the overcoming of difficulties will become easier (Chan, Chan et al., 2004).

12.0.4. Baseline Management

Fundamental to ensure effective management of the scope is the establishment, control, and maintenance of baselines (Haskins, 2010). The baseline gives the formal frozen status of a system. It results in a complete system documentation at a certain time, determined by the parties involved (Werkgroep Leidraad, 2013).

Baselines are established by review and acceptance of requirements, design, and product specification documents. The creation of a baseline may coincide with a project milestone (Haskins, 2010). When the contract definition is done, the first baseline arises (ProRail, 2015). The freezing of the configuration should be the baseline of the system development and CRS. Some documents, like the planning, keep developing next to the baseline (Werkgroep Leidraad, 2013).

Each baseline is placed under configuration control. When changes occur, it can only change the baseline through a documented change management process (Faulconbridge & Ryan, 2014). A baseline supports decision making and comes with certain result-obligation and acceptance criteria (Werkgroep Leidraad, 2013). A baseline thus must be accompanied by performance requirements and acceptance criteria. In complex projects an iterative process repeats itself on multiple detail levels. This leads to a new specification of the system on each level and therefore a new baseline must be established each time to hold gain on each iteration of design (Werkgroep Leidraad, 2013).

12.1. Conclusion

This chapter gives answer to sub-research question 6: *Which parts of the approaches are best to anticipate scope creep, considering both literature and practice?* The paired comparison based on the four criteria cost, integrity, quality and planning gave the parts of the three scope management approaches that were most promising to anticipate to scope creep. These were a Configuration Control Board, implementing an information management system, partnering and baseline management. The IMS and baseline management requires a large investment. Still they are part of the four most optimal factors and therefore it can be said that they add much positive value for the other three criteria. All four must be seen as adding value to the anticipation of scope creep. However, it must be checked whether these factors are realistic and therefore are validated in the next chapter.

13. Validating the realistic character of the factors

In this chapter it is analyzed if the factors that were seen as most potential in chapter 12 are also validated to be the most optimal ones and if they can be realistically introduced in practice. This chapter answers the sub-research question 7: *Can the parts based on theory be implemented realistically in practice?* This question is answered in five different steps, which are:

1. First the factors are again related to the case study analysis. During the analysis some interesting points were raised considering the factors. This is discussed in 13.1;
2. Second the factors are related to the seven scope creep causes found in the case studies. It is analyzed how many of these causes that are found in practice, they could have solved when implemented. It is also analyzed if the factors could be combined. This is discussed in 13.2;
3. Third the factors are analyzed by the use of a survey. This survey shows how many projects used the factors and if the participants would find them realistic to implement and if they think the factor could be of value for keeping control of the scope. The survey also gave room for explanations which are also shown. This is discussed in 13.3;
4. Fourth two experts from the work-field are asked to give their opinion on the four factors and if they would see them realistically being implemented in projects. This is discussed in 13.4;
5. Finally the factors are related to literature in a further extend than in chapter 12 to give the factors more guidance for implementation and see if literature also state the factors as realistic. This is discussed in 13.5.

13.1. Relating the case study to the four factors

The four factors are related to the analysis of the case study. This analysis is discussed in appendix N, O, P. The points raised during the analysis considering the four factors are stated in this section. These points give substance to the realistic character of each factor and focuses with that on the research question. No conclusion is given, only the explanations below.

13.1.1. Configuration Control Board

ProRail and Sweco did not set up a CCB for the project of both Geldermalsen and Nijmegen Goffert. There was a relation between Sweco and ProRail were ProRail reviewed and accepted changes that Sweco suggested. In project Hoekse Lijn there was also no CCB set up. Sweco delivered the EOWs to Omexom and Omexom on its turn to RET. RET reviewed and accepted changes together with Omexom.

It can be suggested that a CCB was not set up due to the standardized procedure that ProRail sets up in every project. Wanting to change this, would require a change in mindset. It could be argued that maybe the client wants to keep control of the scope themselves and therefore are not willing to change their mindset.

13.1.2. Information management system

Information management focuses on managing the information instead of only the documents. This mindset is not yet established in projects. Hoekse Lijn did have a tool for information management but stopped with updating it.

It is needed to focus on having relevant and up-to-date and accurate information instantly and always available for the project members. In project Geldermalsen not all documents were always up-to-date and the version numbers of documents weren't centrally managed just as in Nijmegen Goffert. The work attitude of the employees is also part of this shortcoming. The basis must be laid out correctly but the team members must also put effort in keeping up with the agreed structure. Hoekse Lijn did set this up at the start of the project but afterwards not maintained due to the bad document control of Omexom and Sweco. Keeping up-to-date became hard due to the late reviews and reviews on old versions.

Implementing a tool can easily make information management possible. This tool would be a program like Relatics and is based on four different aspects. The first aspect is having all data in hands. Structuring data is a difficult process due to the large amounts of information and for example late reviews. A problem is that projects still think in the project directory structure. Another approach would be needed to get all data in hands. For example meta data can be linked to information packages and relations between this must be established. Then it does not matter in which folder the information stands, it only matters that the information is accessible.

The second aspect is having a system that adapts to the information needs which was not done. Data was stored in the project directory resulting in many folders without documents. The third aspect is having a simple, intuitive, flexible and scale-able system. The project directory was simple in use but not necessarily flexible. Hoekse Lijn used Relatics, the project directory and Share Point. Individually they were simple in use, but combined not. The fourth factor is that a system must be collaboration focused. The project directory is stable but not a platform. The system was always accessible on the laptop having a Sweco network. The information was not integrated into an external system.

13.1.3. Partnering

Some aspects were easily introduced: Clearly stating responsibilities, a conflict resolution strategy, ensuring the highest standard for project management, willingness to reduce duplication, solving problems together, and willingness to share resources.

Clear commitment to a win-win attitude is a hard thing to establish turns out. Only Nijmegen Goffert had this because they had a strong shared goal of wanting to have a successful project because it was a pilot project. Discussions tend to disturb this relation just as a defensive manner of having arguments. Seeing team members as equal could also be related to the win-win attitude because Hoekse Lijn did not have this and had a bad situation. Generating innovative ideas could be related, because in project Geldermalsen this was hard due to time pressure and in project Hoekse Lijn there was a strong focus on solving mistakes and inconsistencies. Effective communication was written down in a plan, however it turned out hard to always maintain this.

There was no mutual trust in project Geldermalsen and Hoekse Lijn. There was respect and understanding but the business attitude disturbed the relation. Nijmegen Goffert was characterized by great mutual trust. Even though products were not always delivered on time, they communicated clearly on this and this established trust. The early implementation of the partnering process in an earlier phase made the trust even bigger.

13.1.4. Baseline management

All projects did not formally set up baseline management. However, this depends on what is seen as a baseline. It could be argued that the tender dossier and the CRS at the start of the project Geldermalsen could be the first baseline. FIS 1.0, FIS 2.0 and the RVTO could be the others baseline. This can also be argued for Nijmegen Goffert. They did not maintain a documented baseline, but the 3D model they build could be seen as a place where all changes were implemented and iterations could be found.

Establishing a new baseline after each iteration is not seen as a realistic. It is important to consider the dilemma between the addition it will bring and the time it will cost. Baselines can be stated at small detail level, after each review, or even more often, so the question is what is seen as a moment for the establishment of a new baseline?

There is no clear guideline on when to establish a new baseline. Figure 13.1 shows the discussion that can follow where the time-line of a certain design aspect is shown together with a scope change at a certain time. After a change, the client prefers option 1 where the scope change is immediately implemented, however the engineers prefers option 2. They would rather finish the design work they started and then implement the change in all the different work packages and designs at the same time. This discussion is dependent on the project, the impact of the change and the number of work packages its influences. The situations get more complicated when considering that scope changes cause re-engineering. Therefore option 3 is more realistic to happen. Faulconbridge and Ryan (2014) state that even though there may be pressure to meet progress and schedule targets, it is better to stop work and go back in the process and get it right before continuing. Succumbing to the pressure to continue is rarely in the interest of the project.

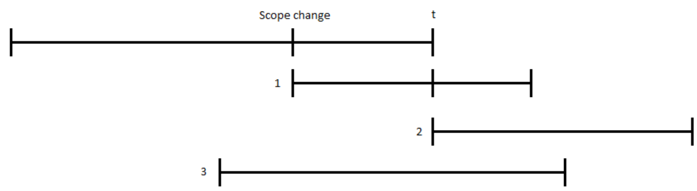


Figure 13.1.: When to implement a baseline

When changes occur, it can only change the baseline through a documented change management process. This was for all three projects not done for the purpose of changing the baseline, but it was done for the purpose of remaining control on the scope and the budget. Furthermore, not all changes were followed by a formal process and there were many ad hoc changes. Small changes and other changes that seemed to have small impact were almost never submitted. This would harm the up-to-date character of the baseline but especially can cause scope creep. Nijmegen Goffert did had one EOW reserved as a place to put changes with a small financial consequence. This process was based on trust and decreased the overhead expenses coming with an EOW.

The project manager of Hoekse Lijn saw changes as only related to a contract where any additional work outside of the scope is reason to receive money. This resulted in not capturing small changes, because a change to a requirement not always results in financial consequences. However, the impact on other aspects are not made insightful and harms the integrity and end quality.

In the formal document certain points must be included. For example an impact analysis must be done, which was mostly not done. Also the interfaces are sometimes named in general but never in detail. This could be a reason for mistakes and thus could cause scope creep.

13.2. Comparing the factors to scope creep reasons

The different factors were analyzed in chapter 9, 10, and 11 to see how they would improve the current situation when followed as intended. This was done based on the four criteria costs, integrity, quality and planning which contained causes and effects related to both the criteria and to scope creep. These causes and effects followed from the literature and case study on scope creep. Priority related to how often they occur in practice was not taken into account.

The four factors will be validated in relation to the scope creep causes find in practice and the frequency they occurred as stated in 8.4. The frequency is related to the three different case studies. Table 13.1 shows the relation between the four factors with high potential and the seven clusters of scope creep. CCB stands for Configuration Control Board, BM for Baseline Management, and IMS for Information Management System. It is shown by an X if the approach could help anticipating the stated cause of scope creep as stated in chapter 9, 10, and 11. The assumption is made here that the different factors can be analyzed independently. Furthermore, it is assumed that they do not contradict each other.

Table 13.1.: Comparing the factors to reasons of scope creep and their frequency

Scope Creep	Frequency	**CCB**	**BM**	**Partnering**	**IMS**
Start of the project					
Wrong interpretations	Occasionally	X	X	X	X
Moving scope while tendered as fixed scope	Frequently	-	-	-	-
Tendered with missing input	Frequently	-	X	-	X
Rationality	Occasionally	-	-	X	-
Complexity	Occasionally	-	X	-	X
Process of an EOW					
High costs involved	Frequently	X	-	-	X
Discussions take long and are arduous	Occasionally	X	X	X	X
Long waiting times	Occasionally	-	-	X	-
Starting before an official approval	Occasionally	-	-	-	-
Time pressure	Frequently	-	X	X	X
Scope management process					
Not formalizing changes	Occasionally	X	-	X	-
Consistency	Never	-	-	-	X
Too much detail	Occasionally	-	X	-	X
Changes till the last moment	Frequently	-	-	-	-
Not anticipating changes	Occasionally	X	X	X	-
Wrong process of reacting on reviews and changes	Occasionally	X	-	X	X
Team composition					
Wrong people on the wrong spot	Never	-	-	-	-
Not enough capacity	Never	-	-	-	-
Project is not correctly managed at the other stakeholders	Occasionally	X	-	X	-
Missing links	Occasionally	X	X	X	X
Parties involved with strong opinions	Frequently	X	-	X	-
Working too good	Frequently	-	-	-	-
Process of the project					

Reviews that take too long	Occasionally	-	-	X	-
Reviews without integrity	Never	-	-	-	-
Setting up products in a wrong order	Occasionally	-	-	-	-
Many disciplines at one place	Frequently	-	-	-	X
Game-like interaction	Occasionally	-	-	X	-
Human Factors	Frequently	X	X	X	X

The different factors all address to some of the scope creep causes. The number of causes they influence are shown in table 13.2 which shows the relation between the frequency and factor. The numbers in the first column are based on counting the number of scope creep causes it influences.

There are still three causes that occur frequently in table 13.1 but are not influenced by one of the four cases. These are having a moving scope while tendered as fixed scope, changes till the last moment and having a team that wants to work too good. Furthermore, the two causes that occur occasionally are setting up products in the wrong order and starting before having an official approval. There must be special attention given to these factors in any project.

Approach	**Number**	**Frequently**	**Occasionally**	**Never**
Total causes	*28*	*9*	*15*	*4*
Configuration Control Board	11	4	7	0
Baseline management	9	3	6	0
Partnering	14	3	11	0
Information management system	12	5	6	1
Implementing all factors	*20*	*6*	*13*	*1*
Not covered causes	*8*	*3*	*2*	*3*

Table 13.2.: Result of the comparison between scope creep frequency and factors

As shown in table 13.2, having partnering would be most effective looking at the number of causes it influences. When taking into account the frequency it influences only three causes that appear frequently in the case studies. This factor therefore seems effective. However, an IMS influences less causes with more frequent causes. Establishing a CCB, and baseline management are less effective. Together the four factors are very effective.

Sub-research question 6 answers whether or not the project used the factors as intended by literature. It can be stated that a CCB was in none of the projects implemented, just as good baseline management or a good IMS. Therefore there follows no results from comparing these two factors to the case studies. Partnering was implemented successfully in project Nijmegen Goffert and of the 14 scope creep reasons it could solve, see table 13.2, 7 did indeed not appear in these projects. Five factors appeared occasionally, namely rationality, time pressure, not formalizing changes, not anticipating changes, and missing links. Two factors appeared frequently, namely human factors and parties involved with strong opinions, see table 8.2.

The before mentioned factors need to receive special attention when implementing partnering. What can be reasoned here is not formalizing changes and not anticipating changes are related to setting up a good scope management system. Partnering does not focus on this and only lessens the effects. Therefore it could be argued that partnering must be combined with a factor focusing on solving these causes. Both can be solved by having a CCB, as seen in table 13.1.

Rationality, time pressure, human factors, missing links and parties involved with strong opinions can be seen as causes that are hard to solve because they are due to the fact that projects are executed by humans with their own characteristics. Only the effects can be lessened and it could help to have a mindset for partnering combined to the other factors.

Table 13.3 looks at combining factors. The table shows the results from most effective to less effective for first 2 factors combined and then three factors combined.

Combination	Number	Frequently	Occasionally	Never
Partnering - IMS	20	6	13	1
Partnering - BM	17	4	13	0
CCB - IMS	16	6	9	1
CCB - Partnering	15	4	11	0
CCB - BM	14	5	9	0
BM - IMS	13	5	7	1
CCB - Partnering - IMS	20	6	13	1
BM - Partnering - IMS	20	6	13	1
CCB - BM - Partnering	18	5	13	0
CCB - BM - IMS	17	6	10	1

Table 13.3.: Result of the combining of factors in terms of scope creep frequency and factor

When looking at combinations, combining partnering and an IMS is the best option followed by combining partnering with baselines. It is assumed that the four factors do not contradict each other, so combining factors is seen as possibility. When combining three factors, then is combining CCB, partnering and an IMS the most optimal decision together with combining baseline management with partnering and an IMS. From this it follows that all factors are effective but partnering and an IMS would be the most effective to implement.

13.3. Survey

A survey was taken across employees of multiple departments within Sweco. The survey results are shown in detail in appendix R. For the survey the participants had to choose a project that was leading for the questions. It was asked whether the four factors were used during the project. In total there were 28 respondents from four different departments.

1. 76% of the projects had a CCB during their project (figure R.1)
2. 55% of the projects had an information management system of which 87% maintained this system (figure R.4)
   76% of the projects had a document structure set up and stored in the project directory
3. 49% of the projects introduced partnering (figure R.7)
   70% of the projects had a focus on cooperation during the project, 52% had a win-win situation with equal partners and on average between 1 and 5 there was 3.52 trust with a standard deviation of 0.972
4. 61% of the projects had baseline management
   49% of the projects had intermediate baselines during the design process (figure R.11)

Additionally, the participants had to score how much value they saw in each factor and if they would see it as realistic to implement. This was based on a five point Likert scale where number 1 says no value/not realistic and 5 says much value for keeping control of the scope/highly realistic to implement. The means and standard deviations are shown in table 13.4. The standard deviation gives the division of results, where 68.3% of the results are between 1 standard deviation above and below the mean. A smaller standard deviation means a more strongly focused result.

Aspect	**Mean**	**Standard deviation**
Value of a CCB	3.52	1.149
Realistic character of a CCB	3.12	0.960
Value of an IMS	4.36	0.822
Realistic character of an IMS	4.06	1.059
Value of partnering	4.12	0.696
Realistic character of partnering	3.39	0.899
Value of baseline management	4.12	0.740
Realistic character of baseline management	3.85	0.939

Table 13.4.: Descriptive statistics

Looking at the value of the different factors, the IMS has the highest mean with a standard deviation of 0.822 which means that 68.3% is between the boundaries of 3.54 and 5. This shows that the high value of this system is widely supported among the participants. The CCB had the lowest mean with 3.52 and has a higher standard deviation, resulting in a range between 2.37 and 4.67. This shows that there is more division in the opinion on the value of having a CCB for scope management.

Looking at the realistic character, it is shown that for all four factors, the value is higher rated than the corresponding realistic character. This shows that all factors are open for improvement in becoming more realistic so it can bring high value for scope management. Again the IMS has the highest mean and shows that most participants feel that implementing this system is realistic. Implementing a CCB is seen as the least realistic. However, when relating this to the actual percentages of projects where it was introduced, this is not in line. With 76% a CCB is implemented the most often of all factors. This would suggest that it is easier to implement, but not to correctly implement as stated by theory. Probably it is implemented in a different form with the same focus points.

The IMS is seen as most realistic factor and as bringing the highest value for scope management. This is followed by baseline management, partnering and finally a CCB. The participants had the opportunity to give some explanation to their answers and these are stated in the following four sections. This is divided into the benefits and improvements and further explains the given scores. The detailed descriptions are given in appendix R.

Statements on having a CCB

Benefits
It would keep the project manageable, ensures clear scope management, it makes clear what the consequences could be of a relatively small change, and it can prevent many discussions during the project. It is good tool to communicate transparently.

Improvements
Setting up a CCB was mostly questioned for small projects as keeping track of changes would take more time than it would deliver, and would result in an overkill. Furthermore, the effect is not visible on the short term and "prevention is better than curing" is not generally recognized.

The client must be convinced for this to work, however he often does not understand that "small" changes can have a large impact. The project and/or the client often gives insufficient room and time to make a thorough assessment and impact determination. The problem is that the discussed changes must often be implemented in the short term. Waiting until the CCB comes together would take too long. Time pressure and available capacity keep this only something to aim at.

Some don't see how this would be implemented or that it depends on the nature and scope of the project. Some say that a CCB already happen in projects but under a different name. It is part of every team consultation where both technical and financial aspects are discussed. It is also seen as contract management where currently technical management is insufficiently taken into account. It could also be the function of the project manager and lead engineer.

Statements on having an information management system

Benefits
An IMS contributes to good information provision, fast retrieval of documents, it keeps track of the integrity between disciplines, makes the monitoring of scope easier and it forces a project team to work more explicit. There are benefits in organizing things properly at the front, to ensure that things are not forgotten and prevent failure. Setting up the environment takes time, but is an investment that pays out later.

Improvements
Sweco has been talking about this for a long time, but there is a lack of people who control the implementation of the system and employees who are not able to handle the system properly. Part of improvement is taking away the ignorance of employees with the system. Furthermore, maintaining and using it properly is a challenge because it is forgotten in the issues of the day.

Mostly it is said that it would be an overkill for small projects, the effort to set up and maintain the system would be too much. It takes time, which is not always considered to be earned back. Some see setting up a simple but effective system in Excel as much easier to adjust if necessary and easier to use for employees. In line with this is that the basis of an IMS works very well, but some think that not all things can be properly arranged in these systems. In addition, the system that is applied must be project-wide applied to add value.

Statements on partnering

Benefits
Good collaboration and shared interests is what really matters and partnering is needed for this. It is happening more and it is paying off, both internally and between the parties. In one project partnering was realized by a follow up session with the client and two mentors, where the aspects of partnering were discussed. One thinks that an ideal win-win situation is not realistic, however a 80% win-win situation is achievable.

Improvements
Some state that successful partnering dependents on the persons working on the project. In practice a client often returns to traditional roles after much is described on paper about cooperation. However, partnering must come from both sides and if one of the parties does not fully commit, it is doomed to fail. But not all parties are ready or open to this change in mindset. Furthermore, it is stated that the view on added value is missing.

Some projects start with trust and a striving for cooperation, but this changed during the project due to mutual failure, not meeting obligations, lack of clarity regarding scope, goals and finance, and a client who does not have clear understanding of the interpretation of requirements.

Partnering requires good agreements in advance so that the expectations are fully transparent. It is essential to discuss with the client at the start of the project and attach a fixed agenda and frequency to partnering activities. However, the organization comes with the necessary costs and for smaller projects participants wonders if partnering is of added value over working together.

Statements on baseline management

Benefits
Baseline management it seen as crucial for the manageability of the project and the control of the scope and it should be the basis of every project. The design becomes manageable and it keeps decisions with their related deadlines clear. It is the basis for structured collaboration and it is important when there are changes in the starting points during a project. CRSs are often not or incompletely provided and are also often subject to changes during the design process. Baseline management could frame this, but also reveals who is the cause of the changes. There must be time and capacity available but it is a good to reflect on a project and its requirements before you begin.

Improvements
Some participants questioned the use of baseline management. They stated that it is unrealistic for small projects, but it could be wise for larger projects. Someone noticed that the client does not understand baseline management and its importance, which makes it unrealistic to implement. Often a baseline in the form of a CRS is present.

Good baseline management is dependent on the people who work on the project. The benefits are seen, but not how to implement this in practice. This follows from the fact they notice that it is not a standard way of working by the client. To work with baselines, strict agreements must be made on how to guarantee integrity at the various levels. It would become more realistic if a separate official can be appointed for this.

13.4. Expert Judgments

Two experts were questioned about the different factors and how realistically they would see them to be implemented. One project manager was asked because he is the one in a project that can choose to focus on the factors. One engineer was questioned because he has to work with the scope but does not have much influence on the process. They critically looked at the factors being realistic or not.

Configuration Control Board

The project manager stated that a CCB will probably not work when it is seen as a stand-alone thing, because it would be an overkill. He recommends it to become integrated with the progress consultations where changes must become a more important part of the agenda. Currently the financial status of the project and possible EOWs are just reported to the client. It is often said that the EOW must be sent to the client so they can look at it. However, during the meeting attention could be given to these changes. During these meetings the project manager of both the client and the contractor must be present, just as the lead engineer, the Rail System Engineer (RSE) or construction manager and the project coordinator. Often it happens that the project manager and the contract manager are the same person within Sweco, where for example for ProRail this is split, this is something to look at for Sweco. The technical divisions do not have to take part of this meetings, the lead engineer can be seen as the first filter who can indicate when an expert is necessary to join.

The engineer is also skeptical about the CCB but for different reasons. He thinks that the different disciplines are working too autonomous and that thinking integral thinking is missing too often. This could be improved, however time pressure makes this harder to reach. A CCB could thus work when sessions and working integral is planned. However, he thinks that interface-sessions give more benefits. Each design phase should be accompanied by a sessions where it is mandatory to come. This must be combined with review sessions where each discipline must reach even though his discipline is not connected. This would be an intern process before going to the client.

Information management system

The project managers states at first that it is crucial to not see an IMS as extra to a project. When seen as extra, it is often seen as to expensive. They must see it as an essential part of the project.

IMSs are used more often. However, the system only has a limited benefit when for example the client changes their CRS at the end of a project. The client can be the limiting factor for the success of such a system, but also the employees can be restrictive. Many employees do not know how to work with a system like Relatics. It happens often that only one person knows the system and that he translates everything to Relatics during the project, while the others work with excel. Instead the system must become part of the project process and integrated with certain processes. For example, The validation moments are now separated from the system, resulting in additional work when the system must be kept up to date. Also the engineer states that the success is related to who controls the system. One person must be assigned with the task of maintaining the system and put all relevant documents in the system. He must receive all documents then to do this. Now documents are circulating on the mail, without a place where they are clustered.

The project manager also states that the tendency is that employees base the covering of requirements to design parts on their expertise and experience. The failure costs due to this are not insightful and are only shown when a new version of the design must be handed in. They see a system as an extra investment of which they do not see yet which failure costs will be reduced.

Finally, it could be useful to have a system that is related to responsibilities. It could also be related to rights were some can edit a document and some can only read it. Additionally, it is said that the project directory is open for many improvements. For example, it is not clear where the most recent versions of documents are to be found. Also the engineer states that a system can support a project, even though it will not take scope creep away in his opinion. He states that the system must be implemented on a large scale to take away the chaos currently found related to trace-ability of documents.

Partnering

The project manager does not sees how this would be implemented, but does see the benefits. He especially believes in having teams match up in terms of personality and character. A project where team members do not feel comfortable around each other will face a difficult process of cooperation, while it is important to consider that cooperation makes a project reach a more successful result. However, contract, requirements, money and different interests make that the cooperation is under pressure. When the budget is already very low at the start of the project, you know that there will be a fight contract with two parties with a strong focus on the requirements. Therefore partnering is harmed by project characteristics.

Practical sessions could help in setting up partnering. The problem is that it is hard to establish without having members feel it as forced. Still there must be put more effort in team building than is done currently. Furthermore, it must be considered how parties could be transparent about their different interests.

There is increasing attention to partnering in the market and the contract forms are changing together with this motion. However, it must also be recognized that sometimes relations are nothing more than business relations and cooperation is not always as essential as is thought. Therefore this depends on the type of project. Also the engineer recognizes the increasing attention to partnering. The client and the contractor are more often meeting to discuss the project and to align the design with their needs. However, when there is a tendency of playing a game around money, they must also recognize this has impact on the project.

Baseline management

The project manager thinks that baseline management is related closely to establishing a CCB. The baseline is the input for these meetings. The question however remains, who will be responsible for maintaining the baselines and when will a baseline be implemented? The design will not be paused till the new baseline is set up. Therefore the project manager sees it in a different way. A few months after the latest baseline they have to look at the current state of the project and if the product still matches the requirements. The baseline and the design must be updated so both match each other and the requirements again, the verification and validation is checked and the planning is updated.

The engineer states that the first baseline always contains the starting points of the project. During the project this is sharpened. The baseline could be divided among different design parts, however this is dependent on the type of project. Often they deliver the entire design in once, so then dividing the baseline would not work.

13.5. Using literature to see if the factors are realistic

Chapter 12 gave insight into the literature that was used to set up the factors during this research. The factors however can be researched in the literature on their realistic character. Furthermore, the knowledge on the factors can be extended by giving it more practical interpretation. This can help making the factors easier to implement.

13.5.1. Configuration Control Board

The CCB is in theory seen as a realistic factor to implement. It thus a group of project stakeholders responsible for evaluating and approving proposed changes, prioritizing the incorporation of approved changes, and scheduling the changes for forthcoming releases. In some projects they may also be responsible for verifying that approved changes are implemented. Everything that is included in their role is shown in figure 13.2. The CCB has two main responsibilities according to Mullins (2005). The first one is controlling the baseline, and the second one evaluating and approving proposed changes (Mullins, 2005). Therefore it can be said that having a CCB is strongly related to the management of baselines.

It could happen that a medium or large project has more than one CCB. There could then be an external and internal board. The external CCB is then related to changes that will impact the client. The internal CCB is the one dealing with changes in design that will not be visible to the client, or will not impact the costs and planning (Chambers & Associates, 2018).

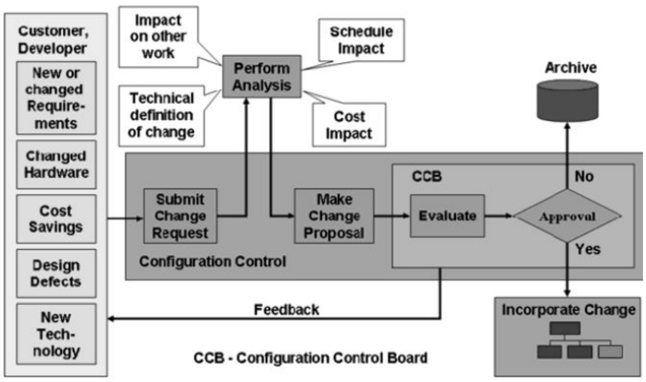


Figure 13.2.: Configuration Control Board responsibilities (Chambers & Associates, 2018)

What is seen as difficult in practice is how to implement this. the Defense Acquisition University set up a procedure for the CCB that can help give realistic substance to the CCB. The steps do not have to be followed in the given order (Defense Acquisition University, 2017):

1. Project Manager: Establish a Configuration Control Board.
    - Appoint a CCB Chairperson with the authority to approve a Connfiguration Control Directive (CCD) Form;
    - Appoint the members of the CCB.
2. Project Configuration Manager: Prepare and distribute the Configuration Control Board agenda.
    - Review the package and distribute the agenda and Change Requests to the CCB members at least five working days prior to the scheduled CCB;
    - Schedule time and place as directed by the CCB Chairperson;
    - File a copy of the agenda in the project configuration management library.

3. Configuration Control Board Members: Prepare for Configuration Control Board.
   - Review or comment on agenda items and assist in resolving issues prior to the meeting;
   - Ensure the requirement or change in baseline is clearly defined and valid;
   - Consider the potential cost and schedule implications of changes or additions to the baseline;
   - Review all action items;
   - Primary or alternate CCB members must be present or must contact the Project Configuration Manager prior to the meeting to state their position on the agenda items.
4. Configuration Control Board Chairperson: Conduct the CCB.
   The CCB may be convened on an ad-hoc basis for an emergency change when determined by the CCB Chairperson. The change may be presented to a full CCB, hand-carried to an individual board member, or polled via e-mail.
5. Review the CCD.
6. Project Configuration Manager: Obtain approval of the CCD.
   - Give CCD Forms to CCB Chairperson for signature and disposition;
   - Ensure each member signs the CCD Forms indicating concurrence or non-concurrence with the Chairperson's decision;
   - Obtain the client's signature on the CCD Forms.
7. Configuration Control Board Chairperson: Assign action items for deferred CCD agenda items.
8. Project Configuration Manager: Prepare and distribute CCB minutes and assign action items.

13.5.2. Information management system

The guidelines for SE state that the introduction of SE means a further increase of the importance of document management. The demonstrability and trace-ability of the technical process must be guaranteed in a high detail level leading to an increase in the number of documents. Also the arguments of decisions must be easy to retrieve. Recording these in a trade-off matrix contributes to the technical process (BAM, 2008). However, looking at what is stated in these guidelines critically, then it can be said that there is not a paradigm shift, even though this is necessary for information management. Projects must shift from document to information management. Documents must still be produced but as a means instead of as a goal (Relatics, 2017). Advantages can still be gained for the realistic use.

Different tools can be chosen for information management, where 'Bouw Informatie Model (BIM)' and 'Relatics' are widely used. BIM is defined as *"A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle"* (National BIM Standard, 2018). The differences that BIM records the information in a 3D visualization and Relatics records the information on paper and is suitable for recording the information to which the design has to comply. Because managing requirements is related to scope creep and because Sweco already uses Relatics, this program is therefore the preferred tool. Also Prorail prescribes Relatics for projects with SE (ProRail, 2015). Appendix C shows experiences of other companies with Relatics.

13.5.3. Partnering

Even though the barriers are less significant than the potential benefits, they must be considered. Partnering can only succeed when all parties work together to control risk events and prevent the barriers from occurring. Nothing will change without considerable effort from all players, having them rethink their attitudes and work for a more efficient and free of conflict project (Black et al., 2000). Successful partnering may require a full appreciation of the complex dynamics of the implementation, an understanding of the impact on the motivation and interests of both individuals and the group, and a sensitivity to the aspects leading to certain ways of working (Bresnen & Marshall, 2000).

The general opinion is that partnering is worth the effort even though parties benefit to varying degrees. Clients can use partnering to help achieve an efficient and successful project. They are often reliable of the expertise and knowledge of an engineering company. However, these are less positive about partnering, because they fear loss of control. They must modify their reaction as partnering receives an increasing focus in construction procurement. Furthermore, the client must recognize their central position. The client can improve the situation by considering four things: setting up new criteria for the selection of partners; ensure that all players share the success in line with the value they add for the client; end the reliance on contracts; introduce performance measurement and competition to ensure improvement, in terms of quality, planning and cost (Black et al., 2000).

The guidance for SE in the GWW sector states that open consultation must receive focus, as non-open consultation takes energy and prevents those involved from seeing the joint value and win-win situations (Werkgroep Leidraad, 2013). A closed attitude can be detrimental to both the image and the progress and thus the success of the project. SE is a collaborative process, where the interface manager must stimulate communication in an open manner (ProRail, 2015). The importance of the competencies of soft skills like attitude and behavior is increasingly being recognized. These skills are especially useful when looking at the important components of SE, like finding the right question, dealing with conflicting requirements and preventing re-work (BAM, 2008).

Within each project, trust between client and contractor must be a point of attention. Parties must regularly meet to establish this. Important during these meetings is having mutual respect, taking into account the common interest and ensure understanding and respect for conflicting interests. This ensures that the parties can discuss risks and opportunities (BAM, 2008). However, the process of trust development is dynamic, complex and sometimes contradictory, and therefore the effects of partnering can vary. Trust and collaboration are sensitive to behavioural aspects like respect and concern and are strongly influenced by intuitive and emotional reactions. Partnering can be successful in a single project when these aspects receive focus (Kadefors, 2004).

The partnering initiative shows steps for good partnership (Gilbert, 2015):

1. Know and respect your partners. Understand where interests align and where they differ; their resources and value; their culture; their specific drivers for engagement; as well as their limitations and internal challenges. Be open and transparent about your own drivers, value and limitations to help build trust.
2. Ensure that all partners have the knowledge and skills around the process of partnering to agree with the principles and co-create the partnership.
3. Identify clear partnership objectives that deliver results and offer significant value to each of the partners, and include specific measurable goals to track progress and demonstrate success and value-add to each partner.
4. Co-create a partnering agreement that sets out clear roles and responsibilities. Also create objectives and a decision-making structure that ensures proper accountability and efficient delivery. Partnerships can be iterative in design and the agreement will need to adapt to this.
5. Build strong institutional commitment by identifying the clear value of the partnership to each priorities. Integrate where possible with other partner activities.
6. Ensure the highest standard of project management to support a task-focused approach, with partners actively engaged in delivering time-limited tangible and practical results.
7. Embed the highest standards of relationship management to ensure that partners are kept fully engaged and valued and that the principles of partnership – equity, transparency, and mutual

benefit – are achieved. Make sure any issues can be recognized and fast dealt with.
8. Ensure strong communication both within the partnership and externally to celebrate success and continue to build buy-in with other stakeholders.
9. Build in ongoing review, including ‘health checks’ to assess the partnership, ensure partners are receiving value, the operations are efficient and the partnership is on track to deliver its objectives, and adjust as necessary.

13.5.4. Baseline management

All project employees must always be able to make use of the same, accurate information. This ensures that the partial products mutually agree, that changes are controlled and that mistakes are prevented. However, to realistically implement, within each project it needs to be determined how this is implemented. Furthermore it must be determined which baselines are used, what information is part of these and how changes are handled (Werkgroep Leidraad, 2013).

The conceptual design has as product the Functional Baseline (FBL). This provides a system-level logical architecture which forms the basis for subsequent lower-level (physical) design. It is crucial for the project that the different requirements analysis are performed using the same FBL. However, it is known that different FBLs exist on projects, which results in incompatible and conflicting preliminary and detailed designs. So, this reinforces the need to look again at the System Requirement Specification and the Technical Performance Measure before starting at the preliminary design (Faulconbridge & Ryan, 2014). Baseline management must thus focused on preventing this.

13.6. Conclusion

The realistic character of the factors is analyzed in five steps. This gives insight into the realistic character of the different factors and difficulties that are to be found when implementing them are discussed. When these difficulties are addressed in the recommendations, the factors can more easily be introduced as intended by literature and therefore more efficient anticipate to scope creep.

First the factors were related to the case study results for sub-research question 4. The analysis gives insight into the motives of the case study projects for implementing the factors or not. Implementing a CCB was not established because the standardized procedure of the client was used. So, before implementation, a change in mindset of the client is needed. Implementing an IMS is hard to establish due to large amounts of information and a missing focus from Sweco on this. These difficulties need increased focus. Some aspects of partnering were easily introduced, but the win-win situation and trust are disturbed by discussions with a defensive manner, no equal team members, not generating innovative ideas, and a business attitude. Furthermore the plans considering effective communication and coordination, turned out to be hard to establish and must be considered for implementing partnering. For baseline management questions were asked like when to establish a new baseline and when to implement this. Before implementing baseline management this must be decided. Furthermore, projects tend to see the products they deliver to the client as baselines, but a strong focus is still missing throughout the project, and therefore the mindset must change.

Second the different factors were related to the causes of scope creep from sub-research question 2 and their frequency in the projects. This analysis shows that all factors seem effective and realistic to implement. An IMS is seen as the most effective followed by partnering. Looking at partnering in the project Nijmegen Goffert the factor did have effect on the scope creep causes. However, it would result in a more effective result when combined with other factors. When looking at combinations, combining partnering and an IMS is the best option followed by combining partnering with baselines. It is assumed that the four factors do not contradict each other, so combining factors is seen as possibility. When combining three factors, then is combining CCB, partnering and an IMS the most optimal decisions followed by combining baseline management with partnering and an IMS. From this it follows that all factors are effective but partnering and an IMS are most recommended.

Third a survey was done to rate the factors in terms of value for scope control and if they are seen as realistic to implement. An IMS brings the most value and is seen as most realistic. A CCB scored lowest, but was introduced in the most project. The participants could give an explanation and therefore each factor received focus points that must be improved for good implementation and these were partly input for the fifth part of this chapter.

Fourth some experts from the work-field were interviewed and gave some critical notes on the realistic character of the factors. It is stated that the CCB will not work as a stand-alone thing, but must be integrated in progress consultations. During these meetings, a focus must be on changes and on remaining the integrity in the design. An IMS is often seen as an extra tool, however to make it work it must be fully integrated with all project processes and the ignorance of employees with the system must be taken away. For partnering effort of the client is essential just as practical sessions and transparency. Baseline management can be implemented when decisions are made on how.

Finally literature is consulted to get more practical interpretation and see if the literature also sees the factors as realistic. The CCB is seen as realistic but is enriched by a procedure that can be followed. An IMS is seen as realistic when a change from managing documents to managing information is established. Relatics is seen as most realistic system to use. Clients have a crucial role in partnering and open consultation, regularly meetings and a focus on respect are essential for realistic implementation. For successful baseline management implementation decisions must be made.

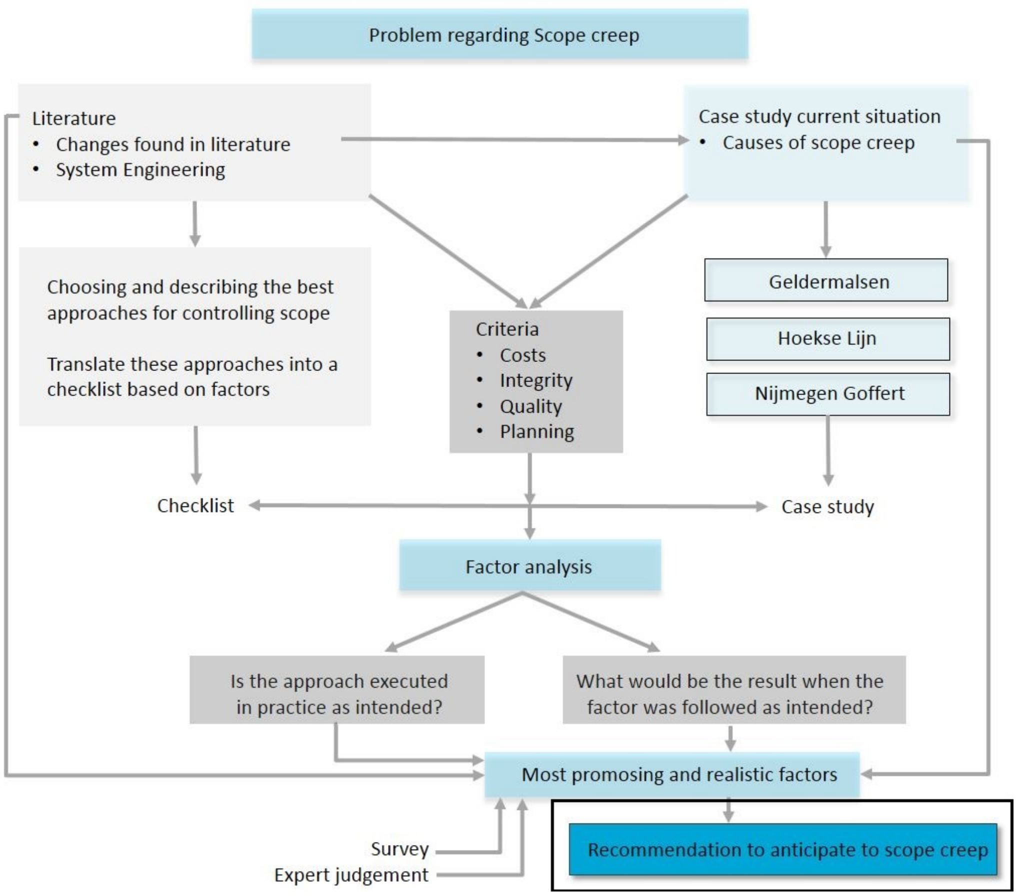
Part E - Conclusion

The chapters of this part:

14. Conclusion of the sub-research questions
15. Recommendations
16. Discussion

Research question that will be answered:

Main research question: *Which course of action is recommended to improve the ability to anticipate scope creep and its effect, having System Engineering as a framework in the design phase?*



14. Conclusion of the sub-research questions

Changes in the design and scope are inevitable, and found to be one of the most frequent, most damaging and largest concerns. Each change can have a different effect or consequence. It is key for the success to manage changes and to have a clear scope. In the design phase, changes can be made the most easiest for the lowest costs. When changes are not formalized and managed correctly, it is a risk contributing to project failure. Scope creep are non-formalized scope changes, whereof the impact is unknown and thus can influence the project negatively without having the project anticipating it. The problem statement therefore was defined as:
Projects cannot anticipate scope creep because the change is not formalized and the impact not researched which results in negative effects on the planning, the budget, and the quality of the end product.

Sub-research question 1: Which causes and effects of scope changes and scope creep can be found in literature?

This question is answered in chapter 5.
Changes that are discretionary, gradual, emergent or required are changes that most easily result in scope creep. Changes in projects usually result from scope changes, difference in work quality and conditions, or uncertainties. These uncertainties follow from the complex and dynamic nature of construction projects. This results in many decisions based on uncertain conditions and assumptions based on existing available information and previous experience. Sometimes assumptions turn out to be incorrect and decisions need to be revised and changes must be made causing rework. Direct effects of project changes include among others rework, time loss, and reorganization of schedule and work methods. Indirect effects include among others loss of productivity, disputes and blame among project partners, loss of float and therefore increased sensitivity to further delays.

Design-generated causes include design errors, design changes, incomplete or inconsistent drawings, and changes in codes and regulations. The lack of good pre-design is the most common cause for scope creep. Changes can be caused by internal or external factors. Internal factors include organizational, project and stakeholder related aspects. External factors include natural unforeseeable circumstances, government intervention, economy or legal issues.

Sub-research question 2: Which causes of scope creep can be found in practice?

This question is answered in chapter 6.
Scope creep can occur in multiple forms. The three different projects, project Geldermalsen, Hoekse Lijn and Nijmegen Goffert, were analyzed on causes of scope creep. The causes found in the projects can be merged into seven main causes accompanied by sub-causes:

1. Start of the project
   Wrong interpretations, Moving scope while tendered as fixed scope, Tendered with missing input, Rationality, Complexity
2. Process of an EOW
   High costs involved, Discussions take long and are arduous, Long waiting times, Starting before having an official approval
3. Time pressure
4. Scope control process
   Not formalizing changes, Consistency, Too much detail, Changes till the last moment, Not anticipating changes, Wrong process of reacting on reviews and changes
5. Team composition
   Wrong people on the wrong spot, Not enough capacity, Project is not correctly managed at the other stakeholders, Missing links, Parties involved with strong opinions, Working too good
6. Process of the project
   Reviews that take too long, Reviews without integrity, Setting up products in a wrong order, Many disciplines at one place, Game-like interaction
7. Human Factors

Sub-research question 3: Which scope management approaches to improve the anticipation of scope creep can be found in literature for projects using System Engineering?

This question is answered in chapter 7.
In practice there is a continuous tension between trust and wanting to keep control of the scope. The relationship between trust and control is a complex one, where control does not operate in opposition to trust but as a necessary complementary mean. Trust in a contractual relationship can facilitate the exchange of information and bring about a reduction in control.

To anticipate scope creep better, both trust and control of the scope is necessary. Therefore scope management approaches that are chosen to improve the anticipation of scope creep must also be related to this. The first approach focuses on improving both at the same time, the second focuses on maintaining control and the third focuses on improving the trust in a project, resulting in:

1. Configuration Change Management
2. Information Management
3. Partnering

Sub-research question 4: How are the scope management approaches from theory executed in practice and is this done as intended?

This question is answered in chapter 9, 10, 11.
The three scope management approaches were analyzed with the use of a checklist. This was subsequently laid next to the three case studies. Each approach was divided into factors that are all essential parts of the approach. This resulted in eleven factors.

Configuration Change Management can be divided into eight factors:

1. **Set up the configuration and the Configuration Management Plan**: None of the projects set up a CMP, even though stated in the contract. A good configuration was set up.

2. **Identifying Configuration Items**: This turns out to be a hard point to set up. The did not define items but did define objects or the SBS, but did not manage them as CIs.
3. **Accurate data and clarity on version and status of documents**: The projects did have accurate data but not version control.
4. **Configuration Control Board**: None of the projects established this.
5. **The establishment of baselines**: The intention was present but not correct establishment.
6. **The processing of changes**: Changes were submitted by an EOW, but not all were formalized. The EOWs did not contain all necessary information. It did not contain requirement numbers, drawing numbers, and interfaces were not always named in enough detail.
7. **Distinction between types of changes**: There was no distinction between types of changes, all were submitted in an EOW or not formalized.
8. **EOW approval**: A change must be approved before implementation, this was not always done.

Information management can be divided into two factors:

1. **Information management**: The mindset for maintaining information instead of documents was not followed. Two projects had the project directory structure, one project combined this with an information management system. However, this was not maintained.
2. **Check documents on accuracy, consistency and completeness**: This received much attention at the start of the project, but afterwards received less attention.

Partnering is seen as one factor:

1. **Partnering incentive**: One project had a strong mindset for partnering and mutual trust, one did not focus on the essential aspects but did have strong collaboration, and one did not have mutual trust, shared goals, a win-win situation or a strong collaboration. Each project did have adequate resources, support from top management and a communication plan. Also a kick-off session was established, but no follow up meetings.

Sub-research question 5:What would be the result if the scope management approaches would have been followed correctly as stated by theory in terms of costs, integrity, quality and planning?

This question is answered in chapter 9, 10, 11.
The analysis is structured by the use of the four different criteria; costs, integrity, quality and trust. Each factor, as stated by sub-research question 4, was analyzed based on these criteria. It was analyzed if a factor takes away the chance on certain causes and effects, which are based on sub-research question 1 and 2. For the costs it is looked at the investment and maintaining costs. These are estimated by the project managers that were interviewed. Also causes related to costs were used here to analyze the factors, like final project costs and overhead costs. For integrity, a decrease of the chance on having certain causes and effects is taking into consideration. Examples of causes are less design errors and less communication flaws. Effects can be less rework and consistency between documents.

Causes that affect the quality are among others loss of rhythm and less risks for the interfaces. Planning included a possible decrease in the chance on causes like a long waiting times on reviews and changes till the last moment. Effects can be time loss and a not good substantiated planning.

It can be concluded that a CMP, baselines and an IMS are accompanied with high investment costs where partnering do not need an investment. However, these factors have strong positive results for the other criteria. Processing of changes also scores high on many criteria just like installing a CCB.

Sub-research question 6: Which parts of the approaches are best to anticipate scope creep, considering both literature and practice?

This question is answered in chapter 12.
The most potential factors follow from comparing the eleven factors to each other. For each criteria the most promising factors can be derived. For integrity for example these are an IMS, a CCB and identifying CIs. The four criteria can be prioritized for the client and the engineering company. Both parties are important to consider for finding the most realistic factor to anticipate scope creep. Prioritizing criteria results in the most potential factors for both parties. The engineering company finds costs and integrity the most important criteria, where the client finds the quality and the costs the most important. Together this leads to the four most important factors:

1. Configuration Control Board
2. Information Management System
3. Partnering
4. Baseline Management

Sub-research question 7: Can the parts based on theory be implemented realistically in practice?

This question is answered in chapter 13.
The realistic character of the factors is analyzed in five steps. First the factors are related to the analysis made for sub-research question 4. Implementing a CCB was not established because the standardized procedure of the client was used. Implementing an IMS would improve the scope control but is hard to establish. Some aspects of partnering are easily introduced, but the win-win situation and trust are disturbed by discussions with a defensive manner, no equal team members, not generating innovative ideas, and a business attitude. For baseline management some questions arises like when to establish a new baseline and when to implement this.

Second the different factors were related to the causes of scope creep from sub-research question 2 and their frequency in the projects. Each factor influences some causes, where partnering influences the most, and an IMS influences the most frequent causes. It is argued that it could be more effective to combine factors in projects. Combining partnering and an IMS is the most efficient option. Still there are some causes that are not influenced by any of the factors.

Third a survey was done to rate the factors in terms of value for scope control and if they are seen as realistic to implement. An IMS brings the most value and is seen as most realistic. A CCB scored lowest, but was introduced in the most project. The participants could give an explanation and therefore each factor received focus points that must be improved for good implementation.

Fourth some experts from the work-field were interviewed about the different factors and they gave some critical notes on the realistic character. It is stated that the CCB will not work as a stand-alone thing, but must be integrated in progress consultations. An IMS must not be an extra tool but fully integrated with all processes. For partnering effort of the client is essential. Baseline management can be implemented when decisions are made on how.

Finally literature is again consulted for a better practical interpretation and to see if the literature sees the factors as realistic. The CCB is seen as realistic. An IMS is seen as realistic to implement when a change in mindset from documents to information is established. Relatics is seen as most realistic system. Clients have a crucial role in partnering and open consultation, regularly meetings and a focus on respect are essential to make it realistic to implement. For successful baseline management implementation decisions must be made.

15. Recommendations

This chapter focuses on the recommendation of this research. First the recommendations for practice will explained in section 15.1. This part focuses on answering the main research question: ***Which course of action is recommended to improve the ability to anticipate scope creep and its effect, having System Engineering as a framework in the design phase?*** Second the recommendations for further research are given in section 15.2.

15.1. Recommendations for practice

The answering of the main research question is based on chapter 13 and on the conclusion in chapter 14. The different sub-research questions gave the knowledge needed for the recommendation in this chapter. There are three recommendations to better anticipate scope creep in practice. These are given in order of importance. First, shown in section 15.1.1, it is chosen to combine the CCB with baseline management. These two factors are complementary and crucial for maintaining the scope. The first one is scoring high on the analysis with the four criteria, the latter is scoring high in maintaining scope in practice and is more realistic. The second recommendation, stated in section 15.1.2 is that an information management system must be implemented. The third recommendation, stated in section 15.1.3, focuses on implementing partnering. Both score good on the value it can bring for scope management, and on the realistic character. They also follow as high potential from the analysis and are seen as very important to manage the scope.

15.1.1. Recommendation 1- Combining the Configuration Control Board with Baseline Management

The Configuration Control Board came forth from the case study analysis as the best factor to implement for anticipating scope creep. For an engineering company this would be the most beneficial factor and for the client the second best in terms of the four criteria. In the analysis based on the four criteria, CCB had strong positive influence on integrity and quality, on planning and costs its influence was mediocre when compared to the other factors. Even though 76% of the survey participants said they established a CCB, it is rated as the least realistic factor offering the least value for scope management. Therefore, improvements are needed to increase the trust in this factor.

It is important to consider that the experts and participants questioned how to implement a CCB. Many participants see a CCB as already part of every team consultation and therefore it is stated that it will not work when it is implemented as a stand-alone thing. None of the case study projects used the CCB as intended and it can be said that a substantial portion of the 76% percent of the survey participants that stated that they implemented a CCB, also did not use it as intended. This can be derived from their explanations. Therefore, the implementation will be easier when the CCB will be incorporated in the current processes and not as a stand-alone thing. Furthermore, integral thinking must receive a focus, because maintaining integrity is crucial for each project and strongly related to scope creep. So, the responsibilities of the CCB must become important part of the agenda of the current team consultations. The CCB has two main responsibilities; controlling the baseline, and evaluating and approving proposed changes. This shows that focusing on baseline management is an essential part of implementing a CCB and the combination of these two factors is therefore recommended.

When looking at baseline management, it can be said that it has a strong positive influence on the causes and effects related to the quality and planning, and it influences the integrity of the design positively. Baseline management received the second highest score in both value and realistic character of the four factors and was introduced in 61% of the projects. Where CCB thus receives higher scores from the analysis with the four criteria based on theory, baseline management scores higher on the survey in practice and is seen as crucial for manageability of scope in practice. When the scope is better managed, the anticipation of scope creep is improved.

CCB influences many of the causes of scope creep that were found in practice, baseline management is less effective. Of the 28 causes found in practice, together they do not form the most efficient combination of factors possible, but they can be implemented the easiest. This is because they are strongly complementary and that not having a focus on baseline management could also harm the process of the CCB. They must give special attention to the four frequent and six occasional causes of scope creep that they do not influence. Some of these can be influenced by the contractor and some are influenced by the client. The causes that must receive special attention are first to strategically think about starting without an official approval and when doing so, discuss this within the CCB and update the baseline. Second, changes that can occur till the last moment must be discussed within the CCB just as the consequences of long waiting times for EOWs and reviews. Third, baselines can be used to give inside on the consistency between documents and reviews. Furthermore, products must be set up in the right order and they must ensure that team members work correctly and communicate their work with the project manager. Finally, they must avoid getting a game-like interaction.

The benefits found in literature are that a CCB is responsible for managing the changes that come up during the process, to give insight into the impact, and it enlarges the ability to anticipate scope changes. The benefits shown by the participants of the survey were the same, supplemented by that it can prevent many discussions because changes and their impact can be discussed at an early stage. Baseline management is realistic, necessary, and in everyone's interest. It is also seen as a useful tool to communicate transparently and as a basis for a structured way of collaboration. It is said that it must be the basis of every project. The design becomes manageable and it keeps decisions with their related deadlines clear.

The survey participants stated that a CCB and baseline management would not work on small projects. Furthermore, the client must have a change in mindset and show effort. The change in mindset is also required to make employees see that prevention is better than curing, even though the effects are not always visible in the short term. The client must give sufficient room to make a thorough assessment and impact determination. The engineering company must make time and capacity available for baseline management. When changes occur, it can only change the baseline through a documented change management process. The CCB must ensure that the information included in an EOW is complete and has a focus on all project aspects it influences. This ensures that the project team can anticipate scope changes fully.

When implementing baseline management, a focus must be on the integrity and ensuring that design parts are using the same baseline. To ensure this, certain decisions must be made. First it must be recognized that each employee is responsible for maintaining the baseline, but there will be one manager/administrator. Second, an agreement on when to establish a new baseline must be made. It is recommended to do this after a large influential change, after the delivery of a design product like a FIS and otherwise each few months based on the nature of the project. At these moments the new baseline is frozen and the configuration and design must be updated such that both match each other and the baseline again, the verification and validation is checked and the planning is updated. This may require some re-engineering or stopping design works, but it is tried to take the loss of rhythm into consideration as much as possible.

Sweco as engineering company must also make certain decisions regarding the implementation of baseline management and a CCB. First, it is better to not incorporate this in small projects. Second, they must ensure that an investment can be made in each project and that time and capacity is available. They must change the mindset within Sweco that prevention is better than curing, and even though the effects are not immediately visible, that the investment is worth taking. The employees must understand that they are also responsible for the maintaining of the baseline. Finally, Sweco works often together with ProRail who works with standardized processes. They must show ProRail that the focus of the CCB is a mutual effort and must receive focus during the meetings.

15.1.2. Recommendation 2 - Establishing an information management system

An information management system takes away most frequent scope creep causes. It was given the highest value for scope control and is seen as the most realistic factor to implement by the survey participants. An IMS contributes to complete information provision, fast retrieval of documents, it keeps track of the integrity between disciplines, makes the monitoring of scope easier and it forces a project team to work more explicitly. Organizing information properly at the front ensures that nothing is forgotten and scope creep can be reduced. Setting up the environment takes time, but the investment pays out later. However, there must be focus on the causes of scope creep it does not influence, like having parties involved with strong opinions, reviews that take too long and long waiting times on approval of EOWs.

The guidelines for SE state that the introduction of SE means a further increase of the importance of document management. Looking at this critically, it can be said that SE does not encourage a complete paradigm shift towards information management. Information management requires that projects shift from document management to information management. Documents must still be produced but only as a means instead of as a goal. It is also seen in the results of the survey that only 55% of all the projects established an IMS of which 87% also maintained the system, and still 76% had a project directory with documents. Therefore, this mindset must change and such a system must be an essential part of each project instead of something extra.

Different tools can be chosen for information management, where 'BIM' and 'Relatics' are widely used tools. A system that focuses on managing requirements, that is already used within the company and that employees already worked with, is recommended. The basis of the system must be laid out correctly, however, the team members must also put effort in keeping up with the agreed structure. The system must be applied project-wide to add value and take away the chaos found related to trace-ability of documents. It could be useful to have a system that is related to responsibilities and rights, such that not everyone can edit each document. Furthermore, someone must have responsibility for maintaining the system and keeping the information up-to-date.

For Sweco, the organization would require a change to establish an IMS. It would require strong investments at the start, which would pay off for each individual project and for the entire rail department. This is a choice that must be made.

Relatics is the recommended program for Sweco, because it focuses on managing requirements, the client recommends this program and because Sweco already uses Relatics in some projects. However, Sweco has been talking about Relatics for a long time, but it does not kick off due to the lack of people who control the implementation of the system and employees who are not able to handle the system properly. It is recommended that the ignorance of employees with the system must be taken away, because there are still employees who have never worked with Relatics. This can be done by a workshop of a few hours that shows employees the basic principles of Relatics. Furthermore, Sweco must show the employees that all needed processes can be arranged in Relatics and must ensure that this is done. The system must be applied project-wide to add value and to prevent double work, and standardized templates can be useful for this. Currently, maintaining and using the system properly is a challenge because it is forgotten in the current issues. The work attitude of the employees is thus also part of the shortcoming found in maintaining the system in some cases and requires changing.

15.1.3. Recommendation 3 - Establishing partnering

Partnering ensures that projects focus on mutual benefits, trust and good cooperation. In practice there is a continuous tension between trusting the other stakeholders and wanting to maintain control of the scope. Establishing trust is desirable since it reduces the costs of monitoring and controlling, while making the working relationship more efficient. When the cooperation between parties is enriched with trust and sharing goals, scope management improves and scope creep will decrease.

50% of the survey participants said to have a mindset for partnering. The case study showed that some aspects were easy to establish, like clearly stating responsibilities, setting up an escalation model, solving problems together, ensuring the highest standard for project management, long term commitment, having adequate resources, having a plan for effective communication, having a willingness to reduce duplication, and being willing to share resources.

However, some important aspects, like trust and a win-win situation, were not introduced in all case study projects. Also in the survey it showed that only 52% had a win-win situation with equal partners. Trust was given a 3.5 out of 5 on average and 70% of all projects said to have a focus on cooperation. So, focus must be given to these aspects. The clear commitment to a win-win attitude is disturbed in the case study by discussions, late implementation of the partnering process and a defensive manner of having arguments. Seeing team members as equal could also be related to the win-win attitude just as generating innovative ideas. Trust was in some projects replaced by mutual respect and a business attitude. Trust was disturbed by failure, lack of clarity regarding scope, goals and finance, and due to not delivering on agreed deadlines.

Open consultations must be a focus point as non-open consultation takes energy and prevents those involved from seeing the joint value and win-win situations. Furthermore, to establish trust, the partners must regularly meet. Good agreements must be made such that the expectations are fully transparent. Furthermore, it is important to establish mutual respect, to take the common interest into account, and ensure understanding and respect for conflicting interests. This ensures that the parties can discuss risks and opportunities. Partnering can also focus on decreasing the game-like interaction that can be a cause of scope creep and can harm for example the success of the CCB and baseline management.

Systems for achieving continuous improvement and conflict resolution are needed for partnering. These systems all formalize, plan and structure the relations. All team members become engaged in maintaining and evaluating the relation and this should increase the perception of equity and reciprocity and facilitate trust. Team building exercises, joint goal formulation, and periodic assessment are recommended. An initial workshop must be organized at the beginning of a project to promote team building and agree on mutual objectives. A fixed agenda and frequency to partnering activities can make it more effective. Also have teams match in personality can make team members feel more comfortable and open for cooperation.

Partnering happens more often in practice and is paying off. The barriers are less significant than the potential benefits, however, partnering can only succeed when all parties work together to control risk events and prevent the barriers from occurring. Nothing will change without considerable effort from all players having them rethink their attitudes and work to make the project more efficient, successful and free of conflict. Partnering must come from both sides and if one of the parties does not fully commit, it is doomed to fail. However, not all parties are ready and/or open to this change in mindset. Consultants are afraid for loss of control and clients must recognize their central position. Furthermore, focus must be put on the scope creep causes it does not influence. These are factors focusing mainly on the start of the project and setting up a good scope management system.

Establishing partnering can be implemented in each individual project and would require less effort. It is something that easily can be done and must already receive a focus in each project. However, Sweco must put effort into the aspects of partnering that are not easily established. Trust, shared goals and a win-win situation must receive focus and are disturbed by process of the projects. Some participants stated that at the start of the project there was trust and a striving for cooperation, but this changed during the project due to mutual failure, or due to lack of clarity regarding scope, goals and finance. Distrust also came forth out continuous failure to deliver at agreed deadlines and a client who does not have clear understanding of how requirements have been interpreted. Therefore, Sweco must focus on preventing this to happen or on transparently communicating about failures.

Sweco must also focus on changing the expectations of the client. Partnering requires mutual effort of both parties, but Sweco cannot easily change the mindset of the client. Therefore, Sweco must show transparency, open consultations and willingness to join practical sessions. Respect and showing understanding are also important.

15.2. Recommendations for research

It is recommended to test the outcome of this research in practice, to show if the recommendations show results in practice. The different recommendations from chapter 15 can be tested in rail projects to see what the outcome would be on scope creep. To see if scope creep decreases, it is needed to set up a better framework to identify scope creep in projects. This can be based on the framework of the four criteria that was linked to causes and effects of scope creep. This framework must be improved, extended and it must be made possible to statistically justify the results. Projects with many interfaces and a smaller run time are recommended for testing to get quick but realistic results. Furthermore, it is recommended to focus with further research especially on the implementation conditions of baseline management and on the effectiveness of certain decisions.

It is also recommended to test the outcome of this research in other branches to see if the results are generally applicable for all infrastructure projects. The recommendation can be made specific for the different branches, as each branch is based on different set of requirements. Additionally, it is recommended to further research aspects that disturb the scope management process. It can be useful to set up a plan for anticipating scope creep, related to project characteristics. A standardized action plan could be established that can be transformed to each unique project and branch.

It is recommended to further consider the other factors that were not part of the four recommended factors as these also have potential to decrease scope creep in projects. Furthermore, it can be interesting to further look into the possibilities of combing factors into a new strategy for controlling scope creep and to test this. Some factors are in line with each other and can easily be combined. For this it can also be interesting to look at other frameworks than SE.

15.3. Conclusion

This chapter focuses on giving recommendations for both practice and further research. This practical recommendation answers the main research question: ***Which course of action is recommended to improve the ability to anticipate scope creep and its effect, having System Engineering as a framework in the design phase?***. It is important to consider that the recommended actions are the factors that came forth as best to anticipate scope creep. The recommendations focus on how to realistically implement these to ensure the best possible situation to anticipate scope changes.

First it is recommended to start introducing a Configuration Control Board together with baseline management in projects. This ensures the basis for scope management and anticipating scope creep and its impact. Secondly, it is recommended that projects are structured based on an information management system. Such a system would make scope management easier just as maintaining the integrity. This improves the ability to anticipate scope creep. Finally, it is recommended to have partnering as this would take away many causes of scope creep. Trust between the parties also improves scope management and can lead to a better ability to anticipate scope changes.

The recommendations for further research considers first testing the outcomes in Rail projects and testing the outcome in other branches. Second, research is recommended in setting up a plan for anticipating scope creep that is related to the project characteristics. Finally, it is recommended to further research the relation between anticipating scope creep and the factors in this research that were not part of the four that were further analyzed.

16. Discussion

16.1. Limitations of the research

By critically assessing the applied research method the following limitations can be found:

- The sample of cases used in this research was of a relative small size and therefore including more cases could have given the conclusion a more generalizable image.
- The literature showed mostly knowledge on the general topic of scope changes. Only few sources made explicit statements on scope creep as defined in this research. Therefore some assumptions are based on scope changes in general. This might have influenced the conclusion and recommendations.
- The checklist that was set up for the analysis was based on a summary of all found literature. There is a possibility that crucial information was not included. This is tried to be set right by introducing new literature on the four factors in chapter 13.
- The analysis of the different factors related to the criteria could have an interpretation bias. This is tried to be minimized by talking to the project managers based on a checklist and the same set of sub-criteria.
- The frequencies of the scope creep causes in the case study projects are estimated values. This was based on the analysis of different documents and on interviews
- The conclusion and recommendation is mainly based on Rail projects that are used as representation for the construction industry of infrastructure projects. However, also other infrastructural project branches could have been included in the analysis. This was tried to correct by also distributing the survey under other departments of Sweco.
- The client was not asked to give their opinion on the topic. This was tried to correct by asking employees of Sweco who used to work at the main client ProRail and by taking into account formal documents of the client that reflected their opinion on certain matters.

16.2. Academic relevance

The academic relevance can be found in four different area's. First, relevance can be found in enriching the theory of the scope management approaches with the practical application. The three different scope management approaches are already made practically applicable by theory, however, this research looks at the practical application in a certain demarcated sector. It focuses specifically on projects in the design phase, that have to deal with many scope changes, of which a large amount is not formalized. This research shows that the scope management approaches are not perfectly use-able in practice and it shows the problems they encounter focusing on scope changes. Many scope management approaches steer to having control of all changes, however this is not realistic. Scope creep can be seen as a flaw in the application of these approaches, because scope creep are changes that are not managed and formalized. The second relevance can therefore be found in realizing that scope creep is a problem that happens to each project and is related to fact that following the approaches as intended could result in an unworkable situation. The theory of the approaches and SE is enriched with knowledge of scope creep and the accompanied problems for projects.

Third, this research shows which causes of scope creep are disturbing the use-ability of the scope management approaches in such a way that projects encounter scope creep. The factors that disturb the project are the seven causes of scope creep. Finally this research gives a recommendation for anticipating and improving the situation.

System Engineering is critically assessed. In the guidelines for SE in the GWW sector it was already stated that it is hard for the construction industry to implement SE as intended. Additionally, this research shows that CCM turns out to be hard to implement. Furthermore, SE does not steer towards the required change in mindset for an IMS, even though it recommends using one. Therefore, this research shows that there is still room for optimization in the theory of SE.

16.3. Practical relevance

The practical relevance of this research can be found in the recommended course of action to anticipate scope creep. Scope creep is a practical problem in each project and it is necessary that projects must anticipate scope creep. By doing so, the negative effects will decrease and less disrupt a project. The recommended factors of the different scope management approaches are the ones that came forth as best factors to anticipate scope creep. This research focused on how to realistically implement these to ensure the best possible situation to anticipate scope changes in practice. Each recommendation can be used for each engineering company, apart from the part made specific for Sweco.

Furthermore, problems were found by the performance of the different scope management approaches. These problems are indicated and a focus can be established on improving these. This would make the general scope control process improve and this would benefit individual projects in terms of budget, planning, quality and maintaining integrity.

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A. System Engineering in the acquisition phase

This appendix will explain the concept of System Engineering that is introduced in chapter 4. It starts with the introduction in A.0.1. After the introduction, the domain of System Engineering is discussed in A.0.2. The next subject that is discussed are the characteristics of System Engineering in A.0.3. Next the process of System Engineering is explained in more detail in A.0.4. Both the technical process is discussed and other process that are supporting the project.

A.0.1. Introduction

The introduction is divided into the definition of System Engineering in A.0.1, the reasons for using System Engineering in A.0.1, the guiding principles in A.0.1, and how it is captured in A.0.1.

Definition

System Engineering can be defined in different ways, and is defined by INCOSE as:

> *"Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, disposal and manufacturing. Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs" (Haskins, 2010).*

Reasons for starting to use System Engineering

The increasing rise of complexity at any given time and cost frame and the missing interdisciplinary collaboration in projects can be approached with SE. SE ensures that the developed product meets the requirements of all stakeholders and helps establishing interdisciplinary collaboration (Gräßler & Yang, 2016). Due to the dynamic environment in the construction industry, a project is never static and sensitive to a lot of changes. SE helps to map the scope and anticipate these dynamics. This leads to having a clear view on the impact of changes and could decrease the amount of scope creep. When working on a complex system, a systematic work procedure is needed. Different approaches can be used, but the construction sector started using SE (Werkgroep Leidraad, 2013).

Furthermore, infrastructural projects are increasingly becoming multidisciplinary. Road construction, civil engineering, installation technology, rail and sometimes other disciplines are integrated in all phases. This results in other forms of contracts (BAM, 2008). The choice for using other forms of contract, requires another role of all parties involved (Werkgroep Leidraad, 2013). Clients increasingly get more distance from the technical design and construction process. SE offers the ability to realize this control and transparency and to explain to clients what choices are made in the design and realization process and what results are derived from it. This prevents errors, optimizes processes, and prevents errors or fixes in a timely manner which are all reasons for scope creep. More attention is being paid to making choices demonstrable and transparent and capturing them (BAM, 2008).

Often SE is understood as translating requirements demonstrable and into a design and a realized product. However, SE also has influence on project management and project support. Thus, applying SE does not only have consequences for the technical process, but also affects the way in which support processes are configured and executed (BAM, 2008).

Guiding principles

The guidance for SE appoints guiding principles in support of successful cooperation. The commitment to SE led to new insights and has sharpened these principles, which are (Werkgroep Leidraad, 2013):

- Centralize the customer demand;
- Offer space for design freedom;
- Think in systems;
- Realize transparency;
- Enlarge efficiency;
- Add value;
- Attention for attitude and behaviour;
- Organize and unlock information in a Specific, Measurable, Acceptable, Realistic, Time-Based (SMART) way

During the life cycle, there is a lot of transmission between teams. Therefore, working clear and explicitly is needed for making the information transmissible. Verification and validation is supportive to this process. Furthermore, during the development of the project the degree of detail is first abstract and becomes concrete. The start contains the wishes of the client and through an iterative process these wishes are specified and decomposed into a solution. The process of going from abstract to concrete is done using the V-model (Werkgroep Leidraad, 2013). Finally, to comply to the ideas of SE, thinking in systems is very important (Werkgroep Leidraad, 2013). A project or building is considered to be a system surrounded by other existing systems. A system consists of different system components, which are called objects. Objects, in turn, consist of underlying objects. A hierarchical decomposition of a system creates a number of underlying system levels (BAM, 2008).

The advantages of SE are:

- Demonstrating accountability quality consciousness. It can be demonstrated that the delivered product is good and meets the requirements. This governs accountability towards the board of directors and the client (BAM, 2008). It leads to a product that is in line with the original requirements more completely. This results in a quality system where quality is measured by the ability to meet the documented requirements (Faulconbridge & Ryan, 2014).
- Offering one language. Without understanding the client's needs, a project may become needlessly complex. It is vital that the client knows what he wants and that he clearly communicates this to other parties involved. Without understanding the client's needs, a project may become needlessly complex (Wood & Gidado, 2008). SE offers one language and the same definitions of term, which decreases failure costs (Werkgroep Leidraad, 2013).

- Reduction of failure costs. By validating, the likelihood that faults are detected at a late stage is reduced. These faults can have far-reaching consequences and do involve high recovery costs. Furthermore, the chances of non-compliance with the customer requirements are reduced. Failure costs are also greatly reduced due to better communication between different disciplines (BAM, 2008). SE therefore has as benefit the saving of money in all phases of the system life cycle (Faulconbridge & Ryan, 2014).
- Efficient use of disciplines. Large, integrated contracts involve the use of large, multidisciplinary teams. Through SMART management of requirements, it is possible to communicate only with the relevant parties about certain requirements, but also to monitor the interfaces with other disciplines (BAM, 2008).
- Continuity in work stock. For assignments to use SE as framework is increasingly requested. When offers are compared to more aspects than just price, a unambiguous method for SE is of great importance (BAM, 2008).
- Understanding the consequences of changes. If the changes are made to the specifications, requirements management can quickly understand the consequences. This reduces the likelihood of errors arising from not completely processing changes. Moreover, the modification of specifications should be minimized as it requires a lot of (administrative) work to process all its consequences. The reality teaches that change is inevitable and clients have to deal with this (BAM, 2008).
- Interface control. The explicit demarcation of a system and its subdivision into components and sub-components provides insight into the interfaces of the system with the environment and between the different components. With this insight, proper integration of the system into the environment can be promoted and the objects can be tuned to each other (BAM, 2008).
- Flexibility in commitment. By explicitly explaining the connection between requirements, objects and interfaces, it is easier to divide responsibility for parts of the design. This creates greater flexibility in deploying people (BAM, 2008)

Capturing of System Engineering

The basis for the process of SE is laid down in the ISO / IEC 15288 standard. This standard sets out frameworks and guidelines for passing through the lifecycle of systems which is abstractly formulated and therefore generally applicable to almost all subjects. For the GWW sector of the Netherlands, the large commissioners ProRail and Rijkswaterstaat developed the “Leidraad Systems Engineering in the GWW sector”. This guide is to be considered as an industry-specific translation of the ISO standard (BAM, 2008). This guideline is considered insufficiently useful by some parties because the emphasis is too much on the technical process however no indications for the equally important supporting processes. In addition, the guidance staff does not yet have enough practical handles to actually get started (BAM, 2008).

A.0.2. System engineering domain

The client of Sweco, ProRail, prescribe SE as framework to work with and to support working with the highly complex projects they face. Regarding Faulconbridge and Ryan (2014) the framework SE is predominantly used during the acquisition and utilization phase of a project. This is based on the assumption that a system can be split into four different phases, namely the pre-acquisition phase, the acquisition phase, the utilization phase and the retirement phase. The business needs for the system are the input for the acquisition phase and will be used to bring the system into service (Faulconbridge & Ryan, 2014). The acquisition phase can be split up into different activities which are the Conceptual Design, Preliminary Design, Detailed Design and Development, and Construction (Blanchard & Fabrycky, 1998). Using SE in the design phase could help leading to cost savings in the construction phase. SE focuses on accurately reflecting the requirements in the design which helps to minimize these costly and time-consuming changes later in the life cycle. There is a greater design maturity in an earlier phase of the project. SE also leads to a reduction in technical risks, since risks are defined early and monitored. The design decisions made can be traced back to the requirements and reduces the risk of failure later (Faulconbridge & Ryan, 2014). This all contributes to the prevention of scope creep.

ProRail requires the knowledge of Sweco mostly in the Conceptual Design phase which is part of the acquisition phase. At the preliminary design phase Sweco is mostly also involved but then together with the contractor in some cases. In figure A.1 the different activities are shown together with the major artifacts and reviews (Blanchard & Fabrycky, 1998).

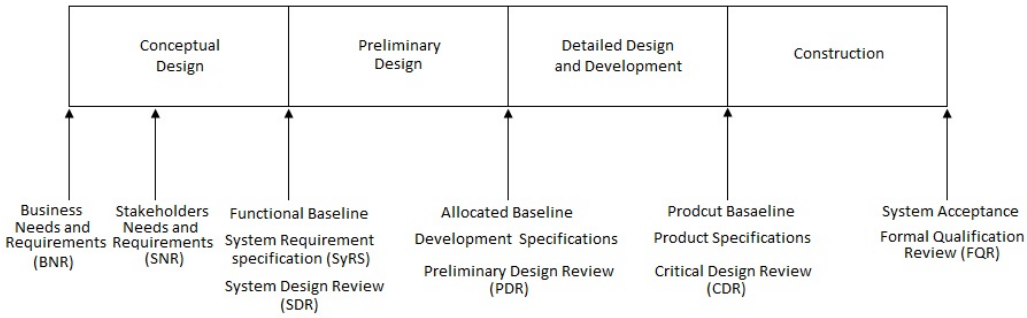


Figure A.1.: Acquisition phase in detail (Blanchard and Fabrycky, 1998)

The conceptual design phase focuses on defining the needs and considering the problem domain and a logical design of the system is completed in this phase. This is done by analyzing and documenting the system level requirements which follow from the needs of the client (Faulconbridge & Ryan, 2014). The conceptual design phase starts with defining the business and stakeholder needs and requirements and scope system. Then the system requirements must be defined, the system-level synthesis must be conducted, and the system design must be review.To know what the system is expected to do the system context, the system boundary and the external interfaces must be defined. The FBL is the major product of this phase and provides the system-level logical architecture which forms the basis for the subsequent lower-level (physical) design. The client is heavily involved in this phase because they need to determine what the system must do and how it needs to perform (Faulconbridge & Ryan, 2014).

The Preliminary design starts with the initial FBL and continues to translate the requirements into design requirements. This ends after a trade-off study in establishing an allocated baseline in which the requirements are allocated to specific physical system elements. This phase include a subsystem requirements analysis, requirements allocation, interface identification, subsystem-level synthesis and finally the preliminary design review. The responsibility mostly lies with the contractor or engineering company who develops the system to meet the requirements of the FBL. The client will start monitoring, reviewing and supporting the progress, keeping their interest in the outcome. The logical architecture in the FBL is allocated to a physical architecture in the form of configuration items as they are described in the allocated baseline (Faulconbridge & Ryan, 2014).

A.0.3. Characteristics of System Engineering

SE is characterized by four different aspects, namely that interfaces (A.0.3) must be managed, that decomposition (A.0.3) is important, that the work is divided into a work packages (A.0.3) and that validation and verification (A.0.3) is a crucial part of SE.

Interfaces

Places where a system or its components affects the environment, and vice versa, are called interfaces. Interaction between a system and its environment involves external interfaces. Interactions between objects within a system are internal interfaces. Experience shows that failure costs often arise at interfaces where the interference between the parts does not work well. Interface management is therefore a crucial part of SE. It is important to start with carefully making an inventory of the interfaces and these must be taken into account by making choices about the methodology for design and implementation (BAM, 2008).

Decomposition

Decomposition is unraveling the whole of requirements, activities, functions and objects and arranging the components systematically in a structure of main components and underlying parts. A widely used technique to keep or make information clear and accessible, is using tree-structures. The profit is found in establishing relationships between different decomposition's at different levels (BAM, 2008).

(a) SBS
The SBS is a division of the system into manageable objects and grows as the design is further detailed. The point of departure must be to minimize internal interfaces between the various disciplines. In order to gain insight into the amount of interfaces and the difficult to control interfaces, the so-called 'N2 chart analysis' can be applied (BAM, 2008).

(b) WBS
The WBS is a structured overview of all project activities. A group of activities belonging to each other is called a work package. In WBS, activities are included in the context of design and realization, but also for project management and can often be found in the project management plan (BAM, 2008). It is a guide for project management and is based on concepts such as costs, scope and schedule management (Faulconbridge & Ryan, 2014).

(c) Organizational Breakdown Structure (OBS)
The OBS is a division of the (project) organization into logical units, such as roads and technical installations. OBS often takes the form of an organizational chart (BAM, 2008).

(d) Requirements Breakdown Structure (RBS)
The RBS or Demand Tree is a hierarchical list of requirements, consisting of 'top-level' requirements and its derived ones. Each requirement specifies the overlying and underlying requirements. The client provides the basis for the requirements tree; The contractor builds up the tree further (BAM, 2008).

(e) Functional Breakdown Structure (FBS)
The FBS is obtained by a functional analysis, whereby the main functions of a system are broken down into underlying sub-functions and functional levels. The purpose of a functional analysis is to be fit for purpose. So, to provide a solution that satisfies the requirements of the client that are explicitly identified or implicitly required (BAM, 2008).

Work Breakdown Structure and work packages

It is believed that effective and efficient work requires division into manageable work packages. The purpose of a work breakdown structure WBS is dividing the work into manageable work packages and this gives a structure for the management of a project (Werkgroep Leidraad, 2013). Project scope definitions can be based on the WBS, because all components of scope management interact with each other through this product. Everything that is included in the WBS becomes part of the project scope, therefore it represents the scope of the project (Khan, 2006). The classification of the WBS can be based on the system design, geographical format, management of an organization, or the process. The whole of the work packages should be consistent with the project planning and the budget. The relevant information, like risks, are linked to the work packages and becomes the basis for the work packages description (Werkgroep Leidraad, 2013).

Therefore, the activities are often also placed under the same responsibility. Due to having a responsible person for each work package, there is a clear relationship between WBS and OBS. The highest level work package, which consists of designing and realizing the main activities, is assigned to the project manager. The structure of the work packages does not necessarily correspond to the structure of the system, nor does a work package need to include the realization of a full object. A work package consist the content described in activities, the result to be delivered, the lead time, references to specifications, relationships to other work packages and the SBS, the budget and the ultimate responsibility for realizing the work package (BAM, 2008).

The WBS should be set up as early as possible; preferably before the first activity actually commences. By allocating costs to all activities of the WBS, an estimate of the total budget required for the project is established (BAM, 2008). There is a relationship between payment and work packages. The contract with the client can determine that payment takes place on the basis of fully completed work packages. Often restrictions apply to the maximum financial scope of work packages, the lead time and/or their content. It is important to make payments fairly similar to the costs incurred. This should be taken into account in the classification of work packages.

Verification and validation

At the core, the meaning of verification and validation is the same, namely the determination of whether performed activities have produced the required result. The distinction is determined by the moment of control and the type of requirements (BAM, 2008).

Verification includes all activities aimed at demonstrating that all requirements are met, including the derivative requirements that were necessary in the design process. So, it includes checking whether the result of work meets the applicable requirements. At the end of each phase this must be checked. It has the aim of preventing errors from occurring during the technical process. Verification does not necessarily involve an additional calculation, measurement or analysis. Sometimes the simple statement that a requirement can be met, for example, based on an explanation and a calculation with result in a draft note, or on the basis of visual inspection, may suffice. The results of verification's are recorded in Verification Reports and Verification Notes (BAM, 2008).

Validation includes those activities that are designed to demonstrate compliance with customer requirements and wishes. These requirements are not always specified in measurable criteria. Validation is a special form of verification based on checking whether the initial requirements and wishes of the customer are met (BAM, 2008).

A.0.4. The process of System engineering

SE is a systematic way of working that will be used throughout the entire project process. However, for the design the process of requirement analyses (A.0.4) and design (A.0.4) is important to consider of the technical process, see figure A.2.

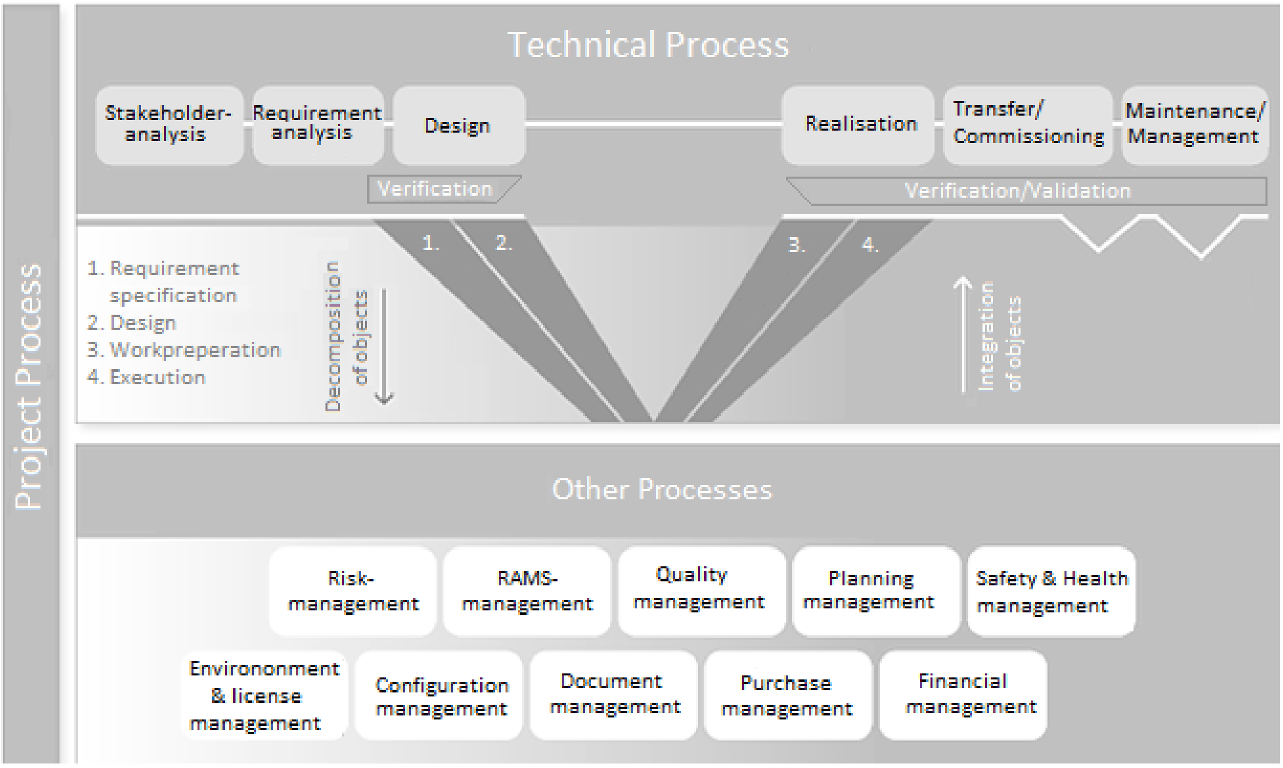


Figure A.2.: Project Process (BAM, 2008)

Requirement Analysis

Delivering a successful project means delivering on time, on budget, with the required quality and while meeting the customer's expectations. To do so, it is important to get back to the basics and define, communicate and get a clear vision on the goal of the project. To establish the vision, at the beginning of the product time must be spend on clearly defining aspects of the project and product scope (Mirza et al., 2013). This is done during the requirement analysis using the (demand) specification in which the client has written down his requirements and those of the relevant stakeholders. The remaining contract documents are linked to this (BAM, 2008).

A good requirement analysis, combined with the award criteria, gives an early insight into the opportunities and limitations of the project. This insight is important to determine the strategy according to which the project is being developed.A thorough analysis of the requirements of the client gives the possibility for correction by the client for unclear or "non-SMART" formulated requirements and obtains insight into the completeness and hierarchy of the requirement set. If requirements are not SMART or unclear, it is important to ask for clarification, this to minimize the chance of discussion with the client about whether or not to meet the requirements. Of non-SMART requirements, it is not possible to objectively prove that they meet the requirements. The requirement analysis is divided into four steps (BAM, 2008):

- Analyzing and structuring requirements;
- Check for unambiguity and formulation;
- Consult with the client;
- Processing and managing requirements.

Generally, the specification of the system consists of a set of different requirements at different levels of detail. The understanding is difficult and adding structure makes it easier to get an idea of the (design) freedoms and the risks of the project. The following characteristics of each requirements need to be considered and can be stated in a requirement analysis table (BAM, 2008):

- **Allocation:** Which organizational unit is responsible for meeting the requirement?
- **Type:** By determining the type of the requirement, contradictions may become visible. Five types can be defined, namely functional, aspect, object, interface and process requirements.
- **Level:** Understanding the levels of requirements gives insight into the design and solution freedom. The levels that can be found from little to much detail are policy, performance, construction, material and building material requirements.
- **SBS:** Is it possible to link the requirements to one or more objects?

Design

The design phase is the phase that has the attention in this research. The purpose of the design process is to find a concrete, realizable solution that meets the requirements of the customer and its derivative specification. The design process becomes more detailed while the process continues, until the correct level of detail is reached. The end design is usually so detailed that it can function and adds value. In practice, the detailed level of the design will be equal to the detailed level of the requirement specification. There is an interaction between the design and the process of specifying. Designs choices lead to new derivative requirements, which form the basis for design choices at a lower level. Each time an object is split, the process for specifying requirements must be followed. After this process a new design is made at the new detailed level (BAM, 2008).

Deduction of requirements The functional analysis and derivation of requirements can be split up into three different steps (BAM, 2008). Starting with establishing the starting point. The basis for deriving requirements is the requirement specification as determined after the requirements analysis. In practice, performing a functional analysis is considered useful if the client has given only functional requirements and not when the question is detailed and limited. The next step thus could be performing the functional analysis. The third step is deriving requirements, which implies that requirements are further specified in underlying requirements. In practice, this is equal to the detailing of the design. Design choices limit the solution area and require further development of the design. The relationship between elements from the SBS and requirements from the requirement tree is written down.

Design method The design process can be divided into six different steps which will be discussed.

1. Setting up the design basis

At the start of a design a design basis is made. This can be made for the entire project or for a certain item. A component to be designed can be an object, but also a combination between objects. The designers must have enough information to make a good design for the particular object and this information mostly include assumptions, standards, binding documents, requirements and interfaces (BAM, 2008).

2. Setting up the verification plan

Before the design starts, a verification plan must be set up. This must be done for each object to be designed. In addition to the actual design, this draft document describes the accountability and explanation of the design. The verification plan must contain among other this a unique identification number, a description, the to be used verification method, the responsible person and a reference to the accompanying work package (BAM, 2008).

3. Think of variants, compare and choose

It is important to try to determine different design variations for an object. If a variant that seems very interesting cannot meet the requirements, it should be considered to submit an amendment to the client. The critical requirements, the cost indication and the risks of the various variants must be compared and on the basis of this a variant is chosen. This can be done by a trade-off matrix where the choice can be retrieved afterwards (BAM, 2008).

4. Elaborating the chosen variant

The selected variant must be worked out to the required level of detail in the particular phase. Ultimately, the elaboration must be such that there are no ambiguities in the execution. The effect is laid down in a draft note consisting of drawings, calculations and an explanation (BAM, 2008).

5. Performing the verification

An essential part of the design process is verification. Regular checks are made on whether the design choices fit within the requirement specification. Upon completion of a design phase, verification takes place according to the verification plan and recorded in a verification report. This will prevent mistakes that are found at a late stage, resulting in high recovery costs. Verification usually takes place after completion of a design phase. Certainly, if different parts are designed by separate teams, these completions is the time to merge the split-downs into one whole (BAM, 2008).

If the verification indicates that a requirement is not met, action is required, which may include adjusting and/or completing the design, performing an additional calculation check, and re-verifying. The results of the revised verification are recorded in a new verification report corresponding to the original report. In the design process also regular checks of design results take place. These interim checks take place prior to formal verification and the expert's expertise plays an important role. This is called 'rating on accuracy', and three levels are distinguished,namely checking on principles level, checking details or checking the design via other angels (BAM, 2008).

6. Checking the completeness

The completeness is checked by the verification note, which is a comprehensive overview of the planned and completed verification's, examinations and inspections throughout the project. Selections are made, for example, by object or phase. This makes it easier to verify that the verification's have been performed (BAM, 2008). It must be checked whether attention is focused on risk management and RAMS (Reliability, Availability, Maintainability and Safety) management, because this is important especially in the design phase because it helps to make the consequences of design choices more visible for the follow-up of the technical process and to support choices (BAM, 2008).

Final result design

The final result of the design process consists of an design based on the implementation of the system to be built. This is laid down in a design document consisting of drawings, calculations and reports. The difference with the outcome of a traditional design process is that the relationship with the WBS, OBS and the requirement is written down in a recognizable way (BAM, 2008).

B. Optimal approach 1: Configuration Change Management

In this chapter the first approach is explained in more detail. The chosen approach is Configuration Change Management, (CCM), defined as: *"the Configuration Management process of administering formal change management procedures. Formal process activities include: receipt and logging of new document work products or CR to current baselines, coordination and conduct of reviews of proposed changes, approval of changes by an approval authority, follow-up corrective actions, incorporation of changes into current baseline, and formal release for project decision making"*(Wasson, 2016).

First in B.0.1 it is explained how System Engineering focuses on changes in a project and how Configuration Change Management is part of this. Then in B.0.2 it is explained what is meant by the term configuration. In B.0.3 the Work Breakdown Structure is discussed in relation to Configuration Change Management and Configuration items are introduced. After it is clear what configuration is and what configuration items are, in B.0.4 Configuration Management is introduced in more detail, followed up by B.0.5 which focuses on the steps to follow for setting up Configuration (Change) Management. Two important parts of the latter are the establishing of baseline, explained in B.0.6 and processing changes, discussed in B.0.7. The processing of changes will be discussed on the basis of different steps to take, but also in B.0.8 the Configuration Control Board is introduced and in B.0.9 change proposals are explained in more detail.

B.0.1. Configuration Management as part of System Engineering

Projects using SE analyze the problem and changes in a project, related to the wish of the client. Therefore, the customer demand is important to consider. SE is phase transient and focuses on optimizing the system in all its phases and on cooperation with the entire life cycle. There is a lot of transmission between teams. Therefore, working clear and explicitly is needed for making the information transmissible. Verification and validation is supportive to this (Werkgroep Leidraad, 2013).

When a project is organizational or technically so complex that change management and management of versions make a critical success factor, it can be decided to explicitly apply CM (BAM, 2008). The implementation of CM is needed in many projects; however, the implementation is complicated and challenging to many companies in different branches (Müller, 2013).

CM was introduced with the arrival of SE (BAM, 2008). It is part of SE and is a process of maintaining the integrity of the system while handling changes to both the data-set and real world engineering system (Lindkvist et al., 2013). CCM is the part of CM that focuses only on changes.

B.0.2. Configuration

The configuration is the whole of objects which together make a system, supplemented with relevant documents and design considerations and cost estimates (Werkgroep Leidraad, 2013). The configuration of a project is a *'documented determination of the status of a design or object at a certain moment in time'* (BAM, 2008). Configuration can also be defined as the relative disposition or arrangements of parts of a CI, which forms a part of the total system. The relative disposition or arrangement of parts is called the baseline. So, *"Configuration Management focuses on managing and controlling the physical and functional make-up, defined in the baseline, of the configuration items that compromise the system"* (Faulconbridge & Ryan, 2014).

It is important to know the configuration of a system beforehand of the project and recorded in, for example, a configuration management-database as fast as possible. Throughout the entire life-cycle it is of importance to make the configuration of the system clear and traceable this so the project staff has throughout the systems lifetime always access to accurate data of all available CI. It is intended that all parties involved use the same information at all times, an in order to have this, agreements must be made on the interface between client and contractor. A clear vision of the configuration helps making it easier to handle in a structural manner when changes appear (Werkgroep Leidraad, 2013). A simple appointment to determine the configuration at a certain time is, for example, the periodic authorization of a document list. Such a list contains all documents used for a design. In addition, the configuration of objects is determined by the different work packages (BAM, 2008).

B.0.3. WBS and configuration items

The logical design is stated in the RBS and the physical design in the Work Breakdown Structure (WBS). The WBS documents the necessary products and associated work packages to produce the system (Khan, 2006). During the requirements allocation, requirements are grouped and combined into logical subdivisions. They are based around a preliminary physical architecture which is formulated by the designers. The design of the system elements can be determined with these groups of functions, which represents the translation form logical to physical design. The subsystems can be broken down further into what is called a Configuration Item(CI) (Faulconbridge & Ryan, 2014). Configuration data is linked to each CI and the technical configuration data is on its turn related to the system requirements (Werkgroep Leidraad, 2013).

To achieve the project's objective, project tasks are divided into separate work packages and then integrated into the final system. (Mirza et al., 2013). These work packages report the work that is needed to produce all the CIs or subsystems. The WBS contains also the work that is needed for the design, development, integration and testing of the CIs (Faulconbridge & Ryan, 2014). Sometimes a subsystem is one CI but usually it will be broken down into multiple. They are selected or designed to perform the group of requirements that are assigned to them. The configuration of each CI is managed as a separate item for the development, design, documentation, review, audit, construction and test (Faulconbridge & Ryan, 2014). At the same time, the physical design is documented using an allocation matrix and the subsystem or CIs list. A detailed WBS allows for more accurate management but also requires devoting more resources to compile and gather information. Therefore, there must be a balance between the desired degree of control and project reporting requirements (Khan, 2006).

Configuration identification focuses on selecting CIs during the preliminary design. Selection of these items is a design decision which is documented through the analysis and allocation of the SRS. The selection of CIs is based on several factors: complexity, interfaces, use/function, existing items available, commonality, criticality, maintenance and documentation needs. The first reason is thus the complexity, namely, in large complex projects, SE is used to make the design problem manageable. Therefore, CI's should be small enough so it can be managed by an individual or small team. However, due to many complicated interfaces, there is always a trade-off between complexity and the number of interfaces required. The division into CIs could also help for commonality, which has the potential to reduce technical risk in acquisition and reducing the issues in the through-life support. The determination and selection of these items is a decision of the design team to satisfy the requirements in the best possible way. However, this is sometimes influenced by the client. The selection progress has an impact on the acquisition process, the operational use and the system support activities (Faulconbridge & Ryan, 2014).

B.0.4. Configuration management

A contract specification describes the requested system and contains a cut out of the system specifications. Incorrect or missing information and new insight could lead to an adaption of the contract specification. When the wishes of the client are changing, this must be documented using requirement management and CCM. The changes assure that the requirements are adjusted, added or expired (Werkgroep Leidraad, 2013).

CM establishes and maintains control over requirements, specifications, configuration definition documentation, and design changes.The objective is to ensure effective management of the evolving configuration of a system during its life cycle(Haskins, 2010). It therefore aims at identifying the characteristics of the selected system components during the acquisition phase. These characteristics can be both functional and physical and are written down as CI.

CM ensures that product functional, performance, and physical characteristics are properly identified, documented, validated, and verified and with that it establishes product integrity. Changes to these product characteristics are properly identified, reviewed, approved, documented, and implemented (Haskins, 2010). So, CM tries to control changes CCM helps maintaining the changes in the system design together with the proposed alternatives and reasons for the certain change. It reports on the change processing and implementation status (Faulconbridge & Ryan, 2014). It thus involves capturing changes to that status and understanding the consequences. The purpose is to ensure that everyone is always working with the right principles and data. Furthermore, it makes sure that changes to assumptions and data are handled using controlled procedures. This will prevent errors. In addition, when errors or changes occur, it is easier to see what the consequences are. CCM can therefore play a useful role in communicating with the client. CCM ensures that the project staff can effectively use the same, accurate information. It realizes that the sub-products in a project mutually agree and that changes are controlled and implemented. This will prevent the happening of mistakes (Werkgroep Leidraad, 2013).

It is important to include moments in the process to freeze data and starting points. At these moments, also referred to as baselines, the configuration is determined (BAM, 2008). A clear vision of the configuration helps making it easier to handle in a structural manner when changes appear. A proposal for amendment is followed by an impact assessment which is based on accurate and right information. On this basis, it can be decided whether changes are acceptable and could be managed when implemented (Werkgroep Leidraad, 2013). CCM can be seen as an engineering management or a technical engineering process. The engineering management process expects that the variance due to dynamic changes, together with its engineering data like design documents, is controlled for over time. The technical engineering domain focuses on defining and configuring sales and design parameters (Müller, 2013).

B.0.5. Setting up Configuration Management

Part of CM is CCM. How exactly CCM is accomplished is something that must be determined within each project. Which baselines will be used must also be determined, together with which information must be part of this, and how changes are made (Werkgroep Leidraad, 2013). CCM therefore implies that the following steps are taken (BAM, 2008):

1. Determine the configuration at a certain time in a baseline;
2. Tracking changes to this configuration;
3. Keeping the documentation associated with the configuration;
4. Check (audit).

The establishment of baselines and the processing of changes are two crucial parts of CCM and will therefore be explained in more detail in B.0.6 and B.0.7. In order to control changes, CM has to be set up correctly, which is done by the following five steps:

1. **Plan**.

CM begins at the beginning of the project when the project management plan is put together (Harrin, 2016). The processes, procedures, tools, files, and databases for managing the project assets need to be created. Furthermore, agreement must be reached on what assets are important, how they will be defined, how they will be categorized, classified, numbered, reported, etc. The results of this up-front planning are documented in a CMP (Mochal, 2007). The CMP is part of the project management plan. The CM process and approach must be documented so that the project team knows what is happening and what is expected (Harrin, 2016).

So, the initial planning efforts should be defined in a CMP which identifies the required resources, defines the to be performed tasks, describes organizational roles and responsibilities, identifies CM tools and processes, and identifies methodology, standards and procedures to be used (Haskins, 2010).

2. **Identify Configuration Items**.

Each item that needs CM is given a unique identifier so it can be tracked. Use the product breakdown structure or the WBS, because these are already numbered. CIs relate to project requirements which can include (Harrin, 2016):

- Project documents
- Products – physical and virtual
- Anything that is going to be created or changed
- Anything that requires limited access by for security or safety reasons

3. **Track**.

It's important to understand the baseline for all configuration items. The purpose of the tracking processes is to ensure that all changes to a configuration item can be tracked throughout the project (Mochal, 2007). The trace-ability matrix must be established for this point. The project manager is responsible for the CM on the project, but maintaining the trace-ability matrix and version control for the items can be done by someone else (Harrin, 2016).

4. **Control the records and manage**.

Configuration records need to be tightly controlled to ensure there is a full audit trail between the original requirement and the final version. This is done through version control. This includes numbering documents, lock documents while editing, and physical security of the project's assets. This part of the process links closely to the change control process (Harrin, 2016). So, processes and systems are needed, designed to identify when assets are assigned to the project, where they go, what becomes of them, who is responsible for them and how they're disposed of. Since a project has a beginning and end, ultimately all the assets need to go somewhere. Each major deliverable of the project should be dissected and it must be shown where all the pieces and parts came from, and where they reside after the project ends (Mochal, 2007).

Managing assets means ensuring that they're secure, protected, and used for the right purposes (Mochal, 2007). This is called status accounting which means that you can see the status of any item whenever needed. This is linked to the trace-ability matrix. When an item is changed or being worked on, the matrix should be updated so that it's clear what is happening to the item. Then the latest version is logged too, so that the project team can always refer to the current version (Harrin, 2016).

5. **Audit**.

Auditing involves validating that the CIs at any given time are the same as what was expected. These expectations are based on the original baseline, plus any change requests that you have processed up to the current time (Mochal, 2007). So, CIs are audited at their final point in the process to ensure that what was delivered meetings the original requirements, regardless of the iterations along the way. Audits are done by an independent party outside of the immediate project team (Harrin, 2016).

B.0.6. Establishing baselines

The objective of CM is to ensure effective management of the evolving configuration of a system during its life cycle. Fundamental to this is the establishment, control, and maintenance of baselines. Baselines are reference points for maintaining development and control(Haskins, 2010). Baseline is a term that is introduced in for management of the scope. The baseline is the position in the project with which the project team moves forward in time as part of the system acquisition (Faulconbridge & Ryan, 2014). A Configuration Baseline can be defined as *'A snapshot at a specific instant in time representing the current state of a system, product, or service's Developmental Configuration technical work products such as specifications, designs, drawings, schematics, parts lists, analyses, trade studies, and so forth that are new or have been revised, reviewed, approved by an approval authority, and released for project decision making'* (Wasson, 2016). The baseline is the cross section of the CCM-database on a particular moment and therefore gives the formal frozen status of a system. It results in a complete system documentation at a certain time, determined by the parties involved (Werkgroep Leidraad, 2013).

Baselines are established by review and acceptance of requirements, design, and product specification documents. The creation of a baseline may coincide with a project milestone (Haskins, 2010). When the contract definition is done, the first baseline arises. The freezing of the configuration is done from the analysis of the needs and functions. In the concept definition, the entire dossier will be frozen for the first time. The information from the process is to be found in the dossier. When changes are needed or occur, an impact analysis is conducted. When a new functional concept is needed, this changed is called a 'Verzoek tot Wijziging' or CR (ProRail, 2015).

Each baseline is placed under configuration control. When changes occur, it can only change the baseline through a documented change management process. Changes throughout the system development must be managed by a formal process to ensure that the impact is researched and handled correctly (Faulconbridge & Ryan, 2014). Some documents keep developing next to the baseline, like the planning of the project. A baseline is primarily used to be able to make decisions, for example about continuing to a different phase. A baseline must be accompanied by performance requirements and acceptance criteria. In complex projects an iterative process repeats itself on multiple detail levels. This leads to a new specification of the system on each level and therefore a new baseline must be established each time. This is to hold gain on each iteration of design and research. At the same time, aspects must become more detailed (Werkgroep Leidraad, 2013).

The freezing of the configuration is a cut out and should be the baseline of the system development and CRS. The CRS and the system development must be written down into one or multiple contracts and specifications. When multiple system specifications in multiple contracts are written down, then the interfaces must be monitored. A baseline supports decision making and comes with certain result-obligation and acceptance criteria (Werkgroep Leidraad, 2013).

FIS is central in the concept definition development phase. SE helps by determining the degree of detail needed in order to decide on the effort which have to be delivered to exclude unknowns and risks in the design. The depth and elaboration can differ in order to make the risks manageable. This helps in determining whether the feasibility and fitness of the design is sufficient and to make a reliable cost estimate (ProRail, 2015).

B.0.7. Processing changes

Both the contractor and client can request changes. If a change occurs, an adjustment in the design can be necessary. Then also an impact analysis is needed to indicate which requirements or changes are added and tests the consequences of this. The analysis also indicates which documents need revision. It may happen that a chosen alternative of the contractor does not meet the contract specification. This is possible when optimization takes place, or when the contract specification turns out to be not feasible. If the deviation in the specification is non-recoverable, the contractor must tune a change with the client, that leads to adjustment of expiry of the relevant claim of the contract specification. The chosen alternative will be discussed with the stakeholders. Furthermore, it is possible that a change in requirements, design or realized products result in (re)execution of validation and/or verification (Werkgroep Leidraad, 2013).

There will always be a need to make changes; however, Systems Engineering must ensure that the change is necessary, and that the most cost-effective solution has been proposed. CCM must (Haskins, 2010):

- Identify and document the functional and physical characteristics of individual configuration items making them unique and accessible in some form;
- Establish controls to changes in those characteristics; ensure consistent products via the creation of baseline products;
- Maintain enough information to ensure system and product integrity;
- Implement a configuration control cycle that incorporates evaluation, approval,validation, and verification of CRs;
- Record, track, and report change processing and implementation status and collect metrics pertaining to change requests or problems with the baseline.
- Perform Configuration Audits associated with milestones and decision gates to validate the baselines.

B.0.8. Configuration Control Board

It is recommended to establish a CCB with representation from all stakeholders and engineering disciplines participating on the project (Haskins, 2010). The CCB is normally charged with the responsibility to manage the changes that come up during the process. The reason for changes varies, ranging from a change to one of the user requirements, to a change in available technology. They CCB investigate the change and decide how big the change is (Faulconbridge & Ryan, 2014).

The CCB should meet regularly to review the process of the changes that are in progress or are proposed. Any party involved can request a change, including the client. These requests must contain sufficient information to decide if the change can be approved. It must contain a reason for the change and a statement outlining the change. The alternatives which are available must be detailed together with the preferred alternative. The preferred detail must show why it can be implemented successfully and how it impacts the system on its turn, especially the impact on other CIs in the design and on the interfaces requirements as described in the baseline documentation. Changes to the baseline documentation should also be included in the proposal for change. To see the impact, trace-ability across the different levels of design is necessary. Sometimes teams focusing on the interfaces are organized so that they are handled correctly and completely. Sometimes it becomes clear that specifications do not comply with the configuration baseline. These non-conformance's could be accepted by the client without going through the change process. These special cases are called a CR (Faulconbridge & Ryan, 2014). CRs are typically initiated as a result of an investigative analysis triggered by a problem report. CRs are reviewed and approved, rejected, or placed on hold by the CCB. They are normally tracked to completion (Haskins, 2010).

B.0.9. Change proposal

For a change proposal a formal document is submitted requesting and specifying a corrective action to a baseline document that contains a latent defect such as an error, inaccuracy, deficiency, design flaw, and so forth. There are two types of change proposals. The first one is the Engineering Change Proposal, or in Dutch the EOW, and the second one is the Contract Change Proposal. They can independently exist, but often coexist since an EOW mostly force a contract change. The contract change results mostly a change in cost or schedule. The content of EOW is stated in the contractual document and must contain sufficient information to evaluate and approve the EOW.This must contain the reason for change, the alternative solutions and the preferred one. Details of the trade-offs and a statement on the impact, must also be included. Furthermore, an impact assessment of the impact on other aspects of the design, the interfaces with other CIs and the likely changes required to the documentation set, must be included. If changes on cost or schedule will follow from the change, the impact of this must also be included in the EOW (Faulconbridge & Ryan, 2014).

An EOW can origin from many things. The customer may request one to address a change in requirements or a change in scope, or an unexpected breakthrough in technology can result in the proposal of an EOW by the supplier, a supplier may identify a need for changes in the system under development, and an EOW can originate to address those changes. These circumstances can lead to a change in scope or requirements and this is reason to conduct an analysis to understand the impact of the changes to the existing plans, costs and schedules. Before an EOW is put into effect, it must first be approved. A minor change of scope usually does not require an EOW, but does require an engineering notice (Haskins, 2010).

There are two sort of changes. Class 1 changes are more major and include changes to form, fit or function of the system which impacts on its turn the cost and schedule. The client must be involved by the approval of these changes. It will be rare that a class 1 EOW would be approved and incorporated with no cost and no impact on the schedule. Class 2 changes are more minor and include all other changes to the system configuration. The client must be involved for information purposes. The customer is also involved in the process of investigating the class of a change. The client can effectively loose visibility into class 2 changes and lose control of the change and its impacts (Faulconbridge & Ryan, 2014).

C. Optimal approach 2: Information management

In this appendix the concept of Information Management will be explained in more detail. First in C.0.1 the need for managing, reporting and documenting is made clear, this in order to keep control of the scope. Then in C.0.2 the tool Relatics is introduced together with the principles of information management. This is explained in more detail specified on System Engineering in C.0.3. Finally, other users of the tool Relatics are introduced in C.0.4.

C.0.1. Need for managing, reporting and documenting

The need to report and document all changes in a careful way follows from the tensions about change and the fact that changes in the construction industry are inevitable (Hwang & Low, 2012). In order to minimize the impact of changes, it is important to record, evaluate and manage all changes to ensure that the effect is appreciated and that the party responsible for carrying out the change, Sweco in this case, is reimbursed when the change is an addition to the original specification (Lester, 2006).

The reviewing and approving of design documents should be done in a better way. This include any delay caused by the consultant engineering in checking, reviewing and approving the design submittals prior to the construction phase. Clients should consider minimizing change orders to avoid any delays due to this. They also need to avoid delay in reviewing and approving design documents (Assaf & Al-Hejji, 2006).

To minimize the impact of changes on a project, change management should be implemented. This must focus on minimizing the negative impact of necessary changes and avoid unnecessary costs. It does not seek elimination of all project changes. However, in practice, there is currently a lack of standards for project change management and methods. This results in poorly managed changes on an ad hoc basis (Sun et al., 2006). The research of Kuprenas and Nasr (2003) also recommend the implementation of management tools to control scope creep. One important focus point is the formalization of pre-design procedures, guidelines, responsibilities and deliverables. However, this turns out to be the most difficult improvement. The culture is mostly to get the most perfect design, even if this causes rework and changes in a late stage. This follows from a strong sense of professionalism and because design engineers were normally not involved in the construction phase (Kuprenas & Nasr, 2003).

The efficacy of change management can vary widely in practice since projects vary in project nature, industrial type, project complexity, project size, contract methods and the level of experience of project participants (Hwang & Low, 2012). So, building an effective construction change management system turns out to be very challenging. A mature software tool that deals with this issue, is hardly found on the market (Hao et al., 2008).

Next to change management, information management is needed. Information about stakeholders, requirements, design components, risks and verification's is stored in numerous documents, spreadsheets, drawings and applications. One of the major challenges these days is to manage all this information effectively. In order to make the appropriate decisions, project members need to have relevant and up-to-date and accurate information instantly available. However, this is not always the case. Information is often scattered and inconsistent while relevant document frequently circulate in multiple versions. Inconsistencies are a risk that follow from this. Significant search efforts, project delays and failure costs are the result of having inadequate information management. Not having the right information might result in a project outcome that does not correspond with the initial idea (Relatics, 2017).

A common approach to deal with all information, is organizing all documents. However, this does not organize the information inside these documents. Documents often contain multiple subjects and heterogeneous information. Classifying a document as a whole therefore ignores its internal information and makes this information untraceable and unmanageable. Standard software does not provide the answer either. Its information structure rarely matches the ever-changing information needs of a specific project. As a result, only a limited scope is covered by those standard complex solutions. A great deal of information is still left un-managed. A paradigm shift is therefore needed (Relatics, 2017).

C.0.2. Information management as Tool

Information management must focus on managing all information instead of only the documents. Relatics is a web-based semantic database which makes capturing, managing and unlocking information possible in an unambiguous and consistent way. It is a cloud platform that is used by large projects in the construction, infrastructure and civil engineering industry to control information within projects.

Information is not stored in a rigid data structure, but as a collection of relationships. The relationships that can be set up can occur between parts, requirements, tests and responsibilities. Documents such as emails can also be integrated in Relatics and connected to other parts. All information relevant to a part can be explored by following the tiers in the grid connected to it. This results in no seek time, no mistakes and no surprises (Relatics, 2017).

Project members can use information management to manage their requirements, tests, risks, tasks and other project objects. This is managed in a coherent network of explicitly described information, which helps projects to be realized faster, with a better outcome and less failure costs. It will help reduce the lead time and provide an increase in control and improve the quality and compliance. The tool Relatics is ISO/IEC 27001:2013 certified (Relatics, 2017).

A tool for information management would be based on four aspects:

1. All data in hands
   It must enable to store all kind of project information. The tool integrates the information in a structured and traceable way. Project changes and requirements are therefore directly visible, which saves time and ensures that the process is less sensitive to failure. Furthermore, due to the accessible and consistent user interface, relevant data is found fast when exploring the information.

2. Adapts to information needs
   There must be a flexible architecture that can be tailored in such a way that it fits to the needs of a certain project. The end user has control over the information needs. Simultaneously with working on the project, information can be changed or enriched which makes the information up-to-date. Information needs become aligned with business needs and project managers are from the start of the project in control.

3. Simple and intuitive
   It must be a simple system what makes it easier to work with and therefore decreases the risk of mistakes. It increases the control of a project and gives more security. New users do not require training to work with the system and it is therefore easily adopted.

4. Collaboration focused
   Information management focuses on a good collaboration between parties. It is believed that the outcome of the project benefits from this. The tool increases the collaboration between the project members, by the fact that it is web based, always accessible from multiple locations and devices, and providing a stable platform. It frees the project of numerous spreadsheets and individual applications. It is also easily integrated with external systems that are often used, like Sharepoint.

C.0.3. Using a tool of information management for System Engineering

Information management provides opportunities to manage the information according to SE and makes projects manageable. Requirements, stakeholders, functions, design components, interfaces, test, activities, work packages and risks are elements for which information can be captured. Throughout the life cycle relations can be set up between different parts of the projects. This results in a benefit for SE on certain aspects:

- Information can be organized in a explicit, coherent network of requirements, design components, functions and other information;
- Relatics as tool can be shaped conform the standards of ISO 15288 and INCOSE Handbook SE and project-specific changes can be made to the system;
- The application can be extended during the life cycle of the project;
- Information can be looked at from all possible perspectives, this due to the fact that there is comprehensive trace-ability;
- There are checks available that ensure that the information is always accurate, complete and consistent;
- High quality deliverables can be generated such as complete requirement specifications, test plans, risk registers, contract documents and interface reports.

C.0.4. Relatics used by other companies related to Sweco

The tool Relatics is the most commonly used tool for information management. Therefore examples will be given of companies that also work with information management in the form of using Relatics. Relatics is used by Witteveen+Bos. They started using Relatics in 2011 for the support of the SE process. It is mostly used to set up contracts. They have one single template and this is adapted to the project specifics. It is not the only information system in projects. They state that the most fitting information system must be chosen for each type of data. These different systems must be linked with having the data on one place (Visser, 2016).

Antea Group combines strategic thinking and multidisciplinary perspectives with technical expertise and pragmatic action. Mark Melis of Antea Group states the following: "Antea Group aims to widely adopt the Systems Engineering method and supports this with Relatics software. This allows us to manage and structure complex projects and to meet the requirements and wishes of our customers. Relatics is user friendly and can be completely configured to the needs of the user" (Melis, n.d.).

Ballast Nedam operates mainly in the Netherlands in the fields of mobility, housing, employment, leisure and energy. Ballast Nedam operates internationally in various areas of expertise. Paul Warmerdam of Ballast Nedam states the following: ”Relatics provides us with the flexibility we need to build our own work space to control our processes. The work spaces help Ballast Nedam to achieve enduring quality for our clients and the society” (Warmerdam, n.d.).

Johan Hekker of Royal HashkoningDHV states the following ”As a multidisciplinary consulting and engineering firm we successfully launched the Relatics environment within our infrastructure projects (highways, bridges, tunnels, light and heavy rail). We use Relatics mainly for contract management (performance auditing) and requirements management (systems engineering). The fact that Relatics is web based makes the software even more useful. Relatics is very easy to use, flexible and scalable. We highly value the possibility to adjust the software during the course of a project to adhere to changing needs.Therefore we use Relatics in a growing number of both Dutch and international projects. Over the years we met in Relatics a very trustworthy partner” (Hekker, n.d.)

ARCADIS is a leading and global, knowledge-driven company. They provide design, consulting and engineering services to companies in the areas of Buildings, Environment, Transportation and Water. Ruud van Tongeren of ARCADIS states the following: ”The advantage of Relatics is that our information is now centrally managed, and accessible from every location. Employees can work simultaneously and since each user is provided with custom roles related to the information he or she is responsible for we keep overall control of the information” (van Tongeren, n.d.).

ProRail is responsible for the construction, maintenance, management and security of the rail network of the Netherlands where the rail network is at the heart of transportation. Maarten Vullings of ProRail states the following: ”Our activities are diverse and include allocating parts of the railway network infrastructure, and building and maintaining the railway network infrastructure and train stations. To manage our construction projects we use Relatics” (Vullings, n.d.).

Rijkswaterstaat introduced Relatics for a wide variety of major infrastructural projects. Among other projects, Relatics is used for the expansion of the road between Schiphol-Amsterdam-Almere, broadening of the road A15 Maasvlakte - Vaanplein, reinforcement of the ’Afsluitdijk’ and the construction of the second ’Coentunnel. Relatics helps Rijkswaterstaat with keeping projects manageable. Arno Eversdijk of Rijkswaterstaat states the following: ”The diversity of information for all our projects is enormous, various stakeholders are involved and with Relatics we keep it manageable” (Eversdijk, n.d.).

D. Optimal approach 3: Partnering

D.0.1. Partnering

The construction industry is a very competitive high-risk business and faces many problems, such as little cooperation, lack of trust, and ineffective communication. This results in adversarial relationships resulting in project delays, difficulty in resolving claims, cost overruns, litigation, and a win-lose climate (Chan, Chan et al., 2004).

Cooperative, strong relationships have proven to be far more beneficial than the competitive, adversarial behaviour characteristic (Chan, Chan et al., 2004). Research has suggested that performance, in terms of cost, time, quality, buildability, fitness-for-purpose and many other criteria, can be drastically improved if participants adopt more collaborative ways of working (Bresnen & Marshall, 2000). The research of Larson (1995) shows that construction projects that were managed in an adversarial fashion had the lowest level of success, and the partners approach reported the greatest level of success across all criteria (E. Larson, 1995).

The main reason for the introduction of partnering is the need to move away from the traditional adversarial relationships in construction contracting and to resolve problems jointly and informally through more effective forms of collaboration (Bresnen & Marshall, 2000). Few industries suffer more from conflict than construction and therefore the industry is expected to gain from a partnering approach to procurement. Partnering is increasingly being used on construction projects and involves the parties to a construction project working together in an environment of trust and openness to realize the project efficiently and without conflict. Partnering is an arrangement between client and contractor which can be either open-ended, for a specified term or a single project (Black et al., 2000).

The definition developed by the Construction Industry Institute is the most widely cited and states: *"A long-term commitment between two or more organizations for the purposes of achieving specific business objectives by maximizing the effectiveness of each participant resources. This requires changing traditional relationships to a shared culture without regard to organizational boundaries. The relationship is based on trust, dedication to common goals, and an understanding of each other's individual expectations and values"* (Construction Industry Institute, 1991).

D.0.2. Benefits

Partnering creates an effective framework for conflict resolution, improved communications, reduced litigation, and cost containment on potential overruns. Partnering leads to win-win situations and synergistic teamwork. It aims to generate an environment of trust, open communication and employee involvement. It has evolved as an innovative approach and lowers the risk of cost overruns and delays. Also, it increases the opportunity for innovation, because of the open communication and trust (Chan, Chan et al., 2004).

Next to a less adversarial relationship, the most important benefits are increased customer satisfaction and increased understanding of parties. Mutual understand will result in the parties working well together to achieve project targets (Black et al., 2000). It also leads to significant cost reductions and reducing of project times. When contractors are early involved they can assist in giving input and maximizing value engineering. Additionally, a focus on learning and continuous improvement can result in improved quality in both of products and processes. Finally, it can lead to better responsiveness to changing market conditions (Bresnen & Marshall, 2000).

Most benefits focus on better relationships rather than project-based benefits such as improved design, quality improvement, reduced cost etc. It can be argued that a better relationship produces the project-based benefits. Partnering thus can work if all team members re-think their attitude and work to make projects more efficient, successful and free of conflict (Black et al., 2000).

For consultants the problem of making decisions based on incomplete knowledge was the most important factor for partnering. This is a due to the fact that consultants often receive imprecise briefs from clients. However, consultants are less positive about partnering than clients and contractors, due to fears of loss of control. So, clients must recognize their central position (Black et al., 2000). Both parties must also recognize that the behaviours that may facilitate trust in the different parties are not necessarily the same factors. Clients and contractors will see the nature of their relationship differently because they are motivated by different and often competing goals. For the client keys to success could be to secure the completion of a fully-functioning facility for low cost, within a reasonable time frame. For the contractor, the project's goals also involve keeping costs low, honoring the letter of contractual obligations, providing functionality within agreed-upon parameters, and delivering the project on time (Pinto et al., 2009).

D.0.3. Contract starting points

The situation can mitigate or amplify the effects of partnering efforts, for example the degree to which participants are able to choose their counterparts. Most public work contracts are required to be awarded on the basis of a full and open, competitive low-bid basis. Contractors are not selected based on their willingness and demonstrated ability to adhere to partnering ideals. Additionally, the binding nature of a low-bid contractual arrangement prevents the necessary flexibility to work out optimal solutions when unexpected problems arise. Furthermore, low-bid, competitive contracting generally prevents the development of a long-term relationships (E. Larson, 1995).

However, as construction projects generally last for at least a year, and as interaction between client and contractor staff is often quite close, there should be a potential for relational trust to arise also within a single project (Kadefors, 2004). Furthermore, it appears that if a contract is awarded on a competitive, low-bid basis this does not affect the success of partnering efforts. So partnering can be successfully implemented on low-bid projects, and it is not a serious impediment to success (E. Larson, 1995). Finally, the development of trust and collaboration may be strongly influenced by intuitive and emotional reactions and sensitive to behavioural aspects such as shown respect and concern. This supports the fact that also single project partnering can be successful (Kadefors, 2004).

One of the most difficult procedures to establish is the mechanism for adjusting price. It is important that parties do not resort to claims. They must instead seek to resolve cost problems together and it is vital that cost control is maintained. In the event of major problems occurring it may be all too easy for the parties to return to old adversarial habits (Black et al., 2000).

The over-emphasizing of the influence of economic incentives makes clients feel vulnerable in their relations with contractors. To gain better control of project outcomes, clients tend to use detailed contractual specifications and close monitoring of performance. However, these counteract the spontaneous development of trust between the parties. Contractors are likely to be perceived as opportunistic and greedy, and clients tend to become distrustful and suspicious. As a consequence, vicious circles of distrust are likely to develop. Spontaneous collaborative interaction is hindered and project relations may deteriorate rapidly when problems arise. More trust would lead to increased efficiency and especially in projects with great uncertainty it may be wise to avoid detailed contractual specifications. This is due to the transaction costs for renegotiation, and because many time is spent on negotiations potentially threatening to the relationship (Kadefors, 2004).

So, the formal contract can be seen as a crucial safeguard against any breakdown of the partnering arrangement. However, it can also be stated that the behaviour is not determined simply by formal structures and systems, but instead is the result of conscious choices and actions and a complex interplay between structural imperatives and their subjective interpretation and enactment. Therefore, economic conditions which encourage clients and contractors to work together towards a common purpose may be essential (Bresnen & Marshall, 2000). A change therefore could be to move from price as the determinant of bidding success to a package of factors with a greater recognition of good behaviour for partnering to be successful (Black et al., 2000).

Once suspicion has been raised about another person's motives or competence, someone tends to focus on detecting signs of opportunism and bad performance. Distrust will be vindicated, while co-operative behaviour will not be recognized. Negative expectations become self-fulfilling prophecies. However, shown trust communicates to a partner that co-operation is anticipated and tends to be reciprocated with a behaviour that validates trust. This initial risk thus allows the trustee to demonstrate his or her trustworthiness, starting a positive, trust-enhancing process. These strategies can thus be both induced and legitimized (Rousseau et al., 1998). Therefore, not too much faith must be put in economic incentives, and they must not overshadow or replace means intended to stimulate intrinsic motivation and mutual trust (Kadefors, 2004).

D.0.4. What is needed to set up good partnering

First of all, it is important to consider that nothing will change without considerable effort from all parties involved (Black et al., 2000). There is a tension between thinking that partnering can be engineered or not. Some believe that the current behaviour in the construction industry is so deeply ingrained that it will be too difficult to move from such a culture. Trust is then informally developed based on length of relationship and mechanisms that support this like repetition, routine and understanding. Others believe that trust, mutuality, openness and alignment can be engineered in a shorter time frame. They propose using formal tools and techniques to develop partnering that is project specific. These benefits are smaller than longer term arrangements, but it is considered possible. Therefore it can be said that partnering can be engineered for a single project (Bresnen & Marshall, 2000).

According to (Chan et al., 2004) nine factors are important to consider:

- **Establishment and Communication of Conflict Resolution Strategy**
  Because of the discrepancy in goals and expectations, conflicting issues are commonly observed among parties. A control and resolution mechanism and strategy must be developed to deal with problems and conflicts. Coercion and confrontation are counterproductive, because parties try to find a mutually satisfactory solution. So joint problem solving can help for problematic issues.
- **Commitment to Win-Win Attitude**
  Win-win thinking is the essential element of the partnering concept, but equity is important in developing this. Win-win thinking also means having open airing of problems and a non-defensive manner during arguments. Various team leaders should organize their team members to work cooperatively for locating and analyzing the causes of problems and focus on seeking solutions

rather than working out the costs of variation. Solutions are worked out by brainstorming among team members and are put into action quickly. There is a sharing of risks, rewards and sharing of ideas.

- **Regular Monitoring of Partnering Process**
Monitoring methods include the evaluation of team performance, well-defined roles and responsibilities, and determining measurable goals of individual responsibilities. The joint evaluation is an outcome of partnering workshops. Measurable goals should help determining and evaluating individual progress performance.
- **Clear Definition of Responsibilities**
The parties should develop aligned relationships to support the objectives and they should understand other parties' missions and how this relates to their job. Each team-member could make decisions alone because of clear identification of responsibility and accountability. Furthermore, the extent of decision-making and authority must be known.
- **Mutual Trust**
Each party should trust, rely on, and understand other parties' decisions. Issues can be resolved in a timely and responsive manner.
- **Willingness to Eliminate Non-value Added Activities**
There must be a willingness to improve processes, reduce duplication, and eliminate barriers.
- **Early Implementation of Partnering Process**
To ensure the success of partnering, multi project agreements and a list of partner-selection criteria should be developed and started at the design stage.
- **Willingness to Share Resources among Project Participants**
There must be a willingness to share resources because this is seen as critical factor for partnering success. The sharing can benefit overall organizational goals. A task force can be set up to work closely, using all possible resources available.

There must be a change in how projects are managed next to a change in attitude. Instead of treating each other as opponent where the loss of the one is the gain of the other, the parties must work as teammates sharing a common destiny. The adversarial relationships must be replaced by open communication, timely decisions, synergy, joint problem solving, and win-win situations. Teamwork, collaboration, trust, openness and mutual respect are important for this (E. Larson, 1995). Another change is that the emphasis must be placed on costs rather than price. Parties must be encouraged to work together with shared objectives which are formulated not only for cost, time and quality aspects, but also for relations and work processes. Team members will treat each other with respect, solve problems quickly, communicate more openly, and try to help all actors to reach their goals. However, there must be a high level of commitment to these shared goals. (Black et al., 2000). Some of these mentioned factors that are essential to have, are stated below:

- **Adequate Resources**
Resources are not commonly shared with others due to the scarcity and competitiveness of them. These include knowledge, technology, information, specific skills, and capital. However, the complementary resources can be a major criteria for assessing partnering success (Chan, Chan et al., 2004).
- **Support from Top Management**
Commitment from senior management is considered an important factor (Black et al., 2000). In order to generate and sustain changes to a collaborative approach, the top management's support and enthusiasm are vital. However, there is still uncertainty about how to narrow the gap between corporate level and what happens 'on the ground'. This behaviour can be influenced by many factors (Bresnen & Marshall, 2000). As senior management formulates the strategy and direction of business activities, their full support and commitment are needed for initiating and leading the partnering commitment. Each party must believe that the other is reliable

in fulfilling their obligations. Open boundaries are important because it can relieve stress and enhance adaptability, information exchange, joint problem solving, and promise better outcomes (Chan, Chan et al., 2004).

- **Long-Term Commitment**
  Long-term commitment can be regarded as the willingness of the involved parties to integrate continuously to unanticipated problems (Chan, Chan et al., 2004).
- **Effective Communication**
  Effective communication is seen as an important aspect for partnering. Contractors see this factor as crucial to successful partnering. Parties should integrate at all levels and freely share information both formally and informally. The involved parties must be able to ask questions about assumptions made by the other party. The reasoning behind assumptions then become clear and understandable (Black et al., 2000). All parties must be committed to having a good communication, as this plays an important role for problem identification and conflict resolution (Chan, Chan et al., 2004). Team building processes and project-wide communication in the early phases of a project influence the behaviour and knowledge of team members. In this way trust-based collaboration is more likely to arise and persist (Kadefors, 2004). Partnering requires timely, open and direct communication of information. The exchange of ideas, visions, and the overcoming of difficulties will become easier (Chan, Chan et al., 2004).
- **Efficient Coordination**
  Coordination reflects the expectations of each party from the other parties in fulfilling a set of tasks. Measuring project performance in the areas agreed to during the partnering intervals, at agreed time intervals and to feed back the results are essential. Good coordination resulting in the achievement of stability in an uncertain environment can be attained by an increase in contact points between parties and sharing of project information (Chan, Chan et al., 2004).
- **Continuous search for improvements**
  Commitment to continuous improvement is seen as necessary for partnering (Black et al., 2000). There must be an active search for continuous measurable improvements. (Kadefors, 2004). Parties will seek new ways to lower costs and differentiate themselves for competitive advantages (Chan, Chan et al., 2004).

D.0.5. Systems for partnering

Systems for achieving continuous improvement and conflict resolution are needed for partnering. These systems all formalize, plan and structure the relations. This has certain effects as result. First, problems and conflicts can be detected early when relations and project goals are regularly appraised. Relations cannot deteriorate beyond rescue. Second, all team members become engaged in maintaining and evaluating the relation and this should increase the perception of equity and reciprocity and facilitate trust. Third planning project interaction can help to ensure that trust relations are used to enable constructive teamwork that supports overall goals (Kadefors, 2004).

These formal systems, activities and mechanisms are thus used to develop and sustain collaborative teamwork between parties from different organizations. However, as processes of trust development are dynamic, complex and sometimes even contradictory, the effects of partnering can vary substantially (Kadefors, 2004). These mechanisms typically include:

- Pre-project team building exercises and facilitation workshops (E. Larson, 1995),(Bresnen & Marshall, 2000),(Kadefors, 2004)
- Joint goal formulation (E. Larson, 1995), (Kadefors, 2004)
- Periodic assessment of adherence to partnering principles (Kadefors, 2004)

- Escalation guidelines for resolving disputes in a timely and effective manner (E. Larson, 1995), (Bresnen & Marshall, 2000), (Kadefors, 2004)
- continuous improvement processes (E. Larson, 1995)
- Total quality management (Bresnen & Marshall, 2000).
- Information technology, like shared databases (Bresnen & Marshall, 2000)
- Monitoring of relations (Kadefors, 2004)

Workshops can be seen as an approach to reach successful partnering. The workshops establish a cultural change. They should establish the procedures to avoid conflict and devise a mission statement (Black et al., 2000). Typically, an initial workshop is held in the beginning of a project to promote team building and agree on mutual objectives. Parties should express their own goals and the consequences for the other party. This provides a deeper understanding of the project's overall goals and of the difficulties and possibilities involved. Common frames of reference are established which builds trust (Kadefors, 2004). Trust may develop quicker when there is team building and more team members have the opportunity to build relational trust. Design consultants can communicate directly with the client in this way (Kadefors, 2004).

D.0.6. Trust

Mutual trust is one of the most important success factors in maintaining partnering relationship (Wong et al., 2008), (Kadefors, 2004), (Black et al., 2000). It is argued that there is an optimal level of trust, and that the more interdependency there is between exchange partners, the more trust is required so as to achieve efficiency and not miss opportunities for improvement (Kadefors, 2004).

Trust is developed through communication and leads to a positive state that works encouraging for cooperation. Trust thus has a strong positive influence on relationships between team members and is important for critical stakeholder relationships. Trust can bring a reduction in control in contractual relationships. It reduces the transaction costs of monitoring, controlling and makes the relationships therefore more efficient. When trust expands, the costs associated with maintaining the relationship with a partner should drop appreciably (Pinto et al., 2009).

However, trust is regarded as a psychological state, not a behaviour, and it is not equivalent to cooperation. Cooperation can be contractual in nature and not necessarily require trust; it may also be induced by coercion (Kadefors, 2004). Inter-organizational cooperation can be induced through fear of sanctions or other coercive measures (Pinto et al., 2009).

If trust is present, people can spontaneously engage in constructive interaction without thinking about what hidden motives partners might have, who is formally responsible for problems, or the risks of disclosing information (Kadefors, 2004). Furthermore, collaboration between contracting parties is essential to accomplish the sophisticated tasks and trust would help this and improve the project outcome. Currently, trust appears to be a stranger in construction contracting where confrontation remains the prevalent environment (Wong et al., 2008).

The critical nature of trust is summed up by Hartman (2002): "A particular challenge in a project environment lies in the temporary nature of the organization. The time available to build trust is severely limited by the window in which the project must be completed. It is further hampered by the fact that there is a high degree of randomness in the assembly of the organization, especially if we include all suppliers and contractors involved. Not only do we face the challenges of inter-company language and cultural differences, but also we probably have teams and groups of people who are involved for one reason only. They are available and have some or all of the necessary skills to complete the project. This and other specific challenges of project delivery put special pressures on trust building that an operational environment does not necessarily have" (Hartman, 2002).

Types of trust

Wong et al (2008) proposed that trust be categorized into system-based, cognition-based and affect-based trust. The three types of trust co-exist and are mutually dependent. A system is as good as its weakest point and therefore a project manager must focus on all three (Wong et al., 2008).

System-based trust focuses on formalized and procedural arrangements without considering personal issues. These arrangements establish trust and strengthen the communication. To develop system-based trust, organizational policy, communication system and contracts/ agreements are considered as the three major attributes (Wong et al., 2008).

- Organizational policy specifies priorities and explains business procedures. It reflects the expected behavior of the employees and the trust they have in the organization.
- System-based trust can be enhanced through a clearly defined system of communication procedures and approaches. Not only does it facilitate convenient and fast communications, it also reduces arguments that may arise due to distorted interpretations. This can mitigate risks.
- Contracts and agreements define relationships and obligations between individuals. They can reduce uncertainties and minimize, share or shift risks among contracting parties. Contracts and agreements show clearly the expectations and obligations which contributes to fair risk allocation, overall project performance improvement and costs reduction. Fulfillment of the system requirements brings about the confidence of the contracting parties and therefore activates trust.

Cognition-based trust develops from the confidence built upon knowledge that reveals the cognitive bearings of an individual or an organization. The exchange of such knowledge can be attained by interaction or communication, formal and informal (Wong et al., 2008).

- Cognition-based trust describes a trusting relationship that builds on mutual understanding through information exchange and acquaintance. Construction projects require team members of different expertise working together. Thus, good co-operation is desirable. Communication forms the bridge for daily information exchanges because working members have to rely on what they have been provided. Information is very important in the construction industry, especially at the planning stage of construction projects. Clients acquire information from the record of consultants and contractors. When communication is absent, this creates fears of exploitation and betrayal, which would result in avoidance of commitment to the team. Good communication leads to mutual trust and it enables the working members to learn about the needs and capabilities of their partners. In the construction industry, communication has been identified as an effective means to reduce conflict.
- Knowledge can be translated from information. Knowledge reveals the consistency, competence as well as integrity of the individual or organization.

Affect-based describes an emotional bond that ties individuals to invest in personal attachment and be thoughtful to each other. It enhances the process of evaluation and information exchange, improves performance and well being of the team (Wong et al., 2008).

- Being thoughtful can be demonstrated by showing care and concern. It eliminates unfavourable attitudes and raises kind awareness of other people's feelings
- The attempt of an individual to make emotional investment illustrates his enthusiasm on spending time, energy and effort on a person that he thinks is good or helpful. Affect-based trust derived from emotional investments reduces defensiveness, unhealthy competitiveness and disruption, eliminates frictions and enhances team spirit and morale in working relationship.

E. Checklist Configuration Change Management

This checklist is structured according to and based on the information in appendix B. The information in the appendix has been investigated on matters that have to be introduced to implement the approach. Each practically applicable part of this appendix is therefore included in this checklist. This checklist on its turn was analyzed and forms the basis of the analysis in chapter 9.

Consider the customer demand

Set up configuration of a project: documented determination of the status of a design or object at a certain moment in time

Know the configuration of a system beforehand of the project

Recorded the configuration in a configuration management-database as fast as possible

Information must be transmissible, always accessible and up-to-date

- Work clear and explicitly
- Make sure the project staff has throughout the systems lifetime always access to accurate data of all available CIs
- Make agreements on the interface between client and contractor so each team member has the same information at all times

Make a document list containing all documents used for a design.

Set up the WBS

- Contain the work needed for the design, development, integration and testing of the Cis.
- Integrate the separate work packages into the final system
- the physical design is documented using an allocation matrix and the subsystem/CI list.

Set up the RBS

Establish Product integrity

- Maintain enough information to ensure system and product integrity;
- Ensures that product functional, performance, and physical characteristics are properly:
  - identified,
  - documented,
  - validated and verified
- Changes to these product characteristics are properly
  - identified,
  - reviewed,
  - approved,

 - documented,
 - implemented

The steps for CM

- Identify and document the functional and physical characteristics of individual configuration items, making them unique and accessible in some form;
- Record, track, and report change processing and implementation status
- Coordinate and conduct reviews of proposed changes
- Ensure consistent products via the creation of baseline products;
- Implement a configuration control cycle that incorporates evaluation, approval, validation, and verification of CRs;
- Perform Configuration Audits associated with milestones and decision gates to validate the baselines.

1. Plan

- Create the processes, procedures, tools, files, and databases for managing the project assets
- Agreement must be reached on what assets are important, how they will be defined, how they will be categorized, classified, numbered, reported, etc.
- The up-front planning's are documented in the CMP
- The planning
  - identifies the required resources,
  - defines the to be performed tasks,
  - describes organizational roles and responsibilities,
  - identifies CM tools and processes,
  - identifies methodology,
  - identifies standards and procedures to be used
- The CMP is part of the project management plan.
- The configuration management process and approach must be documented

2. Identify

- Each item is given a unique identifier so it can be tracked, include:
  - Project documents
  - Products – physical and virtual
  - Anything that is going to be created or changed
  - Anything that requires limited access for security or safety reasons

3. Track

- It's important to understand the baseline for all configuration items.
- The trace-ability matrix must be established
- Every time the item is changed or being worked on, the matrix must be updated so that it's clear what is happening to the item. Then the latest version is logged too,

4. Control the records and manage

- Configuration records need to be tightly controlled to ensure there is a full audit trail between the original requirement and the final version.
- There must be version control. This includes numbering documents, lock documents while editing, and physical security of the project's assets.
- Show where items after the project ends.

5. Audit

- Auditing involves validating that the actual configuration elements (whatever they are) at any given time are the same as what was expected
- these expectations are based on the original baseline, plus any change requests

For a change to be acceptable/manageable when implemented

1. Determine the configuration at a certain time in a baseline;
2. Tracking changes to this configuration;
3. Keeping the documentation associated with the configuration;
4. Check (audit).

Set up Baselines

- Snapshot representing the current state of a system, product, technical work product:
  - specifications, designs, drawings, schematics, lists, analyses, trade studies
  - Do this when they are new or have been revised, reviewed, approved by an approval authority, and released for project decision making
- The freezing of the configuration is a cut out and should be the baseline of the system development and CRS.
- The CRS and the system development must be written down into one or multiple contracts and specifications
- A baseline must be accompanied by performance requirements and acceptance criteria.
- Each baseline is placed under configuration control.
- Establishment, control, and maintenance of baselines.
- **When:**
- Include moments in the design and implementation process to freeze data and starting points. At these moments the configuration is determined
- When the contract definition is done, the first baseline arises.
- In the concept definition, the entire dossier will be frozen for the first time. The entire set of information from the process is to be found in the dossier.
- When a new functional concept is needed, the process of a requires for amendment is followed, this is called a 'Verzoek tot Wijziging'
- When changes occur, it can only change the baseline through a documented change management process.
- With iteration a new specification of the system on each level occurs and a new baseline must be established each time.

It is recommended to establish a configuration control board

- CCB must represent all stakeholders and engineering disciplines participating on the project
- The CCB investigate the change
- The CCB decide how big the change is
- The CCB should meet regularly to review the process of the changes that are in progress or are proposed.

When the wishes or requirements are changing, this must be documented using requirement management and CCM

- The changes assure that the requirements in the specification are adjusted, added or expired
- Report on the change processing
- Report on the implementation status
- Report on the consequences

In more detail, A change request

- Changes throughout the system development must be managed by a formal process to ensure that the impact is researched and handled correctly
- **Two types of change proposals, EOW or Contract Change Proposal**
- The content of an EOW is stated in the contractual document
- For a change proposal a formal document is submitted requesting and specifying a corrective action to a baseline document that contains a latent defect such as an error, inaccuracy, deficiency, design flaw, and so forth.
- Included in the formal document must be:
- The EOW must contain sufficient information to evaluate and approve the EOW.
- must contain a reason for the change and a statement outlining the change.
- must contain the details of the trade-offs, the alternative solutions and the preferred one.
- The preferred detail must show why it can be implemented successfully and how it impacts the system on its turn
- Do an impact analysis to indicate which requirements or changes are added
- To see the impact, trace-ability across the different levels of design is necessary.
- The impact on other CIs and aspects in/of the design
- The impact on interfaces requirements as described in the baseline documentation.
- Changes to the baseline documentation
- The likely changes required to the documentation set
- The impact on cost or schedule, if the case
- **Then:**
- Before an EOW is put into effect, it must first be approved.
- Approval of changes by an approval authority
- follow-up corrective actions
- incorporation of changes into current baseline
- formal release for project decision making

Specifications that do not comply with the configuration baseline

- Are typically initiated as a result of an investigative analysis triggered by a problem report, are called CRs.
- Can be accepted by the client without going through the change process.
- The chosen alternative will be discussed with the stakeholders.
- CRs are reviewed and approved, rejected, or placed on hold by the CCB.
- They are normally tracked to completion
- See if the change in requirements, design or realized products result in (re)execution of validation and/or verification

F. Checklist Information Management

This checklist is structured according to and based on the information in appendix C. The information in the appendix has been investigated on matters that have to be introduced to implement the approach. Each practically applicable part of this appendix is therefore included in this checklist. This checklist on its turn was analyzed and forms the basis of the analysis in chapter 10.

Change management should be implemented (This is discussed in E)

- Record, evaluate and manage all changes to ensure that the effect is appreciated
- Make sure that the party responsible for carrying out the change is reimbursed when the change is an addition to the original specification

Reviewing and approving of design documents

- Better review and approve any delay caused by the consultant engineering in checking, reviewing and approving the design
- Clients should consider minimizing change orders to avoid any delays
- Clients need to avoid delay in reviewing and approving design documents

Information management is needed

- Project members need to have relevant and up-to-date and accurate information instantly and always available
- Organize all documents
- Managing all information instead of only the documents
- Information is not stored in a rigid data structure, but as a collection of relationships
- Integrate documents such as emails and connected to other parts
- Have a coherent network of explicitly described information

Implementation management tools to control scope creep are based on four factors 1. All data in hands

- Store all kind of project information.
- Integrate the information in a structured and traceable way
- Project changes and requirements are directly visible
- Have an accessible and consistent user interface

2. Adapts to information needs

- The end user has control over the information needs
- Information can be changed or enriched simultaneously with working on the project
- Have up-to-date information
- Align information needs with business needs
- Have project managers from the start of the project in control
- Adjust during the course of a project to adhere to changing needs

3. Simple and intuitive

- Have a system that is flexible and scalable

4. Collaboration focused

- Have a system that is web-based is recommended
- Have a system that is always accessible from multiple locations and devices
- Have a system that provides a stable platform
- Do not have numerous spreadsheets and individual applications
- Integrated the system with external systems, like Sharepoint

Manage the information according to SE

- Manage and structure complex projects
- Meet the requirements and wishes of the customers
- Achieve enduring quality for clients and the society
- Manage the requirements, tests, risks, tasks and other project objects.
- Organize information in an explicit, coherent network of requirements, design components, functions and other information;
- Capture information for:
  - Requirements
  - Stakeholders
  - Functions
  - Design components
  - Interfaces
  - Test
  - Activities
  - Work packages
  - Risks
- Check to ensure that the information is always accurate, complete and consistent;
- Manage the information centrally
- Look at information from all possible perspectives
- Have a comprehensive trace-ability;
- Set up relations between different parts of the projects throughout the life cycle.
- Generate high quality deliverables such as complete requirement specifications, test plans, risk registers, contract documents and interface reports
- Provide each user with custom roles related to the information of his responsibility

G. Checklist Partnering

This checklist is structured according to and based on the information in appendix D. The information in the appendix has been investigated on matters that have to be introduced to implement the approach. Each practically applicable part of this appendix is therefore included in this checklist. This checklist on its turn was analyzed and forms the basis of the analysis in chapter 11.

Both parties must recognize that the behaviours that may facilitate trust in the different parties are not necessarily the same factors.

Calculus-based trust, in which trust is a rational choice deriving from the assumption that the trustee is believed to seek to perform an action that is beneficial to the trusting party.

- Economic conditions which encourage clients and contractors to work together towards a common purpose may be essential
- Move from price as the determinant of bidding success to a package of factors with a greater recognition of good behaviour for partnering to be successful.
- Emphasis must be placed on costs rather than price.

Mindset

- Establishment and Communication of Conflict Resolution Strategy
- Commitment to Win-Win Attitude
  - Equity is important in developing win-win thinking among parties.
  - having open airing of problems and a non-defensive manner during arguments
  - Solutions are worked out by brainstorming among team members
  - There is a sharing of risks, rewards and sharing of ideas.
- Regular Monitoring of Partnering Process
  - the evaluation of team performance,
- Clear Definition of Responsibilities
- Mutual Trust
- Willingness to Eliminate Non-value Added Activities
  - There must be a willingness to improve processes, reduce duplication, and eliminate barriers.
- Early Implementation of Partnering Process
- Willingness to Share Resources among Project Participants
- Ability to Generate Innovative Ideas
- Know and respect your partners
- Identify clear partnership objectives that deliver results and offer significant value
  - Include specific measurable goals to track progress and demonstrate success and value-add to each partner.
- Ensure the highest standard of project management and relationship management

Needed

- Adequate Resources These include knowledge, technology, information, specific skills, and capital.
- Support from Top Management
- Long-Term Commitment
- Effective Communication
  - Parties should integrate at all levels and freely share information both formally and informally.
  - The involved parties must be able to ask questions about assumptions of the other party.
  - Team building processes and project-wide communication in the early phases of a project
- Efficient Coordination
  - Measuring project performance in the areas agreed to during the partnering intervals, at agreed time intervals and to feed back the results of project team evaluation
  - An increase in contact points between parties and sharing of project information
  - Continuous search for improvements

Practical sessions

- pre-project teambuilding exercises and facilitation workshops;
  - Promote team building
  - Agree on mutual objectives
  - Goal formulation
- joint goal formulation,
- periodic assessment of adherence to partnering principles,
- escalation guidelines for resolving disputes in a timely and effective manner,
- continuous improvement processes;
- total quality management;
- information technology, like shared databases,

System-based trust focuses on formalized and procedural arrangements without considering personal issues.

- Organizational policy specifies priorities and explains business procedures.
- A clearly defined system of communication procedures and approaches.
- Contracts and agreements show clearly the expectations and obligations which contributes to fair risk allocation, overall project performance improvement and costs reduction.

Cognition-based trust develops from the confidence built upon knowledge that reveals the cognitive bearings of an individual or an organization.

- Communication/interaction is a means of exchanging information.
- Knowledge can be translated from information. Knowledge reveals the consistency, competence as well as integrity of the individual or organization.

Affect-based describes an emotional bond that ties individuals to invest in personal attachment and be thoughtful to each other. It enhances the process of evaluation and information exchange, improves performance and wellbeing of the team.

- Being thoughtful can be demonstrated by showing care and concern.
- The attempt of an individual to make emotional investment illustrates his enthusiasm on spending time, energy and effort on a person that he thinks is good or helpful.

H. Document list Project Geldermalsen

Documents:

- *GM-0164459 Opdrachtbrief*, date of version 06-07-2015
- *CM-01632771 Voornemen tot gunnen* date of version 17-06-2015
- *150805 Conceptplanning v1.0*, date of version 05-08-2015
- *150905 Kickoff MWLL Presentatie*, date of version 05-09-2015
- *20150727 343422 MLL Plan van Aanpak TBB v0.1*, date of version 07-27-2015
- *Annex 2 - Vraagspecificatie - Realiseren van de opdracht - versie 1.0 definitief*, date of version 26-03-2015
- *NvI 1 Vragenlijst d1 0 d d 30042015*, date of version 30-04-2015
- *180206 Interne financiële rapportage SOG*, date of version 06-02-2018
- *Bijlage Y-2 CRS Verificatie v1 dd 11-01-2016*, date of version 11-01-2016
- *Bijlage Y-3 Verficiatie opdracht WP 1.1.1 v1*, date of version 22-01-2016
- *10 CRS Corridor Amsterdam -Eindhoven*, date of version 30-03-2015
- *10 CRS PHS Geldermalsen*, date of version 30-03-2015
- *10 CRS VMLL versie 1D*, date of version 30-03-2015
- *GM0164625*, Contract adviseur; overeenkomst van opdracht tussen ProRail B.V en Grontmij Nederland B.V. inzake Geldermalsen - Engineering 'Spooromgeving Geldermalsen', date of version 29-04-2014
- *04.5 Appendix 4.5 - Format Verzoek tot Wijziging*
- *FIS SO-Geldermalsen D2.0 07-04-2017*, FIS 2.0, date of version 07-04-2017
- *FIS SO-Geldermalsen-vC1.0-22-01-2016*, FIS 1.0, date of version 22-01-2016
- *SWNL0194398 Opdracht*, EOW 13, date of version 27-01-2016
- *SWNL0199790*, EOW 18, 31-01-2016
- *343422 TN59122 EOW-26 FIS 2.0 v1.5*, date of version 04-11-2016
- *343422 TN59122 EOW-42*, EOW 42, date of version 20-04-2017
- *343422 TN59122 EOW-49 2.0 getekend*, date of version 13-06-2017
- *343422 TN59122 EOW-49*, date of version 21-03-2017
- *SOG Urenbesteding* Excel with hours derived from ORACLE, 22-12-2017
- *Voortgansrapportages of each month* for example March on 29-04-2016

Interviews:

- *Project manager*, multiple times
- *Lead engineer 1*, multiple times
- *Lead engineer 2*, multiple times
- *Process Coordinator*, multiple times
- *Engineer related the civil construction*, date 14-12-2017

I. Document list Energy Supply Hoekse Lijn

Documents:

- *Intentieverklaring Omexom Grontmij*, date of version 04-09-2015
- *Getekend contract d.d. 26-10-2015*, date of version 26-10-2015
- *Aanbestedingsdossier energievoorziening HKL versie 3.0*, date of version 27-07-2015
- *341911 Aanbiedingsbrief Hoekse Lijn*, date of version 30-06-2015
- *Evaluatie Hoekselijn dd09112017*, date of version 09-11-2017
- *Auditverslag RET Hoekse lijn 14-01-2016 fin*, date of version 14-01-2016
- *Officiele brief*, date of version 11-11-2016
- *Officiele brief naar Omexom*, date of version 25-04-2016
- *160318 contract uitvoering C3 RET EV Hoekse Lijn*, Ingebrekestelling, date of version 16-03-2017
- *Wijzigingsformulier 5207938-W-062 Tholense V2.0*, EOW 24, date of version 22-07-2016
- *HL-EV-MW-005 - wijziging CU of Alu* EOW 5, date of version 04-07-2016
- *EOW - W-037, EOW 37*, date of version 08-07-2016
- *EOW -MW-067, EOW67*, date of version 24-02-2017
- *EOW -MW-068, EOW 68*, date of version 24-02-2017
- *RET-EVHL-03001WP0,03-ALG Documentenplanning R6.1 07-10-2016*, date of version 07-10-2016
- *Oracle Export*, date of version 04-05-2016
- *341911, MeerwerkOverzicht - overall-versie 3.3*, Overview of additional work, date of version 10-05-2017
- *RET-EVHL-0.03.1-ALG Contractplanning R1.0 06-11-2015*, date of version 06-11-2015

Interviews:

- *Project manager*, multiple times
- *Process Coordinator*, multiple times
- *Engineer*, date 20-12-2017

J. Document list Nijmegen Goffert

Documents:

- *NEG 05 Vraagspecificatie Annex 1 - beheersen van de Opdracht*, date of version 13-02-2012
- *Bijlage 2 bij annex 2 - CRS-station-Nijmegen-Goffert-definitief*, date of version 19-10-2011
- *320121-Goffert-Eisenspec-v1-JV-21-05-2013-TDi*, date of version 21-05-2013
- *320121 - Kick-off 11 september 2013 v01*, date of version 11-09-2013
- *320121 - Ondertekening EvdL F95AEFAF*, Contract signing, date of version 04-07-2012
- *320121 - UO-01-02 - 3D overzichtstekening*, date of version 17-05-2013
- *Nota-Beeldeisen-Station-definitief*, date of version 15-05-2013
- *320121 - Onderbouwing projectafwijking mei 2013 v02*, Motivation letter about Optimization of costs, date of version 23-05-2013
- *Goffert - input tbv bespreking 16 mei 2013*, date of version 16-05-2013
- *Document 01 - Eisenspecificatie*, date of version 21-05-2013
- *320121 - oracle 28 augustus 2013 fnd-gfm*, Hour-clarification, date of version 28-08-2013
- *EOW029*, date of version 13-06-2013
- *320121 - Bijlage 2 - Verzamelstaat projectafwijking mei 2013 v02*, date of version 21-05-2013
- *20151013 - Tevredenheidsverklaring realisatie Nijmegen Goffert v01*, Satisfaction statement, date of version 13-10-2015
- *Functieboom goffert*, date of version 27-02-2013
- *2013-01-21-320121 - Goffert-verificatie rapport referentieontwerp v0.1*, Verification report SRS, date of version 28-01-2013
- *320121 - Financieel Overzicht v08 september*, Finance overview, date of version 18-08-2014

Interviews:

- *Project manager*, multiple times
- *Engineer construction and manager backoffice part Nijmegen Goffert*, date 12-12-2017
- *Engineer construction*, date 12-12-2017

K. Geldermalsen: Scope Creep

Scope creep was found in seven different area's in project Geldermalsen, which will be discussed in this appendix. This forms the basis for the scope creep causes in chapter 6. The areas are (1) Cancelled EOWs, (2) Time pressure, (3) Difficulties regarding the process of EOWs, (4) SE products, (5) the FIS, (6) Spoorbouwmeester and the architect, (7) Examples of scope creep.

K.0.1. 1. Cancelled EOWs

During the project of the Geldermalsen, there were 62 additional work packages established. Some EOWs were cancelled. This can be due to various reasons. When it was clear that the client would not accept the change or pay for it, the EOW was cancelled. However, sometimes effort is already put into work regarding the EOW or re-engineering is required. Seven EOWs were cancelled. Only the hours and accompanied costs can be found in ORACLE (see H, SOG urenbesteding).

EOW 11
The effort of this EOW, which resulted in costs of around €1500 have taken place between 2-12-2015 and 31-12-2015. A pricing has been established and several people were contacted. Furthermore, the offer has been reviewed, a draft request has been created and this has been further developed after consultation with ProRail. The EOW has subsequently been adjusted in response to a review and consultation. Subsequently, the quotation was drawn up after which additional work took place. Subsequently, reconciliations took place, there was contact between people and the last choices were made. The quotation was then reviewed at certain points and adjusted as a result of the discussions that took place and a quotation amount was then drawn.
EOW 12
Costs, approximately €200, are found in consultation, writing quotation texts and drawing management.
EOW 27
Costs are approximately €2500 and can be found in making a sketch design of the overhead line . Furthermore, there are costs in drawing up the construction cost estimate for the overhead line sketch and discussing the new track plan.
EOW 29
The costs are included in setting up the quotation, and are approximately €150.
EOW 45
Costs are involved in re-booking hours of an internal consultation/DBVision an in the track design of DBvision and are approximately €850.
EOW 51
Time is spent in recovery of the settlement time of the Randweg, resulting in approximately €500.
EOW 58
The work of this EOW is partly included in EOW 59. The hours have been posted on EOW 60 and are based on studying the existing situation and the escalation of the RVTO. Furthermore, there is time spent in drawing management, resulting in approximately €1300.

K.0.2. 2. Time pressure

Project Geldermalsen endured time pressure according to the progress report (see H, VGR MeiJuni). Time pressure laid pressure on the design and the FIS product and resulted in not formalizing additional work and re-engineering. There was not always enough time to first research the impact of a change and thus is reason for scope creep. According to the lead engineer, the planning is constantly subject to changes following interpretation differences in scope. The planning has been adjusted many times and more than is average for rail projects. EOWs with time consequences have been implemented resulting in adjusting the planning often. Furthermore, the assignment has been interpreted differently than how ProRail initially intended it. The FIS product is an example of this. Sweco thought they had to merge the three accessible FIS files which was estimated to take a week. However, drawing up a new FIS was what ProRail intended and this took a few months, see figure K.1.

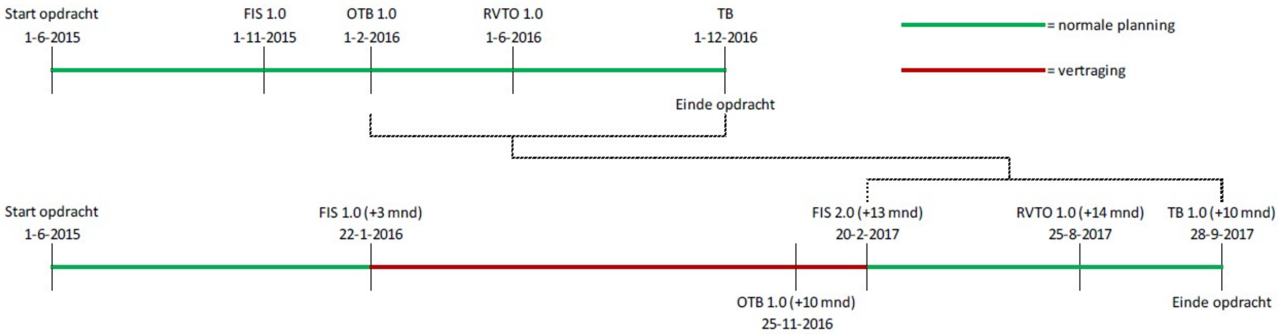


Figure K.1.: Geldermalsen planning (Voortgangsrapportage)

K.0.3. 3. Difficulties regarding the process of EOWs

Many effort has been put into getting work formalized and the EOWs approved, to ensure that work is carried out on the basis of an assignment. However, this does not always appear to be the case in practice. Both Sweco and ProRail value the processing of EOWs, however, various activities were already taken up and carried out without a contract extension based on formal steps. When work was carried out without an assignment, this was based on close consultation with ProRail with the aim of not allowing the planning to suffer under the process of formal commissioning. Nevertheless, this is a very undesirable situation and a major concern for Sweco (see H, Voortgangsrapportage). It is reason for scope creep, because the formalization does not happen before introducing a certain change.

In July 2016, it appears that ProRail has approved only a small number of EOWs by mail. Sweco, however, attaches great importance to a formal agreement and therefore wanted to receive signed EOWs as fast as possible. The time debate and EOW discussion resulted in agreement on scope, hours and budget regarding EOW 1 to 25. In August 2016, it was reported that Sweco received a large number of orders, with the exception of EOW 13 and 18. These are two examples of work that was already carried out, without having approval of ProRail (see H, Voortgangsrapportage).

EOW 13 was finally approved on 27-10-2016 (see H, EOW 13). However, looking at the hours spent, the work started on 11-1-2016 with the drafting of the quotation and was further picked up on 14-6-2016 because the agreement was reached in this month. However, official approval was received in November and the work was already finished at that time. The work included drafting of the design document including hours of preparation, consultation, audit report,reporting and hours spent in the transfer workshop. The use of consultations after 31-08-2016, are settled in a new EOW. There is only a budget to process review comments on the existing scope (see H, SOG urenbesteding).

EOW 18 was finally approved on 30-1-2017. On 15-3-2016 a change of assignment was submitted by Sweco approved by the project manager of ProRail. The hours are made starting on 9-5-2016 running until 14-6-2016. The work has been carried out in a fully demonstrable manner and Sweco needed to receive the performance statement. In November 2016 it was mentioned that a letter of assignment is missing and in January 2017 the official ProRail order letter was received. In March 2017 the performance statement was submitted to ProRail but not yet paid. The result was finally put on 31-12-2017 for a cost-to-go approval (see H, EOW 18).

So, till January 2017, a catch-up has been made in the performance statements. However, it appears between January and March 2017 that performance statements are still not returned within 10 days. Contract management run slowly through prolonged discussions about EOWs. Reactions from ProRail remain unanswered and actions by ProRail must always be repeated by Sweco. A lot of time and money is lost due to the inadequate handling of EOWs and performance statements and/or the absence of reaction or review. A lot of time and money is lost to the process (see H, Voortgangsrapportage). The discussions regarding EOWs where a result of an unclear scope of the project according to the lead engineer. Therefore there was no clarity and no strict way to indicate what was part of the original scope resulting in delays and discussions.

There are examples where Sweco finished work, but is waiting for the Declaration of Performance. However there are also EOWs were the approval have been given but some documents are still missing. These are the EOWs in the progress reports which state that the work is already 90 to 100% ready (see H, Voortgangsrapportage). Some examples of this are:

- Maart 2017:
  "EOW 15 remains a question and lies with ProRail. The EOW consists of three parts, all 3 submitted, 2 commissioned and 1 paid. Sweco has performed all activities demonstrably and is waiting on the remaining performance statements."
  "For EOW 36 an agreement has been reached on 30-11-2016. The order letter is still missing and with it the signed performance statement. The work is 95 percent ready."
- April 2017:
  "EOW 42 is finished and Sweco waits on a reaction of ProRail."
  "EOW 49 is finished, adjusted and submitted again, Sweco waits on a reaction of ProRail."
- May/June 2017:
  EOW 22, 48, 49 and 54 are already finished but Sweco is still waiting on an assignment letter.

This follows from the fact that in practice there is not always a waiting for an assignment from the client. The theory says that work may not be done without instructions, however, if ProRail shows intention to pay or writes an assignment, the project team often already starts working on it, according to the project manager. There is too much confidence in the fact that it will be approved by ProRail. Furthermore, the contractors often let themselves be tempted by time pressure, threats or by good faith. Sweco can be given the choice to delay a product and waiting for approval, or be cooperative and trusting and carry out the asked additional work.

A major problem is that drawing up an EOW asks much effort, and that these costs are not paid by the client. When an EOW is approved, already much work is put into the EOW. This makes it difficult to choose the level of scope management. An EOW is not always submitted when additional requirements can easily be carried out because that segment of the design is currently being processed. This does result in a small impact and does require time of team members, but it does improve the end product. Still, the possibility should be used to extend the baseline with the extra requirement to prevent that these requirements are never written down and become ‘floating requirements’, which is reason for scope creep, according to the Lead Engineer.

K.0.4. 4. SE products

This section will be divided into the product SRS and CRS. Both were point of discussion and reason for uncertainty in scope.

SRS

Initially, the SRS was part of work package 1.3.2. The goal of this work packages was obtaining complete and validated specifications with which the product scope can be designed, put out to tender and realized. ProRail requires that the customer requirements included in the CRS are correctly detailed in order to demonstrate that the design meets the set requirements. The SBS and SRS of the previous engineering project of the VMLL and PHS Geldermalsen projects serve as the basis for this work package and must be merged into one product of each, which in turn form the basis for the requirement specifications in the tender dossiers (see H, Annex 2).

However, after tendering, the input for the work package was not completely delivered. The SRS of both VMLL and PHS Geldermalsen was promised but not given. Given the formal absence of these, Sweco cannot efficiently carry out our work in accordance with the work package and planning. The absence was reported on 11-10-16 (see H, VGR Okt). The SRS of VMLL was supplied by ProRail after the notice. However, it was still of insufficient quality for the tender dossier. Based on an interview with the RSE of ProRail and the intended alliance manager, it was proposed to write a plan of action for the SRS, partly as part of ProRail's intention to raise the quality level of SRS and the tender dossier. Sweco had subsequently started working on this. In the middle of November, ProRail returned to this agreement where-after a consultation took place mid-December (see H, EOW 42). Sweco already made, based on the agreements, expenditures, even though these are not in line with the original work package (see H, Voortgangsrapportage) and EOW 42 is linked to those agreements (see H, EOW 42). It is agreed in December that Sweco will, within the basic assignment, draw up an SRS for the Nieuwsteeg and the Travelers Tunnel only. The remainder will be made by ProRail.

In January 2017 the SRS was delivered to ProRail according to schedule. Because Sweco did not receive a timely response to the issue list, Sweco was unable to include this in the SRS on time, resulting in an un-efficient process. The review comments were delivered late by ProRail, even after recalling of Sweco. Therefore the review comments on the SRS are not handled (see H Voortgangsrapportage). Eventually, the work regarding the SRS was continuously unclear, there were many differences of opinion, and this resulted in a delay in time and costs, according to the lead engineer and project manager.

The idea of SE is that during the verification and the validation of the design the CRS and SRS must be starting points to validate and verify against. However, the vast majority of the SRS was now made by ProRail. This product was completed after the FIS was already finished, because the waiting times were too long. Project Geldermalsen therefore was tested against the CRS instead of against the SRS. ProRail ultimately used the Sweco design and the FIS to draw up the SRS. In addition, there was also the fact that the CRS was also subject to change, so the lead engineer stated that there was little to hold on to in this project.

Integration of CRS

Between November 2016 and January 2017, Sweco indicates that the integral CRS of 1-9-2015, delivered after the tendering procedure by ProRail, is not an exact combination of the three CRSs that were provided during tendering. In the verification and validation of the project, Sweco has continued to base their work on this integral CRS. However, it appears that additional requirements and starting points have been added to the integral CRS. Sweco has therefore carried out additional work in comparison to the three initial CRSs. Sweco investigated the consequences for design, verification and validation and submitted EOW 53 for this. This has been submitted for acceptance on 25-1-2017. Sweco, in consultation with ProRail, first provided the substantiation of the EOW (see H Voortgangsrapportage). Sweco has prepared a file for EOW 53, which provides an overview of the additional requirements that must be added to the CRS. This is a list of extra requirements, doubtful cases, requirements that do not match each other and requirements that cannot be traced. In total it is 72 requirements that have been given a status in this file.

Table K.1.: Requirements in the CRS that are special

Extra?	Item numbers	Item numbers
Not traceable	13	CRS-SOG-6.1.2.1.012
Not traceable	5-6	CRS-SOG-6.1.2.1.004-005
Does not match	29-42-43-44-46-137-141-145-160	CRS-SOG-6.1.2.1.028, 041 t/m 043 CRS-SOG-6.1.2.2.002 CRS-SOG-6.2.2.001 – 005 – 009 CRS-SOG-6.3.3.001
Does not match	28	CRS-SOG-6.1.2.1.027
Does not match	122	CRS-SOG-6.1.3.020
Does not match	152	CRS-SOG-6.3.1.003
Doubtful	31, 93, 100	CRS-SOG-6.1.2.1.030 CRS-SOG-6.1.2.5.001 - 008
Doubtful	35	CRS-SOG-6.1.2.1.034
Doubtful	105 t/m 109 - 116	CRS-SOG-6.1.3.003 t/m 007 CRS-SOG-6.1.3.014
Doubtful	119	CRS-SOG-6.1.3.017
Extra	77 t/m 82, 84 t/m 92, 130 t/m 135, 146 t/m 148, 153 t/m 158	CRS-SOG-6.1.2.4.003 t/m 008 - 010 t/m 018 CRS-SOG-6.1.3.028 t/m 033 CRS-SOG-6.2.2.010 t/m 012 CRS-SOG-6.3.1.004 t/m 009
Extra	51, 72	CRS-SOG-6.1.2.2.007 - 026
Extra	62 to 71, 83	CRS-SOG-6.1.2.2.018 t/m 027 CRS-SOG-6.1.2.4.009
Extra	125-126	CRS-SOG-6.1.3.023 – 024
Extra	129	CRS-SOG-6.1.3.027

Then this EOW gets cancelled. Afterwards, Sweco shared with ProRail the extra requirements and starting points for the integral CRS. In an email, ProRail informed Sweco to still use the 3 'old' CRSs to prevent such additional work. If review comments are made later in the project that go back to the CRS, consequences will be for the account and risk of ProRail (see H Voortgangsrapportage). When the list of requirements from table K.1 is compared to the requirements set which has been used to validate and verify the FIS, it is possible to derive requirements that are eventually used, and requirements that are not used. The requirements that have been used in the final verification of the FIS are the following requirements:

This has cost a lot of process management to manage all this. Furthermore, researching which requirements were additional took a lot of effort of the Sweco employees. The uncertainty led to a lot of confusion, delays and demands that contradicted each other, as was stated by the lead engineer. As can be seen, many of the additional items are not mentioned in the final validation

Item number	Commentary	Validated?
5 and 6	Not traceable (Outside scope SOG)	Does not apply (exceeding requirement)
13	Not traceable	Yes
28	Does not match (Outside scope SOG)	Yes (exceeding requirement)
29	Does not match	No
31	Doubtful	Yes
35	Doubtful (Outside scope SOG)	Does not apply (exceeding requirement)
44	Does not match	Attention point
46	Does not match	Yes
51	Extra (Outside scope SOG)	Attention point
105 to 109	Doubtful (Outside scope SOG)	Does not apply
160	Does not match	Yes

Table K.2.: Requirements in the FIS validation

document, and of those mentioned, only a few were inside the scope and validated as yes, see table K.2. So, this process took a lot of time and resulted in an unclear process and an unclear scope. This resulted in re-engineering, mistakes due to wrong starting points, and discussion on scope.

K.0.5. 5. FIS

Project Geldermalsen consists of the merging of project PHS Geldermalsen, project (VMLL, and the Amsterdam-Eindhoven passenger corridor project. During the engineering of these projects it was decided by ProRail to integrate the projects into one project: Spooromgeving Geldermalsen. Sweco is asked to integrate, update and further develop the input products to the level that the Implementation Decision can be taken. In the 'Elaboration of the Variant' phase, the integral FIS and the RVTO must be made (See H, Annex 2). So, the goal of Sweco's assignment was to create a coherent story of these three projects by merging and updating the documents of these. The different FIS products were all approved for the separate projects and therefore it was assumed that they provided a good basis for the FIS of this project.

However, it turned out that ProRail had another intention and saw an optimization of the FIS projects as scope. As the lead engineer states, Sweco had to clarify that their offer was not based on this. Eventually, ProRail asked Sweco to draw up a contract for additional work to elaborate on the desired design optimization's in a new FIS. The name of the new FIS becomes FIS 2.0 SOG and the additional work was put into EOW 26 (see H, EOW 26).

ProRail made a list of 10 optimization wishes / proposals to adjust the track layout and the signaling. Implementing these optimization's in the FIS design has a major impact on the track position of the Geldermalsen railway emplacement. Because the track position forms the basis for the effect studies for the 'Ontwerptracébesluit (OTB) procedure, translated into Design Trace Decision procedure (DTD), the effect studies should be adapted on the new design. The starting point for the elaboration of FIS 2.0 is the addition of all 10 optimization's. Based on these points 12 of the 17 chapters of the FIS need adjusting just as 16 of the 25 appendices (see H, EOW 26).

Sweco submitted a proposal for a scope description for the new FIS on the 15th of June 2016. This was again sent to ProRail on the 30th of June. On the 19th of August, Sweco received a brief response from ProRail to the scope description that the EOW can be completed. After this Sweco has an order by e-mail to start with the FIS 2.0 written down in EOW 26. In anticipation of the official Sweco assignment, ProRail has given a small budget in order to be able to make the start (see H, Voortgangsrapportage). In thee first version of EOW 26 the financial consequences are calculated to be rather large. After consultation a revised version of the tender has been submitted on fixed sum and with a one-off discount, thereby closing at 2/3 of the calculated price. For the discount some starting points are handled. First, the scope will be frozen and further iteration strokes will not be worked out in the FIS. Second, possible deviations from the design prescriptions by factors other than the design process or the CRS are not part of this EOW. Finally, repairing observed deviations in reusable existing infrastructure is not part of this EOW (see H, EOW-26).

So, Sweco was not reimbursed for all their work and there have been many negotiations about the EOW that is based on the scope of the FIS. This has resulted in high delays in many other aspects. Adjusting the FIS with 10 optimization's requires a turnaround time of 4 to 6 months. After approval of the FIS by ProRail, working on the RVTO can be started. The optimization leads to adjusting of the track design, signalling, the effect studies, the construction cost estimations and the DTD. Furthermore, by modifying the FIS, a revised CRS is needed (see H, Voortgangsrapportage). If ProRail had been clear about the expectations in the initial call for proposals, this could have been prevented. The suggestion was raised that the FIS products were ready for merging, and as a result there was a very large increase in work (lead engineer).

The RVTO has been started after successful delivery of the FIS. However there was a delay due to the late arrival of review comments on the rail axis and lack of full input. As a result, the integration of the RVTO could not start. In order to better manage the RVTO process, progress meetings were planned with ProRail and Sweco.

K.0.6. 6. Spoorbouwmeester and the architect

Bureau Spoorbouwmeester was founded in 2001 on the initiative of the management boards of NS and ProRail as an independent advisory body for the design assignments within the railway sector. Bureau Spoorbouwmeester is a small team and is led by the Spoorbouwmeester. Their goal is to create recognizable conditions for the rail sector as a coherent system with as substantive basis the Spoorbeeld. A recognizable image makes the track accessible, clear and user-friendly and enhances the feeling of trust and safety among travelers. This creates added value for the future of (rail-bound) public transport. Bureau Spoorbouwmeester, as carriers of the rail identity of stations and equipment, provides new inspiration to the tradition of architecture and design (Spoorbeeld, n.d.).

During the tender, time is calculated for discussing issues with stakeholders. The design is discussed in workshops where also Bureau Spoorbouwmeester is involved. The Spoorbouwmeester and the architect often do not find time an issue as they see time as subject to the quality of the end product. The amount of workshops needed does not matter to them (Lead engineer). Sweco does not write down on what amount of workshops the tender is based. Sweco thinks for example that three workshops will be a reasonable amount. Sweco then would make an EOW of all the extra workshops. However, in practice, reasonableness is always reasoned from the project's interest. It is often stated that the each workshop was seen as needed and thus as reasonable, resulting in not approving the EOWs of Sweco. Sweco should avoid this situation, according to the lead engineer.

On the contrary, the fact that the Spoorbouwmeester has a strong opinion about the design is not necessarily negative. A lot of time and money is invested in a project which becomes an iconic element in the environment. Therefore it is needed that time is spend on the design, as argued by the engineer of the construction. So, it can result into scope creep, but it can also make the design of a higher quality. Making agreements on what is reasonable and set a deadline for coming up with changes can solve the scope creep and still give room for a good qualitative design.

Project Geldermalsen is put on the market before contacting the Spoorbouwmeester. As a result, he started to influence the project when he gained insight into the project. He indicated at a number of points that he wanted to see it differently and influenced the scope. Up to the last moment, changes were introduced on his part, as said by the engineer of the construction. Furthermore, as stated by the lead engineer, a list is drawn up during the workshops of points that the different parties would like to see adjusted or added to the design. Often it is asked whether this can be adjusted at short notice and this is regularly promised. This is partly dependent on the person present at this workshop. Often the choice falls on doing things quickly instead of processing them in an EOW, because these EOWs each time take at least eight hours. Drawings must be made, checked, released, printed and processed and this also influences the integrity of the design.

K.0.7. 7. Examples of Scope Creep

EOW49

Geldermalsen is a special project, because in addition to the railway track, the environment was also part of the scope. The forecourt, the backyard, the ring road, underpasses and the platform layout were part of the scope and are described in work package WP1.1.4b Design Station & Transfer - Tunnel. EOW 49 concerns this work package and the additional work resulting from this.

From the end of 2015 till the submitting of this EOW, there have been various consultations about the layout of the station, both the platforms, the forecourt, Kiss and Ride, bus stop, pavilion and the bicycle sheds. For this purpose, a plan was initially made and various options presented. Subsequently, a station arrangement drawing, able for discussions, was made by Sweco outside the original assignment. This drawing has been adjusted after all consultations with stakeholders, such as the layout around the transfer points, but also with regard to bicycle storage and platform layout. The last adjustment was in October 2016 (see H, EOW 49 2.0). Three workshops of 8 hours took place that are not reimbursed, regarding the bicycle parking, platforms, passenger tunnels, progress design transfer, fields and equipment.

The CRS does not mention transfer solutions on the platforms, adjustments to the forecourts and refurbishment of bicycle parking facilities. This also applies to the middle platform 3/4 and modifications to the VMLL scope (see H, EOW 49). In the revised integral CRS 1.0, requirements have been added. Additional work would concern the elaboration of the establishment, including equipment, of the entire station, where only eastern platform 1 has been requested. Meanwhile it is also clear that of the VMLL scope there are no equipment and platform outline drawings available and that the entire station including platform 3/4 has to be worked out. In addition, a new requirement was that the entire station must be equipped with new station furniture (see H, EOW 49).

Sweco, in consultation with ProRail, first provided the substantiation of the EOW on 13/6/2017, but a reaction has not been made by ProRail on this. In addition, Sweco indicated what the costs already incurred were (see H, Voortgangsrapportage). An agreement has been reached with ProRail to still execute only the layout of the eastern platform in accordance with the basic assignment and to omit the layout of the other domains. The substantiation with regard to the additional work still to be carried out has thus proved redundant (EOW change of assignment). Nevertheless, ProRail promised to come back to the additional work that was already carried out, but a reaction remains unanswered. Sweco has already delivered platform line drawing of the eastern platform at the beginning of April (see H, VGR april)

With regard to the bicycle parking facilities, the design has been set and changed 3 times, for the last time 30-11-2016 (see H, EOW 49 2.0). According to the lead engineer, there was a long discussion going on about the design of the bicycle parking space with respect to the track. The design has been changed several times from either perpendicular or parallel to the track. A lot of time and money has been spent on this. This had several reasons changing between the fact that it was more convenient to place it differently, until the architect who found it fit better in the design in a different way in respond to the proposals of the design. This was done in a workshop with the architects' bureau, with the Spoorbouwmeester and the environment. According to the engineer related to the construction, the bicycle sheds also have been changed in response to the NS, who felt wanted to re-position the bikes. The other change followed from the integration into the new environment. The Lingendonk district, developed by Dura Vermeer next to the station, had lines of sight on the stacked bicycle shed and this was not considered desirable.

Rail access point

The CRS requirements related to the Rail access point, are not in line with each other. CRS item 45 says that the current functionality must be retained. However, CRS item 46 says that the maintenance area must remain accessible, which can lead to a relocation of location, conflicting the current functionalities (see H, CRS). A Rail access point is a place on the railway track, where special vehicles can be placed on the railway track to transport construction site equipment or to help in case of incidents (Rail Safety Solutions, n.d.). This specific case has led to many questions to ProRail by the lead engineer and project manager. In the end, it was decided to keep item 45, but a lot of research had already been done into the possibilities. This has caused delays, cost a lot of time and with this, costs have also been incurred.

Traveller tunnel

The entrance to the passenger tunnel is a design point that has changed often. Bureau Spoorbouwmeester was involved in this. Because of social security, sight-lines to the end of a tunnel are required. However, the preliminary design that was delivered by ProRail was not optimized on this point. ProRail had not presented the design to the railway architect of ProRail,resulting in a strong opinion when the design was shown to him. So, optimization took place by moving the tunnel slightly between the various boundary points given. Furthermore, a large void has been added for more daylight. A lift has been relocated and stairs have been changed to a different location. This resulted in a change of the stairs on the other side of the station, due to symmetry in the station. The social safety had to be improved and was done, as stated by the construction engineer.

K.0.8. Conclusion

This project endured many wrong interpretations and a client that tendered this project as a fixed scope while maintaining the project as a moving scope. Also there was missing input at the start, for example of the Spoorbouwmeester. Additionally with the process of the EOWs, there were high costs involved, there were long and arduous discussions, there were long waiting times and they started before having an official approval. This was also due to the time pressure on the project. Furthermore, the scope control process was hard due to missing consistency and not all changes were anticipated or formalized. Furthermore, they had to deal with stakeholders with strong opinions and missing links between employees. Additionally, the products were not set up in the wrong order, like the SRS. There were many disciplines involved and this made maintaining the integrity hard. Finally, human factors are always involved in a project.

L. Energy supply Hoekse Lijn: Scope Creep

Scope creep could eventually be found in five different areas. This forms the basis for the scope creep causes in chapter 6. The areas are: (1) Organization, (2) EOWs submitted afterwards, (3) Cancelled EOWs, (4) Reviews that were late, (5) Additional wishes and requirements. Finally some examples of scope creep are given.

L.0.1. 1. Organization

Energy supply Hoekse Lijn was set up differently than other projects. Therefore it is important to start with discussing the organization of the project. Sweco, or Grontmij, was working for Omexom. Omexom was the link between RET and Sweco. All documents were send to Omexom and Omexom would send it to RET. This was a bit of a traditional way to arrange the project.

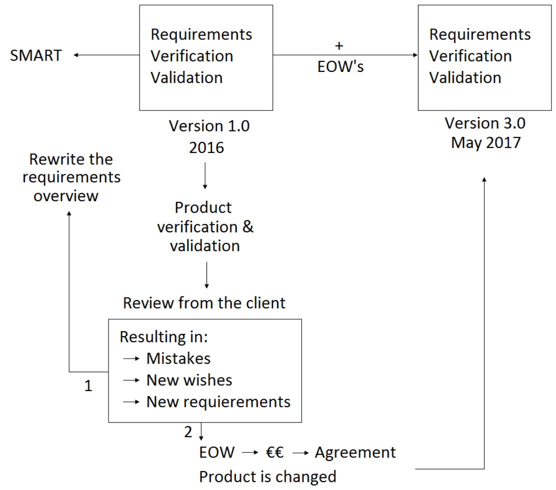
At Sweco at first the project organization was not set up correctly. When taking into account the amount of the assignment and the number of days they will work on the project, it shows that 7.6 persons should work on the project at each day. However, the organization was only 2.5 man at the start. During the the evaluation of the project on 09-11-2017 it was stated by both Omexom and Sweco that there was no starting with a complete team by both of them (see, I, Evaluatie). After a few months Omexom put more capacity on the project and named extra managers. Also the team of RET had a capacity problem. They had a team that was too small (Project Manager).

There was no general project control especially focusing on scope and time management. The wishes of the RET were followed without binding consequences to those. RET was not kept to agreements such as review terms (see, I, Evaluatie). Furthermore, there was more a client – contractor relation between Sweco and Omexom instead of working as partners what was the intention at the start of the project (see, I, Evaluatie).

Within Omexom there were some problems that influenced the process. They did not manage and control the new wishes and requirements in a proper way. There was no good scope control and this made the process for Sweco harder (Project Manager). In an official letter sent by Sweco to Omexom on 11-11-2016, see I, it is said that the teamwork does not occur as was agreed on. This was regarding the situation with the in default of Omexom and Sweco. In this letter Sweco states that there was agreement on the fact that Sweco would always be present by meetings with RET and that a closing planning would be set up mutually to reach the end delivery date. However, Omexom did not put energy in making a mutual planning that was realistic for both parties, and started the conversation with RET without involvement of Sweco.

Certain mile stones were agreed on, without Sweco having influence on these dates. Sweco have sent two emails in October, stating that they could not vouch for meeting the mile stones. However, when not meeting the mile stones, Omexom stated that Sweco was shortcoming and they also received an in default. Sweco sent a letter stating that they disagreed. Sweco was not included by meetings with RET, only during the escalation (See, I, Evaluatie).

Furthermore, the process of scope management is not always followed as should, as shown in figure ??. It shows that the requirements and verification is written down at the start. After the product validation and verification a review is given, which results in new wishes and requirements and mistakes that the RET want to see solved. However, this is not looped back to the requirement set as should, see option 1 in figure ??. What happens is that they implement the changes into the product, like option 2. The wishes and requirements were not updated, changes were not written down, and there was not a new product set up to validate. The verification was fixed with reasoning backwards.



2. EOW submitted afterwards

So, when the project started, the project team did not have the right capacity to work on the project. Furthermore, they did not have enough experience to have a good grip on the project. There came a lot of additional work and changes from the RET and Sweco was carrying out these wishes. However, they did not formalize the changes in scope (Project Manager). From an audit it became clear that monitoring the status of the scope should take place during a meeting with the project manager, but this happens inadequately (see I).

In February, the project manager of Sweco leaved the project and another project manager took his place. After February also the capacity was changed into on average of 8 man and they started with gaining inside into the additional work they had carried out. Only 6 EOWs were set up in the months before this. They wanted to get a clear picture of the current scope to get paid for the work done, but also to maintain the integrity of the project again. A lot of work was carried out without management of the changes that were issued. The control of the scope was set up again (Project Manager). 75 EOWs were set up after this moment and can be found in different parts of the project. The scope of the project was the engineering of the system and the verification and validation of this. This part did not receive additional work, as it was laid down in other parts:

- The verification and validation of the product
  This part was not part of the scope and when asked to work for this cause, an additional work package was established. EOW 1 is based on the additional verification and validation.
- Extra scope
  This part consisted everything that was added to the scope. It contains only extra work that had considerable consequences to start the process of setting up an EOW.
- Term extension
  This part consisted the work that needed the be done due to an extension in term. This resulted in additional work and therefore was also set up as additional work.
- RAMS
  This part consisted the work that needed the be done due to an improvement of the RAMS. This was additional not part of the scope. This resulted in additional work.
- Additional wishes and requirements
  This was a grey area. When a wish or requirement resulted in a large amount of additional work it became part of the extra scope part. However, many additional wishes and requirements had small consequences and no changes in planning or costs as result. These were not formalized.

The additional work that was carried out is put into different packages of multiple EOWs, see table L.1. After the submitting of EOWs in August, the work was stopped due to a discussion about the EOWs. After the summer of 2016 all work that was carried out but not formalized was formalized. After August 2016 the additional work were mainly extra's in scope (Project Manager). It is said during the evaluation (see I, Evaluatie) that the process of formalization asked a lot of effort and time. On average it took three to six months.

EOW package	**EOW number**
Cancelled EOW's	2-3-6-8-13-24-25-27-28-30-35-36-37-38-39-41-46-51-55-56-61-67-68
July 2016	1-4-5-7-9-10-11-12-14-15-16-17-18-19-20-21-22-23-26-29-31-32-33-34-40-42-43-44-45-47-48
August 2016	7-9-10-11-12-14-15-16-17-18-19-20-21-23-34-45-47-49-50-52-53-54-57-58
December 2016	1-52-62-63
February 2017	1-4-29-31-32-33-40-48-50-57-59-60-64-65-66
March to September 2017	22-42-53-65-69-70-71-72-73-74-75

Table L.1.: EOWs divided into different packages

Many EOWs were established afterwards, in July and August. The work that was put into these EOWs was already carried out without formalization and can therefore be called scope creep. These changes already had impact in terms of costs, planning, quality and integrity of the design. Only the costs were afterwards taken care of (Project Manager).

Multiple EOWs are based on a certain escalation that resulted in a in default. In a meeting between RET and Omexom it became clear that RET were unhappy about the delivering of products. So a recovery plan was set up by Sweco and Omexom. In a reaction on 15-2-2016 a strict deadline is set on the 14th of March that year. However, this deadline was not met resulting in an in default for Omexom that they passed on to Sweco (see I, Ingebrekestelling).

RET states in the in default that three terms were not met (see I, Ingebrekestelling). However Sweco states that only one deadline, the one of 14-03-2016, was not met. Sweco did not meet this deadline, because they are dependent on the input of Omexom. Omexom is responsible for the suppliers and purchase, and Sweco is responsible for the processing of the technical information belonging to a specific design component. Before Sweco can carry out and complete its work, Omexom will first have to purchase and make agreements regarding the delivery of the technical information (Email conversations). Sweco was unable to complete its products because Omexom did not purchase on time and did not decide which supplier would supply which components. Sweco depends on data from these suppliers to complete the design products (see I, Officiele brief).

That the lack of data would lead to failure to meet the fatal deadline was regularly the subject of discussion between Omexom and Sweco, but has never been formalized with a letter. Sweco has, however, recorded this in the progress planning towards Omexom which Omexom in turn has provided to the RET (see I, Officiele brief). Sweco delivered what could be delivered, the rest was included in the weekly progress report that was drawn up and provided every week since February to Omexom and Omexom in turn to the RET (weekly progress report).

Omexom was could purchase directly after the assignment, but after verification of the offers by Sweco, a number of main components were found not to meet the plan of requirements of RET. After this, a process was set in motion by Omexom to see if the existing suppliers and products could be accepted or to look for alternative ones. In this process financial considerations also played a role, with the result that Omexom did not buy in time (Email conversations).

EOW 1 is partly based on the fact that after a QuickScan it became clear that certain components were not complementary with the requirements of RET. The engineering had to be done with unknown products and therefore there was many re-engineering. Because technical information was lacking and review comments of RET and Omexom were very late, the design could not be finished. The re-engineering delayed the process. This therefore had consequences in both planning and financial terms. The costs are estimated on approximately €130.000. Some other EOWs related to the in default of Omexom lead to costs of approximately €80.000.

Other EOWs that were formalized retroactively, are based on other incidents that occured during the process. For example EOW 32 is based on a decision made by Sweco. Input of RET on water levels on multiple locations was missing. It was decided to not wait on the input of RET due to possible stagnation in the planning. This had interfaces with certain elements. For example the water levels and foundations are connected, and the departments water and soil mechanics had to align. Another example is EOW 45 that is based on the request of Omexom to change drawings into packages that are ready for production. This was part of the scope of Omexom and not of Sweco. Sweco therefore did additional engineering work. In the planning this has consequences due to its interfaces with other areas. Engineering work had to be redone and drawings changed.

3. Cancelled EOWs

Some EOWs were cancelled. This can be due to various reasons, some were cancelled due to the result of negotiations. When it was clear that the client would not accept the change or pay for it, the EOW was cancelled. Another option was putting the EOW in another additional work package. Cancelling has as consequence that effort is put into the preparation of the EOW and into negotiations and sometimes in already putting effort into the engineering considering this point to establish that the EOW seems necessary (Project Manager). Furthermore, when no agreement was found, Sweco was still obliged to continue with the work, this due to 11.2 in the contract.

EOW 24 was not accepted and was based on a change set up by RET which included an adapted basic diagram for the door circuits of the HVI and HKL rooms resulting in realizing an extra circuit for the doors. This influenced the planning as there were interfaces with four other areas. The financial consequences are estimated at approximately €7000 (see I, EOW 24).

EOW 37 includes the setting up of change requests for Omexom. These were accepted by the RET without financial consequences. However, Sweco calculated the financial consequences to be approximately €12.000 because many hours will be put into drawing up, controlling and supplementing the change requests (see I, EOW 37). EOW 67 is based on a reconciliation of a quotation. The financial consequences are approximately €1200. However this EOW is cancelled so no work is paid and consequences are neglected (see I, EOW 67).

4. Reviews that were late

RET was very late with sending reviews on design documents of Sweco. The review should be received within ten days, while sometimes this took them a couple of months (Project Manager). The additional wishes and requirements became in a very late stage clear due to the late reviews (Process Coordinator). The long waiting times also influenced the design. It could happen that reviews were given on version 1 of design documents, while the design process during the waiting time already optimized to version 5, see figure L.1. The received review was however still based on version 1. The hard part here was that RET don't need to accept the design and they are not obliged to give information during the process (Project Manager).

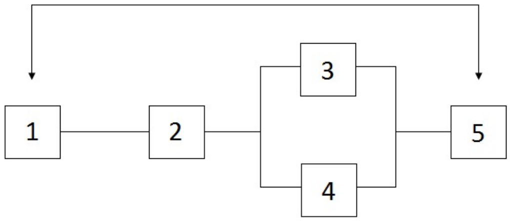


Figure L.1.: Review process example

In an internal meeting report of 1-9-2016 it is said that the status of the review report documents is important. The response from RET to some Toetsingsrapport Documents (TRDs) is too long, while their reaction is required to complete the products. The reactions to the TRDs can lead to a stagnation in the planning as well as in the preparation of drawings for for example the execution. This cannot take place without reviews of the RET and Omexom (Internal meeting report). Examples of this will be given in this subsection.

In document documentplanning, see I, different documents are seen together with their reviews of the RET. For example the short circuit calculation DC in this document has 3 reviews, which shows that review 1.0 took them a month to check, review 2.0 took them a bit longer than 2 months and the latest review was not signed yet in October as the document is last updated on 7th of October 2016. As shown in table L.2, a month is very common for a review to get.

Version	Date of submitting	Signed review
R1.0	22-1-2016	25-2-2016
R2.0	25-3-2016	02-6-2016
R3.0	24-6-2016	

Table L.2.: Example of dates of submitting of review products

The late reviews can also become clear from the review report documents. The document, concerning the fire alarm systems, also shown in L.2, is send on 19-02-2016 and found to be not accepted on the 21-4-2016.

Toetsingsrapport Document — **TRD 025** — RET AARDIG ONDERWEG

Projectteam Energievoorziening Hoekse Lijn

Versie: 01

Gegevens te toetsen document:

Kenmerk	RET-EVHL-03002WP1.16-GS-HHH		
Documenttitel	Tekening Brandmeldinstallatie locatie GS HHH		
Toelichting	Document per mail verstrekt d.d. 19-02-2016	Archiefcode lokaal RET	Code van document

Historie van het te toetsen document:

Versie	Datum	Status	Conclusie	Naam behandelaar	Handtekening en datum
A	19/02/2016	Ter acceptatie	Niet geaccepteerd		21/04/2016

Figure L.2.: Two examples long waiting time on review

A strange situation is that of the review of the project management plan. The document is send by email on 7-11-2015. This version is accepted on 10-12-2015, see example 1 in ??. However, 6 days later, the review is not accepted, see example 2. Then, version 2.0 is first not accepted on 27-1-2016, but after having phone contact with Omexon, where they could give further explanation, the project management plan is accepted on 26-02-2016, see example 3

Toetsingsrapport Document — Projectteam Energievoorziening Hoekse Lijn — **TRD 011** — Versie: 01 — RET AARDIG ONDERWEG

1

Gegevens te toetsen document:			
Kenmerk	RET-EHVL-0.07.1-Alg PMP R1.0 06-11-2015		
Documenttitel	Projectmanagementplan		
Toelichting	Document per mail verstrekt d.d. 07/11/2015	Archiefcode lokaal RET	Code van document

Historie van het te toetsen document:

Versie	Datum	Status	Conclusie	Naam behandelaar	Handtekening en datum
1.0	06/11/2015	Ter acceptatie	Geaccepteerd		10/12-2015

2

Historie van het te toetsen document:

Versie	Datum	Status	Conclusie	Naam behandelaar	Handtekening en datum
~~1.0~~	~~06/11/2015~~	~~Ter acceptatie~~	~~Geaccepteerd~~		
1.0	06/11/2015	Ter acceptatie	Niet geaccepteerd		16/12-2015

3

Historie van het te toetsen document:

Versie	Datum	Status	Conclusie	Naam behandelaar	Handtekening en datum
~~1.0~~	~~06/11/2015~~	~~Ter acceptatie~~	~~Geaccepteerd~~		
1.0	06/11/2015	Ter acceptatie	Niet geaccepteerd		
2.0	31/12/2015	Ter acceptatie	Niet geaccepteerd		27/01/2016
2.0	31/12/2015	Ter acceptatie	Geaccepteerd		26/02/2016

Bevindingen toetsing:	Actie
Na telefonisch overleg waarbij Omexom nadere uitleg heeft gegeven, wordt versie 0.2 alsnog geaccepteerd.	O

Figure L.3.: Example Project management plan

This also happens with the review of the RAM plan, see example 2 in figure L.4. It is accepted by a certain person, but a month later, the same document turns out to be not accepted by another person. This is due to the fact that there was a meeting in which the RAM plan was going to be discussed by RET. Based on this meeting they wanted the plan changed. However, this influences the work of Sweco negatively, because they already started working on an accepted plan.

This followed from the fact that reviews never were completely closed. RET changed their wishes and came with additional things to add to the design (Engineer). Also in an official letter sent by Sweco to Omexom on 11-11-2016, it is discussed that there is a constant flow of new input of Omexom and new wishes of RET. This results in additional work and the design process is therefore delayed. Furthermore, Sweco delivered many concept documents to Omexom, but the receiving of the review comments took very long of both RET and Omexom. Sweco also discusses the fact that Omexom would state that the quality of the designs is not correct. However, Sweco states that if certain requirements are not met, that would follow from the constant changing of requirements by Omexom and RET (see I, Officiele brief). An example of this is shown in figure L.4, as example 1. Version 2.0 became not accepted three times in a time span of 7 months. Each time they came with additional wishes that they also wanted to be seen in the document.

Historie van het te toetsen document:

Versie	Datum	Status	Conclusie	Naam behandelaar	Handtekening en datum
1.0	22/01/2016	Ter acceptatie	Niet geaccepteerd		25/02/2016
2.0	25/03/2016	Ter acceptatie	Niet geaccepteerd		02/06/2016
2.0	25/03/2016	Ter acceptatie	Niet geaccepteerd		15/10/2016
2.0	25/03/2016	Ter acceptatie	Niet geaccepteerd		18/10/2016

Bevindingen toetsing:	Actie
Op 14-10-2016 is deze TRD besproken met Omexom/Sweco. Als aanvulling zijn er afspraken vastgesteld. Op 18-10-2016 is er telefonisch overleg geweest met C. Grunder m.b.t. de impedanties (deze zijn in dit document aangepast) tevens nog aanvullende opmerkingen.	

1

Toetsingsrapport Document
Projectteam Energievoorziening Hoekse Lijn

TRD 005
Versie: 03

RET AARDIG ONDERWEG

Gegevens te toetsen document:

Kenmerk	RET-EHVL-0.12.4.1.-Alg RAM-plan R2.0 11-01-2016				
Documenttitel	RAM-plan				
Toelichting	Document per mail verstrekt d.d. @@@@@		Archiefcode lokaal RET	Code van document	

Historie van het te toetsen document:

Versie	Datum	Status	Conclusie	Naam behandelaar	Handtekening en datum
1.0	06/11/2015	Ter acceptatie	Niet geaccepteerd		
2.0	11/01/2016	Ter acceptatie	Geaccepteerd		27/01/2016
2.0	11/01/2016	Ter acceptatie	Niet geaccepteerd		25/02/2016

2

Figure L.4.: Example long time span

So the reviews came very late and they added sometimes extra wishes or requirements to these reviews. This made the process even more sensitive to scope creep. Furthermore, they changed assumptions in a later stage of the design so the documents needed to be changed (Project Manager). Because the review often took a long time this influenced the entire process (Engineer). Stated in an official letter sent by Sweco to Omexom on 11-11-2016, it is discussed that Omexom was basing reviews on outdated documents. They already received updated documents however did not receive review comments on those. Those reviews also included additional work in terms of extra wishes of RET (see I, Officiele brief).

A good example of late changes of the RET is the cross subsection in the design of the overhead lines. There was no written down requirements regarding the cross subsection characteristics, so Sweco chose a cross subsection of 500mm. However, in a very late phase of the design, the 500mm had to change into another value. this resulted in extra added work which could have been avoided by an earlier decision or earlier response to the design (Project Manager).

It can also be seen in the document planning that almost all documents end with at least a 3.0 version. Many documents also have a version 4.0, 5.0 or even a 6.0. For example the foundation, pile plan, cross-subsection has a sixth version. And the building installation drawings have four review versions, with a time span of seven months.

Another example is that of the functional design, shown in L.5 that eventually had six different versions. The review came two months later twice and the total time span was very long. This example followed of the fact that it is not possible to determine the level of detail that is tendered for. Every review round gives the opportunity to add new points because they themselves can decide that a review is not complete (Engineer).

Toetsingsrapport Document — **TRD 006**

Projectteam Energievoorziening Hoekse Lijn

Versie: 05

RET AARDIG ONDERWIJS

Gegevens te toetsen document:

Kenmerk	RET-EHVL-4.2.1.1.-Alg Functioneel ontwerp Installatie R1.0 06-11-2015		
Documenttitel	Functioneel Ontwerp		
Toelichting	Document per mail verstrekt d.d. 07/11/2015	Archiefcode lokaal RET	Code van document

Historie van het te toetsen document:

Versie	Datum	Status	Conclusie	Naam behandelaar	Handtekening en datum
1.0	06/11/2015	Ter acceptatie	Niet geaccepteerd		10/12/2015
2.0	22/01/2016	Ter acceptatie	Niet geaccepteerd		26/01/2016
3.0	14/03/2016	Ter acceptatie	Niet geaccepteerd		19/05/206
4.0	10/06/206	Ter acceptatie	Niet geaccepteerd		23/06/2016
5.0	04/08/2016	Ter acceptatie	Niet geaccepteerd		14/10/2016

Figure L.5.: Example

5. Additional wishes an requirements

When a wish or requirement resulted in a large amount of additional work, it became extra scope. However, the wishes and requirements with an uncertainty about the largeness of the impact, did not become formalzied, because this would result in many EOWs. It was chosen, that the other four areas in which EOWs were submitted, gave enough income to balance the extra work of this part. Still, these wishes and requirements could have consequences for the integrity of the design. The level of detail of these additional wishes and requirements was so large that managing them was very difficult which also came forth out of the insufficient scope control of the project and of Omexom. Formalizing all changes was seen as unworkable situation (Project Manager).

Furthermore, the contract had as result that when a difference in insight took place, Sweco still had to take up the work. Sweco had to do that immediately. There was no time to first look at the impact and consequences before starting the work, due to 11.2 in the contract. Sweco always had to follow what the client wished (Process Coordinator). This was hardened by the fact that the process of reviews was never completely closed, as said before. This resulted in a continuous flow of changing requirements, extra wishes and new insights. There was no room to react on the review rapports. Therefore the changes always needed to be followed up (Process Coordinator). Some of the changing wishes and requirements will be discussed.

Discussion component choices

During functional design, there was no definitive information available about the component choices. This concerns 10 installations like the rectifier and the high-voltage distribution device. The components discussion that took place had a large impact on the project. Components were prescribed in the specification that did not meet the requirements. The functional design has been drawn up on the basis of the quotations and due to not passing on the concept at first, the RET stated very late that it was not accepted. In February 2016 the components are still not chosen, resulting in a lack of clarity about the final dimensioning of the components and a lack of sight drawings and circuit diagrams. Due to the absence of an assignment, the suppliers could not provide more information than the necessary (Overzicht verloop Hoekselijn). RET did not believe the suppliers, so product specifications had to be tested many times and there was a constant discussion.

An example of RET not believing suppliers is that they did not believe that the blow-off of the high-voltage distribution device could just get out of the ground, which can be done according to specifications. A direct current distribution device blows in case of a short-circuit to the top, but for this purpose explosion hatches had to be placed on the outside as well as the realization of the cable connection via this hatch. Which normally just goes through the front of the installation (Engineer). Also EOW 12 is an example. Additional effort was put in showing RET that certain components were indeed the best solution for the problem. However this resulted in planning -, integrity -, and financial consequences of approximately €4000 (Change form EOW 12).

Transformers

This discussion about the components is in line with the example of changing wishes of the transformers. They changed the wish of the winding material many times (Process Coordinator). The supplier expressed it preference for a transformer with a winding of aluminum. However, the RET came up with additional requirements including that the winding material must change to copper. In an email on 20-01-2016 it is said that this is possible, however will be followed by a price increase. The losses, dimensions and weight will also be different of the transformers. On 15-02-2016 a change request is submitted by Omexom for a change into aluminum transformers. They argument that in the plan of requirements the winding material is aluminum and they state that during a meeting with RET this is discussed and RET accepted that change (see I, EOW 5). However, on 14-03-2016 RET changed the winding material back to copper. Eventually EOW 5 is set up on 4-7-2016 for this change of copper to aluminum. In the change request it is said that there is impact on the planning due to the interfaces with 10 other areas. The change also has interfaces with the heat load, ventilation and construction calculations, the setup drawings and the verification of the supplier documents.

L.0.2. Conclusion

This project gives different causes of scope creep. First causes were found like not enough capacity, wrong people on the wrong spot, missing links between employees, not correct project managed at the other stakeholders, and stakeholders with strong opinions. Also causes related to the process of the project were found like reviews that take too long and are without integrity, setting up products in the wrong order and game-like interaction of the project managers. This influenced the scope control process resulting in not formalizing and anticipating changes, and into a wrong process of reacting on reviews and changes. Furthermore, there were many changes till the last moment, and changes with too much detail. Finally, human factors, missing input with the tender, wrong interpretations, time pressure and complexity of the project influenced the project.

M. Nijmegen Goffert: Scope Creep

Scope creep was found in different area's in the project of Nijmegen Goffert and will be discussed in this appendix: (1) Continuous optimization's of the design, (2) Rationality, (3) Control in terms of EOWs and employees, (4) Time that is needed for an EOW to process, (5) Many disciplines were found on one place, (6) Examples of scope creep. This forms the basis for the scope creep causes in chapter 6.

M.0.1. 1. Continuous optimization's

The project entailed making a detailed description of the definitive design, for the purpose of the tender for the realization. This is based on the pre-design. After the summer of 2012, the architectural design of the roof was not ready. In order to save time, in consultation with ProRail it was decided to cut the delivery of products into two parts. In part A, Grontmij worked out the entire station excluding the hood. Part B would be the additional delivery in which the architectural design of the hood would be included (see J, Motivation).

Part A was delivered in September 2012 and reviewed in October. However, this review showed that the architect was not only involved in the evaluation of the design of the hood, but also in the design and review of the basic station. The involvement of the architect resulted in the station having received a substantial upgrade and has therefore become a very pleasant and socially safe environment for the traveler. Due to the closer involvement of the architect, there was a need for intensive coordination between architect, modeller, municipality and constructor. Agreements have been made about this with ProRail. The coordination between these parties resulted in a cyclical and iterative design process in which several additional changes were made by various technical disciplines, sometimes repeatedly (see J, Motivation).

Some examples of design activities that have arisen from the optimization process are adjusting the layout of the station (consequences for cables and pipes, telecom, overhead line); the installation of architecturally sound lighting (consequences for electrical installations, additional light calculations, cables and pipelines); designing a new type of technical space and repeatedly relocating it (consequences for telecom, electrical installations, cables and pipelines); changed visions of stair locations and entrances, which once again changed the platform layout (see J, Motivation).

Following this, the vision on the hood was changed and the architect came with an adapted design. This design again needed to be calculated constructively. This resulted in a new iterative process with the architect. However, ProRail decided to freeze the design at the end of November 2012, and with that the design process with the architect. The agreement states that the period from the end of November until the beginning of January 2013 would be used by Grontmij to carry out all remaining changes (model, drawings) and to complete the work on the basis of the this freezing. The process agreement concerns, among other things, the coordination with the architect. In addition, a bonus is given for timely delivery of the end products. However, this agreement could not be observed for plausible reasons. On the 25th of November, the design was not yet at rest, which led to a cyclical design process, more alignment and more monthly reports (see J, Motivation).

In December 2012 the architect presents the design to Welstand. Apart from the materialization, the image (design) is also slightly adjusted. This had consequences like that the contour of the hood is no longer in accordance with the structural model. The agreement to share the visualization with Grontmij in time, so that Grontmij could also take over the finishing of land heads and technical space in the model, has not been fulfilled. The work could not be delivered due to this in January 2013. Another reason for this is that Grontmij had no modeling capacity in December for one week (see J, Motivation).

So, after the review of the basic design there is an architectural optimization of the entire station. This releases the set baseline. There follows a new iterative design process. Delivered products had to be revised, sometimes repeatedly. In addition there were a number of bottlenecks and extra costs for for cables and pipelines, telecom and other disciplines (see J, Motivation). The final tender documents, that were the result of this process are finished around the end of may, for example the requirement specification was finished on 21-05-2013 (see J). The entire process can also be seen in figure M.1. This is based on the input for a meeting, the requirement specification and the hour-clarification in J.

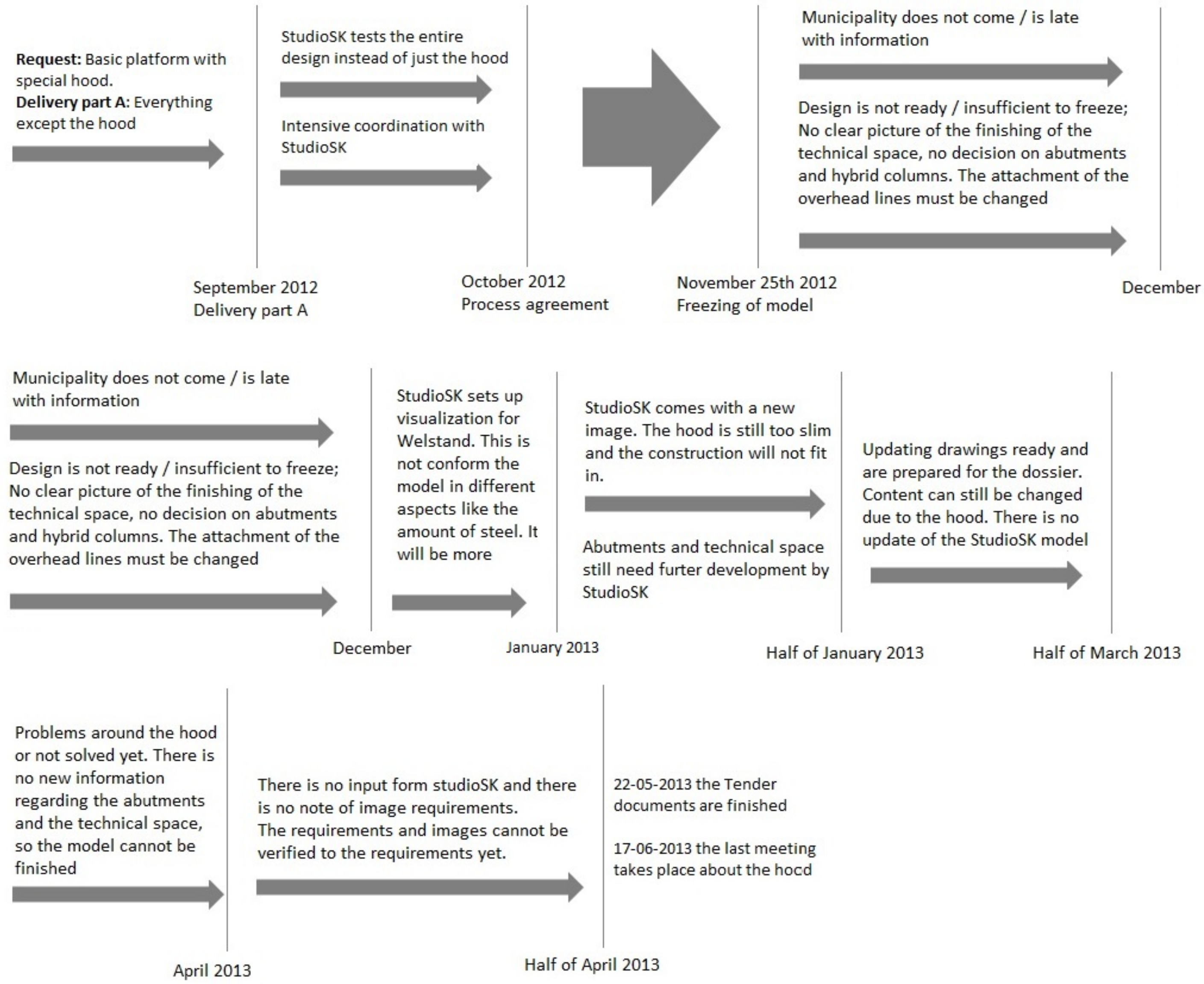


Figure M.1.: Overview of the time-line of the project

The consequences of the discussion with the architect and some other bottlenecks are numbered and explained shortly in table M.1 (see J, Input bespreking). All are part of EOW 22.

Table M.1.: Factors that are influenced

1	Extra tuning with StudioSK in Zwolle / Utrecht; weekly or biweekly
2	Extra calculation of the construction for changed insights in design from StudioSK and for checking possibilities of the design for example for the corners of the side wall
3	Extra effort with regard to cost calculations for example due to more use of steel
4	Changed location of the technical space resulting in the redesign of a version that was finished in September of the cables and pipes and updating the model
5	Insights of the finishing of the abutments changes continuously. Effect on model work and the environment of the incline
6	The design of the columns bicycle bridge changes at repetition from concrete, to steel or hybrid. Consequences are constructive calculations and adapting of the modeling
7	There are different visions of the platform, the equipment, and the signage
8	Length, location and appearance of slope stages changes from northeast to southeast
9	Landing of embankments on platform changes with as consequence model adjustments
10	Move overhead lines portal with as consequence restraining portals and making new transverse profiles
11	The portals will still be placed at 1 meter from the outside of the platform and then the overtaking span seems possible. As a consequence the change portals in the model must become wider
12	The plan for the lighting is not clear. This is moved forwards multiple times due to changing insights
13	The attachment of the overhead lines cannot be in the hood at elevators due to the stiff point. They will be attached at the heavy beams at the front hood. This has as consequence that there is a moving suspension point which will result in restoring portals, a new cross section, new detail engineering, and model adjustments
14	Fencing changes, sometimes it is glass or sound screen, sometimes open fencing. this results in many model modifications
15	The model can be adapted to new insights, shelters, storage space, technical space and the like.
16	There is a discussion about rainwater drainage. The municipality does not want underground storage / crates. This has as consequence that ditches must be designed and installed. This on its turn has as consequence the adaptation of the space of the bicycle parking, the insertion ditches, and problems with space dissolving
17	The municipality has a strict requirement considering deep sewers, namely to remain outside a zone of six meters of the sewer. Resulting in various studies into solutions to comply with this but it seems not possible, 4 meters is feasible. Furthermore the investigations require model modifications (corner hood, corner side walls, staircase adjustments)
18	Cutting back is necessary due to more expensive failure of the hood and other aspects. The side walls of glass will be removed. This can be done by following extensive calculations that show that these facades are not necessary for roof the construction.

The costs can be found among others in construction calculations, model adjustments, and in other cost items like taking the track and the safety into account. The costs were agreed to be €60.000 after the process agreements but eventually were almost twice as high (see J, Input bespreking).

M.0.2. 2. Rationality

The architect does not want discussions about money to stand in the way of obtaining an optimized design. The architect asks many questions that require a great deal of researching options. He for examples asks what will happen if the angle of the hood is 25 or 20 degrees instead of 10 degrees. To answer this, Grontmij has to re-model and carry through these changes for each aspect. Changes will also be made, which later will be turned back as for example with the fence work, stairs, location of the technical room, and the location of the platform (see J, Motivation). This resulted in having the time spent being subject to the design. The iterative character is part of the process, but contractors label a price to the time spent on this. This always results in a discussion about what is rational for the project and what will be paid or not. Furthermore, due to time pressure, these changes and its financial consequences are formalized afterwards (Project manager). However, this results in a process where changes are introduced without researching the impact first.

M.0.3. 3. Control

Not everything can be under continuous control and not everything can be foreseen. Sometimes additional work is done on an aspect of the design. This can be due to unforeseen reasons. However, these hours are mostly not reimbursed. This is due to the process of starting to work after approval of an EOW. Then, when it turns out that more work is needed or more hours need to be spent, this is not always straightened. Due to the good collaboration this was then taken for granted resulting in small changes that are not formalized (project manager).

Another control that turned out hard to establish, was that of the work of the engineer. The engineers want to do the best work they can, however this is not always clear for the project manager. They sometimes spend extra work on optimizing the design or taking mistakes out of the design, even when not part of their scope. This can affect the integrity and is a form of scope creep. Two things can happen to improve this situation. First it could be made clear that it is not part of the scope. They can agree on the fact that the design could still be optimized but they stop and focus only on their scope. The other option would be that the engineer takes this to the project manager or lead engineer and that they would discuss this with the client. When the client agrees, it could become part of the scope, otherwise, they would still have to ignore it (project manager).

M.0.4. 4. EOWs take time to process

Also in this project EOWs take time to process and this can become long periods. For example EOW 24 was send on 13-06-2013. The assignment came at the 17th of July. However the performance statement was send again on 12-08-2013 and eventually the accepting of the payment came at the 30th of September. This is a process of almost four months (see J, Financieel overzicht).

Additionally, it takes time to set up an EOW. The entire process is accompanied by high overhead costs. Therefore ProRail normally does not want EOWs for an amount smaller than thousand euro. However, this harms the process of formalizing all changes (Project manager). In the project Nijmegen Goffert this was solved by the project manager in a way of setting up a EOW that reserved a maximum amount of €10.000. All small changes that had a small financial consequence were put into this EOW based on directing instead of fixed sum. This takes away the overhead expenses spend on an EOW. This was mainly based on trust and in the end was used for 75%. This amount came forth out of ten different things like drawing up a memorandum of the sewer or setting up the green compensation plan (see J, Financieel overzicht).

M.0.5. 5. Many disciplines in one box

There were many disciplines concerned with the design of the platform and therefore many interfaces (Engineer construction). When one thing changes, many other disciplines had to update their design and start with new starting points. In this optimization it became clear sometimes that certain options were not possible which again needed changing of the different disciplines. The integrity therefore was a focus point and was hard to manage. This laid pressure on the project and enlarged the chance of having scope creep.

M.0.6. 6. Examples of Scope creep

There have been a number of bottlenecks in the project that resulted eventually in scope changes. Most of the work due to these was reimbursed afterwards. The impact therefore was not made insightful and became clear after the introduction of the change. Some examples will be given in this section.

2D image to 3D model

One example is with regard to landscape integration. It appeared that the image of the municipality (2D) that had been delivered was not fit in 3D. The environment was hilly, but this was not taken into account correctly in the 2D model of the municipality (Project manager). There was insufficient space reserved for the slopes. This meant that the design had to be adapted in consultation with the municipality (see J, Motivation).

When the design was translated into 3D and had been redesigned to fit in the available area, it lead to adjustments to the layout of bicycle parking facilities in number and placement. Intensive coordination with the municipality was needed to solve the integration problems and again led to adjustments(see J, Financieel overzicht). The reaction time of the municipality was not very fast (see J, Motivation).

This assignment was outside the scope ProRail, but for the building of the model and the image formation the landscape integration was included in the model at the request of ProRail and the municipality. There were also changes needed to part A. Fore example the location of the stairs needed to change which resulted in changes to connecting embankments which resulted in needed model modifications. The financial consequences resulted in approximately €13.000, stated in EOW 11. This document was made at 07-03-2013 and submitted at 04-04-2013, however not accepted. Therefore it became part of EOW 22, which includes the long list of changes in table M.1. However this was also rejected. This EOW was then submitted in parts upon request. This example became part of EOW D/EOW 30 named at 13-06-2013 (see J, Financieel overzicht). The fact that it took long to accept was a risk for Grontmij. Furthermore, the impact already took place before the change was formalized and the work already finished before the EOW was accepted.

The design of the hood

The hood had a point that ran 20 meters. During strong wind, it would deform 200 mm under static conditions. In dynamic conditions this could be about 1.5 meters which is dangerous. The architect proposed to keep the hood half open but to keep the 20 meter point. Grontmij researched this, but concluded that it was still impossible and the hood had to be shortened. Partly because of the very strict rules on movement of the elevator shaft and the overhead lines. Since there was more than 60 meters between the two upper portals, there had to be a suspension point on the roof for the overhead lines (construction engineer). When the hood was adjusted this had consequences like re-examining the structural stiffness, changing the model, rebuilding portals and adjusting of a loop of overhead contact lines. The type of portals remained unclear for a long time due to design wishes from architect (see J, Motivation). The last hour spend on discussing the hood is made on the 17th of June 2013 during a meeting (see J, hours clarification). The last calculation is recorded on the 11th of June 2013. This shows that this remained an unclear disturbing factor till a very late phase of the project. This is also shown in figure M.1.

M.0.7. Fence

As stated in the financial overview (see J) there was discussion about the fence. The model must be changed multiple times due to a change in the material of the fence. It started as a fence, then it turned into glass, where after it became a fence again, when finally it became glass resulting in many model modifications (see J, Input bespreking). This change must be introduced in the tender documents, in the drawings, in the calculation, in the cost estimations which have to be accepted again and there must be made a budget reservation (Project manager). The hours spend on this were afterwards formalized. In the note of image requirements (see J) it can be seen how the end result must look like, see figure M.2.

Figure M.2.: Example of fence in the end result

M.0.8. Conclusion

This project gives rise to different causes of scope creep. First, at the start of the project it turns out that decisions on rationality are needed. Furthermore not able to predict the entire complexity of a project is a cause that is almost unavoidable just as having missing input and having a client that tendered the project as a fixed scope while maintaining it as a moving scope. Furthermore, it is found in this project that there are high cost involved with the process of an EOW and they solved this with an EOW that gave room too changes with small financial consequences. Additionally, the scope control process was not perfect. There were still changes not formalized. There were many changes till the last moment asking for large details and sometimes they did not anticipate changes or started before having approval. This project also endured some problems with the team composition. They had some stakeholders with very strong opinions and employees that wanted to work too good. Furthermore they had many disciplines in one place which made the process of the project hard. Finally, human factors always play their part in each project.

N. Analysis Configuration Change Management

This chapter analyzes whether CCM is used in all three projects as intended. The analysis is based on the checklist in E. The completion of the analysis follows from two different things. First, documents lay a basis for this analysis together with the lessons learned from the analysis of scope creep. Second, different interviews were hold based on the checklist. The main interviewee is the project manager and the lead engineer of the different projects.

N.1. Analysis project Geldermalsen

When a project uses SE, the wish of the client becomes one of the corner stones of the project. So, to conduct a successful project with good use of SE and CCM, the customer demand is important. Within the project of Geldermalsen the customer demand also stood central. This follows logically from the fact that the requirements of the client are leading and the contract makes sure that the wishes of the client are followed.

Within the project of Geldermalsen a work packages was set up by ProRail to make sure that CM was followed. These were work packages 1.5.1 and 1.5.2. Work package 1.5.1 is named the assignment of Configuration Management. The goal of this work package is "Timely delivery of the complete set of management documents, which the then current standards of the managing body satisfies. Also, have at all times an overview of and insight into the current documentation that collectively describes the product scope".

Work package 1.5.2 is named Configuration Management Transfer. The goal of this work package is "Translating the project scope of an infrastructure project into an explicit specification of infra-information to be delivered on the basis of the ProRail operating instructions".

Important parts of work packages 1.5.1 are the following:

- CM must comply with ISO10007;
- CM consists of the parts:
  - Controlling the configuration of the work that the contractor carries out himself;
  - Control the interfaces with the (design) products of other engineering and consultancy firms;
- Control the process by maintaining various status overviews;
- The contractor carries out a configuration audit every quarter in accordance with ISO10007 and processes the results in the progress reporting;
- Make an inventory, review and record of relevant basic data to be delivered;
- Look up and retrieve where necessary current versions and additional documents required for the realization of the assignment. The here meant information collects the contractor independently from the managing authorities inside and outside ProRail;

- At the moment that regulations (RIC) or drawings change in ARTIWIN, the contractor will draw up an impact analysis and indicates the consequences for the process and product scope. If this leads to a 'VtW' or CR of the Contractor, then the Contractor will inform this at an early stage, in accordance with the submitted format. For this, the client gives a unique number;
- At the moment that changes occur, the contractor determines whether a new pre-notification must be made and does that after agreement with the client (RSE) independently with the managed authority;
- The registration and request of documents in Artiwin must be done according to PRC00021;
- The CR must comply with the format Appendix 4.5 - Overview of changes. The CR serves to have a clear and unambiguous title and a clear description;
- The CR status overview must comply with Appendix 4.1 - Progress Report;

(See Vraagspecificatie in H)

N.1.1. Plan

At the start of the project there must be processes, procedures, tools, files, and databases created for managing the project assets. The project team did set up these aspects in order to manage the project. Furthermore, they had an agreement on what assets are important, how they are defined, categorized, classified, numbered and other things. This is written down in the contract and the requirement specification and is therefore decided by ProRail. The plan must be written down in the project management plan, which is done. Furthermore the CMP must be set up and stated in the project management plan. The project did not set up a CMP and therefore did not follow what is said by literature on the CM process. They did also not document the configuration management process as they did not explicitly define the process. Therefore the mindset of CM was missing in this point, even though in the contract there was stated that it must comply to the ISO standards of CM.

There must also be set up a planning with certain parts included:

- Identify the required resources, this was stated in the planning and in the plan of action, (see conceptplanning and Kickoff in H);
- Define the to be performed tasks, this was stated in the planning (see conceptplanning in H);
- Describe organizational roles and responsibilities, this was done, however not stated in the planning but in the Kickoff of the project, see H;
- Identify CM tools and processes, this wasn't done during this projects
- Identify methodology, this was stated in the contract, but not mentioned in the project or planning. Also the work package regarding CM wasn't mentioned in the planning, this is shown in N.1 (see conceptplanning in H);.
- Identify standards and procedures to be used, this was stated in the plan of action and written down in the contract, (see Plan van aanpak and Vraagspecificatie in H).

Figure N.1.: Planning (see conceptplanning in H)

N.1.2. Identify

An important part for CM is setting up the configuration of a project. When thinking of the configuration of a project in a way of knowing all the documents and information for the design, then in this project that was the case. The configuration of the system was known beforehand of the project, because this was all the information that was available at the start of the project.

In order to set up a configuration, CIs must be selected and each item must be given certain information. The selection of CIs must be based on the design which is documented through the analysis and allocation of the SRS. During the project of Geldermalsen, there is no selection made of the CIs and there was no SRS available at the start of the project. So, the basis of CM of setting up a list of configuration items is not followed. This is probably because in the construction industry there are no different items as in other industries. However there were objects which were the basis for certain design parts or work packages and were therefore based on the WBS and were validated after products were delivered. The project set these items under control, so it can be said that there was some sort of configuration control, but not as intended by literature.

The configuration of each CI must be managed as a separate item for the process of the project. The objects however were not seen as separate items for the development and were not placed under explicit management. They were all part of the design and therefore were all taken into account and fell under scope management.

Other important parts are linking configuration data to the CIs. This is not done during the project. Another point is linking technical configuration data to the system requirements. It can be said that this is done in the validation of the CRS of the FIS products. However, there is room for improvement here, by linking the data in a system where the relationships can be made clear and a link can be made fast to the needed data. Furthermore, data was linked between the different disciplines, however between client and contractor no linking of data was done.

N.1.3. Tracking changes

It is seen as needed to understand the baseline for all configuration items, which were lacking in this project. For the objects they did know the starting points, as they were written down in the requirement specifications. Sweco did not track their items, objects or documents. This mostly did not happen due to lack of time and money and because there was no management stirring into doing this. Taking into account the different designs they set up, it can be said that the project staff had access to these versions and therefore had access to accurate data. There were version numbers of certain documents and there was a list with all documents needed for the design.

However, due to a lack of an overall document with all the different products named or a program that traced version numbers, there was no clarity on this. It is recommended to establish a trace-ability matrix but such a document was not established and therefore not used to track the different objects. Furthermore, CM prescribes that the project staff has throughout the systems lifetime always access to accurate data of all available CIs. As stated, the project staff had access to the different documents so the configuration and all information was always accessible. But the different individual objects containing multiple items were not always made clear and traceable or placed under individual control.

To make information transmissible, always accessible and up-to-date, it is also recommended to make agreements on the interface between client and contractor. During the project of Geldermalsen, there were no agreements on sharing documents at the same time. In the contract it was written down that all documents must be submitted for reviews, however there was no agreement on sharing documents next to these official submitting moments. The assignment was not based on having all information during the process at the client his side. They only want to see the end products and not all details and decisions regarding this. They could have asked for this knowledge, but this didn't happen often.

N.1.4. Control records and manage

This section is in line with the section of tracking information. The first point is that configuration records need to be tightly controlled to ensure there is a full audit trail between the original requirement and the final version. Partly this was done, the trail can be found but this was not centrally managed or done systematically. The review procedures is standardized and these reviews are sometimes included in the FIS products so it becomes clear that it was applied in the new version. The review is always a standardized list and systematic process where both parties can react on a review. Therefore reviews can be trailed, however this is not centrally managed in the project directory. What can help this process is recording the configuration in a configuration management-database as fast as possible. This is not done in this project. They did not set up a clear and workable database. Finally, there must be version control, but during the project, documents were numbered but not locked during editing. Furthermore, there was no centralized traceable process considering the versions of documents.

Setting up integrity in the project

To establish product and system integrity, enough information must be maintained. The identification and documentation is done using the WBS and the verification and validation must be based on the CRS and SRS. Furthermore, it is important to record, track, and report change processing and implementation status. So, changes to these product characteristics must be properly identified, reviewed, approved, documented, and implemented. This will be discussed in N.1.6.

Looking first at the WBS, it can be said that project Geldermalsen worked by the use of a WBS. This was set up by ProRail and was the guideline for the integrity of the project. It contained the work needed for the design, development, integration and testing of the requirements. Following CM, the separate work packages must be integrated into the final system by the use of the WBS. This indeed happened en resulted in the FIS of the project. However, CM also prescribes that the physical design is documented using an allocation matrix and the subsystem or CI list. This was not done, each object was verified for each design part followed from the WBS structure and not from the matrix or list.

For the integrity the RBS, SRS and CRS must be set up. There were many discussions about both the SRS and the CRS as can be seen in K. Eventually it turned out that Sweco was only responsible for the SRS on the Nieuwsteeg and the travelers tunnel. The rest of the SRS would be set up by ProRail. Furthermore, the FIS process is an iterative process in which, normally, the CRS and SRS are sharpened in a number of months. The end products must be verified on the basis of the CRS and the SRS. However, the vast majority of the SRS was now made by ProRail and the project had to wait a long time for these products, since they had only been completed when the product had already been delivered. This project, therefore, was not properly tested against the SRS and only tested against the CRS.

N.1.5. Audit

Auditing involves validating that the actual configuration elements at any given time are the same as what was expected. At the end of each product that was delivered, so FIS 1.0, FIS 2.0, and RVTO, there was a validation. It was checked if these were the same as the original document with requirements plus any change requests, and therefore was followed up correctly as is stated by CM. It is also recommended to perform Configuration Audits associated with milestones and decision gates. This was done based on the Plan-Act-Do-Check circle without an external party. It can be said that the formal check was, as said, the validation at the end of each product. During the process of the designing there are intermediate validations, these happen during technical internal project coordination sessions. These sessions have less focus on the integrity than during the formal validation.

N.1.6. Using Configuration Change Management for changes to the system

In order to deal with all changes, it is recommended to establish a CCB. The CCB must represent all stakeholders and engineering disciplines that are participating on the project. ProRail and Sweco did not set up a CCB for this project. There was a relation between Sweco and ProRail were ProRail reviewed and accepted changes that Sweco suggested. ProRail could have talked to the other stakeholders about changes, but this was not known by Sweco.

The management of the configuration and changes can be supported by implementing a configuration control cycle that incorporates evaluation, approval, validation, and verification of CRs. During the project this was a automatic process not necessarily set up for this purpose but following the different steps.

N.1.7. Baselines

A baseline is a snapshot representing the current state of a system, product, technical work product. The freezing of the configuration should be the baseline of the system development and CRS.During the project of Geldermalsen, there was no working with baselines and they did not formally set up baselines. It could be argued that the tender dossier at the start of the project and the CRS at that moment could be the first baseline and the delivered product the other baselines.

A new baseline should be set up when there are new requirements or requirements have been revised, reviewed, approved by an approval authority, and released for project decision making. During this project they did not set up baseline management and made no formal freezing of the system development and CRS when things changed. They did not put the baseline under control during the working on these products, but they did control the end products and validated them with the CRS and the added changes. So, between version 1.0 and 2.0 of the FIS product, the changes are added to the product. Therefore the products can be seen as baselines even though they did not explicitly call this baselines.

Another important part is that a baseline must be accompanied by performance requirements and acceptance criteria. Sweco received a CRS of the three different projects that must be combined during the project of Geldermalsen. It would be essential that a validation has taken place on these products and on the accompanying design drawings they received at the tender. In the Note of Information (see H) at the start of the project many times it is asked whether a validation could be sent. Once the following is asked: "The CRS contains various requirements with regard to passenger flows, capacity, transfer space, etc. Can the candidate assume that these requirements have been correctly incorporated in the accompanying design drawings with regard to widths of tunnel/transfer and rising points? The explanation states that for the follow-up engineering, it can not be assumed that the requirements have been correctly incorporated into the supplied designs. The requested products within this request must comply with the current regulations. So, also from this it becomes clear that at the start there was no validation and therefore no acceptance criteria were sent by the client on the CRS Sweco received. Therefore Sweco set up their own validation criteria in the validation of the products (see Bijlage Y2 and Y3 in H).

Furthermore, when changes occur, it can only change the baseline through a documented change management process. This was not done for the purpose of changing the baseline, but it was done for the purpose of remaining control on the scope. The process of an EOW is a documented change management process and it can therefore be said that this was followed.

N.1.8. The processing of changes

CCM makes a change between CRs and other changes to the system. Specifications that do not comply with the configuration baseline and result in a new functional concept, are called CRs. These, in contrast to an EOW, could be accepted by the client without going through a change process. However, ProRail does not distinguish different changes. They used the EOW procedure for both.

There is in literature also made a distinguish between two types of change proposals, the EOW or a Contract Change Proposal. Here did ProRail also not make a difference. The EOW was leading and in most times also had a influence on the contract and was then stated in the EOW. Therefore the contract change proposal were processed, but under the name of an EOW. The wished content of an EOW was written down in the contractual document in the appendix.

CCM states that all changes must be managed by a formal process to ensure that the impact is researched and handled correctly. Not all changes were followed by a formal process and there were many ad hoc changes. If this would have gone perfectly there would be no scope creep. Small changes and other changes that seemed to have small impact were almost never submitted.

When a change proposal is set up, there must be a formal document submitted, requesting and specifying a corrective action to a baseline document that contains a latent defect. This however does depend on the nature of the change. There are EOWs were in general wording it is written down what the requested change is. There are also cases were it is written down which requirement will be changed and then it is changed in the CRS or SRS. The example of the bicycle parking is one. The parking is multiple times changed of location and angle. The number of places needed in the parking is defined in the SRS and CRS. However, the location can be changed and that is not written down in these documents. It happens that these changes are a result of a conversation between two people and are changed in the drawings. When the drawings are reviewed and approved, the drawing then is the formal document stating the definite location. The project therefore is not only based on documents like the SRS. The baseline must also be the documents that enrich the SRS.

What must be included in the formal document

Change proposals must be coordinated and reviews must be conducted of the proposed change. This is done by having a formal document and is followed by Sweco in most cases. The formal document must contain sufficient information to evaluate and approve the proposal which was always the case. However, certain points that a formal document must contain were lacking:

- It must contain a reason for the change and a statement outlining the change;
  The EOW did always had a statement on the reason for the change and what it withholds.
- It must contain the details of the trade-offs, the alternative solutions and the preferred one;
  This was not always the case as it depends on the initial change proposal. Sometimes the trade-off was already made in the products and was not stated in the EOW. Sometimes the EOW was based on making an advice on something and then the solution was not needed to give.
- The preferred detail must show why it can be implemented successfully;
  This is not always possible and was therefore not always done, for example with an advice.
- An impact analysis must be done to indicate how it impacts the system on its turn;
  This was not always done and can be seen as a shortage.
- An impact analysis must be done to indicate which requirements or changes are added;
  The products that needed changing were sometimes named in the calculation of hours. It was mostly not stated in the EOW, because they took care of the integrity of the products during the design process based on the knowledge of the project. They therefore did know which products needed changing, but did not explicitly state it in the EOW.
- To see the impact, knowledge on the trace-ability across the different levels of design is necessary;
  This abstraction level was mostly not stated in the EOW. The changes did result sometimes in changes of an earlier product. The RVTO could for example result in changes in the FIS. This was mostly handled by cover notes and sometimes it was stated in the EOW.
- The impact on other CIs and aspects in of the design must be shown;
  This was most of the times not named in the EOW.
- It must contain the impact on interfaces requirements as described in the baseline documentation;
  This is sometimes named as part of the consequences on the planning. Interfaces are then mostly named in general, without specification. So for example it is stated that drawings of a certain subject need revision, but which drawings are not named.
- It must contain changes to the baseline documentation;
  This is stated in the description of the EOW as far as baselines are used.
- It must contain the requirements that in the specification are adjusted, added or expired;
  The default was that the requirement numbers, as stated in the CRS or SRS were not always mentioned in the description.
- It must contain the likely changes required to the documentation set;
  As said before, sometimes the interfaces were mentioned, and sometimes other design aspects that needed changing were mentioned, but this was not always the case.
- It must contain the impact on cost or schedule, if the case;
  This was always stated, as there was on the form for EOWs a special box for these consequences.

Results of an EOW

Before an EOW is put into effect, it must be approved. This was not always the case as stated in K. It is shown that multiple times the EOW was accepted when the work was already finished. The approval came very late and this was a risk that Sweco took. Sometimes there was approval via e-mail but this is not a formal approval. The approval came from ProRail and formal release was a signed EOW form, a letter signed regarding the budget changes and a performance statement. Then the assignment was put in the system of Sweco so the project team knew of the approval.

After approval changes must be put into the current baseline. Because there was no baseline management, this was not done. On the other hand, they did write down the effect on the design documents. Additionally, changes are normally tracked to completion which was not done during this project. A change became after approval part of the scope and scope management. It could be argued that the scope was seen as the old scope with added changes, which is comparable to baselines.

N.2. Analysis project energy supply Hoekse Lijn

To conduct a successful project with good use of SE and CCM, the customer demand is important. Within the project of the Hoekse Lijn the customer demand also stood central. The scope is validated and the reviews of the clients are always followed. These reviews showed the wishes of the client.

The project of the Hoekse Lijn set up technical management which described aspects like validation, verification, interface and configuration management (see I, PE). The part focusing on CM had as goal "To document the current configuration, to administrate and manage changes, so that the most up-to-date information is available at all times. Good CM guarantees that designs, requirements and interfaces are well defined and traceable. CM must also be set up for all activities that are directly or indirectly related to the configuration of the subsystems. Focused on controlling and safeguarding of the configuration status and the implementation of new configurations."

Important parts of this section are(See I, PE):

- The supplier must perform the following activities:
  - Configuration identification;
  - Configuration control;
  - Generate configuration status overview;
  - Run configuration reviews.
- The supplier must set up a Document Breakdown Structure (DBS).
- The supplier must:
  - Keep the configuration up-to-date;
  - Permanently assign the Documents with status to an official who monitors the configuration;
  - Have an internal change procedure, in which it is clear which person or persons may authorize Changes;
  - To determine the impact of changes to the configuration by all relevant experts.
- The supplier must deliver each 4 weeks a configuration status overview.
- The supplier must, for partial deliveries, early commissioning and delivery, have recorded the exact configurations concerning all physical and logical objects in the configuration database of the management system.
- An accurate review procedure must be drawn up and implemented for each type of configuration item.
- The DBS must be constructed hierarchically from configuration items. These must be provided with a clear and complete description. Upon delivery of the work and during the multi-year Maintenance (Optional) the supplier must have recorded the exact configurations concerning all physical and logical objects in the configuration database of the management system.
- Each configuration item includes at least a title, a type of configuration document, a unique identification number, a description, a status, a version number, a date.
- The output of a work package must be traceable to a configuration item from the DBS. In the DBS, underlying documents must refer to parent documents.

N.2.1. Plan

At the start of the project there must be processes, procedures, tools, files, and databases created for managing the project assets and this was done in order to manage the project. Furthermore, all parties knew their role and their function which made the management easier.

The plan must be written down in the project management plan, which Omexom was responsible for. Grontmij also worked at this plan. The CMP was also the responsibility of Omexom and must be set up and stated in the project management plan. However, Omexom did not communicate on having a CMP or used it as guidance. The CM process was not correctly documented and therefore the mindset of CM was missing. Grontmij did follow the process and gave the input for the plans to Omexom and they wrote the plan. However, large parts were not followed.

There must also be set up a planning with certain parts included. However, the planning of this project was already in an early state ignored. Some things, like the organization roles and responsibilities were written down in the job description. Other parts were responsibility of Omexom but, when established, never showed to Grontmij. Omexom was also in charge of the project control but they never really controlled the process. Omexom did not give feedback on versions that were sent to them and did not capture administrative things. The input of changes were not managed throughout the project even though agreements were made for this.

N.2.2. Identify

An important part for CM is setting up the configuration of a project, this means a documented determination of the status of a design or object at a certain moment in time. The configuration was established, written down and put into Relatics together with all information of the tender phase. The requirements were all put into Relatics and used for later validation.

In order to set up a configuration, CIs must be selected. Each item must be given a unique identifier so it can be tracked, including project documents and products, anything that is going to be created or changed and anything that requires limited access for security or safety reasons. The selection of a CI must be based on the design. During the project Hoekse Lijn, it was stated in the project requirements (see I, PE) that CIs must be established. Omexom was responsible for this, but did not do this. Eventually only a document list was established for Grontmij. Grontmij was only responsible for the design of the system and the input and output for this was all written down. This was the list that was leading in the project.

The configuration of each CI must be managed as a separate item. They things necessary for the system were all part of the design and therefore were all taken into account and fell under the management of the scope but not as intended by CM. Furthermore, configuration data was not linked to the items. There was linking of information in the validation of the project requirements. However, there could be an improvement done on this point, by linking the data in a system where the relationships can be made clear and a link can be made fast to the needed data.

N.2.3. Tracking changes

It is seen as needed to understand the baseline for all CIs, but these were not defined. The RET wanted the requirements to be traceable and not the items. Additionally, Grontmij shifted their focus from administrating, to making sure they would get paid for everything.

Another important part was making sure the project staff has throughout the systems lifetime always access to accurate data of all available CIs. Because items were not set up, this did not happen. There was accurate data within Grontmij. When looking at the relation with Omexom and RET there was a shortcoming in the communication from Omexom. This resulted in reviews on old versions and documents that did not end up with the RET. Therefore accurate data was not always available. It is recommended to establish a trace-ability matrix but this was not done.

N.2.4. Control records and manage

This section is in line with the section of tracking information. The first point is that configuration records need to be tightly controlled which contains version control. For the project of the Hoekse Lijn, a document planning with version numbering and data of when it must be delivered was established. Grontmij started the document planning, but Omexom took this over according to the plan. So, to make information transmissible, always accessible and up-to-date, there where agreements on the interface between client and contractor. However, it turns out that Omexom did not register documents and versions. After the first large amount of EOWs in July, this became clear. They did not keep track of what was delivered to RET and what they did receive of Grontmij. Grontmij then updated the version document list, but eventually it turned out this was also not kept up-to-date.

Grontmij stopped delivering all versions because it resulted in many effort but it delivered no contribution. Many documents finally ended in many versions and it was hard to keep overview. Furthermore, when they worked on a document, the version was not updated. Only the documents that were sent to Omexom received a version. When documents needed to be sent was stated in the planning, however, the planning was let go. This made the project difficult to manage. Furthermore, as stated in L, there was a large discussion on the components, which resulted in many difficulties regarding versions of documents and their delivering.

What can help this process is recording the configuration in a configuration management-database as fast as possible. This was done in Relatics but was let go eventually. The requirements changed not via a formal process, but via the reviews. The product was changed, but the Relatics database was not updated. In June 2017 it was stated that Relatics was not up-to-date.

Setting up integrity in the project

To establish product and system integrity, enough information must be maintained. The identification and documentation is done using the WBS and the verification and validation must be based on the Project requirements (see I, PE). Changes to these product characteristics must be properly identified, reviewed, approved, documented, and implemented and will be discussed in N.1.6.

So, looking firstly on the WBS, it can be said they worked by the use of a WBS. This was set up by RET and was the guideline for the integrity of the project. Following CM, the separate work packages must be integrated into the final system by the use of the WBS. The WBS was based on a decomposition of the system. However, CM also prescribes that the physical design is documented using an allocation matrix and the subsystem or CI list, which is not done. They only established a document list that was used for the design. For the integrity the RBS, SRS and CRS must be set up. Only the project requirements were set up. Omexom was responsible for this.

N.2.5. Audit

Auditing involves validating that the actual configuration elements at any given time are the same as what was expected. During the validation this was checked. However, the document against which the validation was done, was re-established afterwards, see N.2, and Relatics was not updated. It is also recommended to perform Configuration Audits associated with milestones and decision gates. There was an internal audit and an audit between Omexom and Grontmij. This was not done by an external party.

N.2.6. Using Configuration Change Management for changes to the system

In order to deal with all changes, it is recommended to establish a CCB. During this project there was no CCB set up. What happened is that Grontmij delivered their projects and EOWs to Omexom and Omexom on its turn to RET. RET reviewed and accepted changes together with Omexom. Also RET and Omexom talked to stakeholders, but this not known by Grontmij.

N.2.7. Baselines

The freezing of the configuration should be the baseline of the system development and CRS. In this project baselines are mentioned in the Project specific requirements (see I, PE). It is stated that: "The technical management plan results in tuning many aspects and as a result of this the basic principles and relevant baselines must be laid down at the interfaces. This is part of the CM process, in which the current configuration and starting points are documented so that the current information, as well as agreed assumptions and agreements for all parties involved, are always transparent. With adequate implementation, it must also be ensured that designs, requirements and interfaces and baselines are well defined, traceable and controlled". So it is said that the technical management plan must consist a description of the management activities including the management of baselines and their extension as a result of their own prepared project documents and the maintenance and further development of management structures, including WBS, SBS and object specification, to be followed up and periodically validated on the existing main structure and available systems (Relatics).

It is important to consider that Omexom had the responsibility of these plans. However, it can be said that baselines are not established, controlled or maintained. When the contract definition is done, the first baseline arises. The CRS and the system development were written down into one or multiple contracts and specifications at the start of the project and this was the first baseline of the project. However, a baseline must also be updated for changes and iterations. During this project the baseline was not frozen in Relatics or in another way throughout the project. Which is also important is that a baseline must be validated and the criteria for the validation were set up, but on a high abstract level. So, a designs must meet standards or norms, but the article and paragraph numbers within these standards that needed considering were not stated.

A baseline can only be changed through a documented change management process. The process of an EOW is in line with this but was not done for the purpose of changing the baseline, but it was done for the purpose of remaining control on the scope. However, designs were adapted to changes but not consistently implemented in Relatics. Omexom did not communicate about this with RET. The requirement sets were not adapted, only requirements that could not be fulfilled were named and changed. The project manager did state that they should have done this differently. Each change should have been formalized and written down. When, for example, components were chosen during a meeting, this was not written down but followed for the design. However, the client sometimes came back on things they had said previous and then it turned out to be the problem of Grontmij because they could not show what was discussed during the meeting.

A configuration control cycle can be helpful and during the project this was an automatic process not necessarily set up for this purpose. Furthermore, the evaluation in terms of reviews was a process that never really stopped and of which the approval came very late. Additionally, the validation and verification was not looped back. This can be seen in N.2. Instead of following path 1 and re-establish the documentation set, the wishes and changes were immediately introduced and at the end the validation criteria were changed so it would fit the final product.

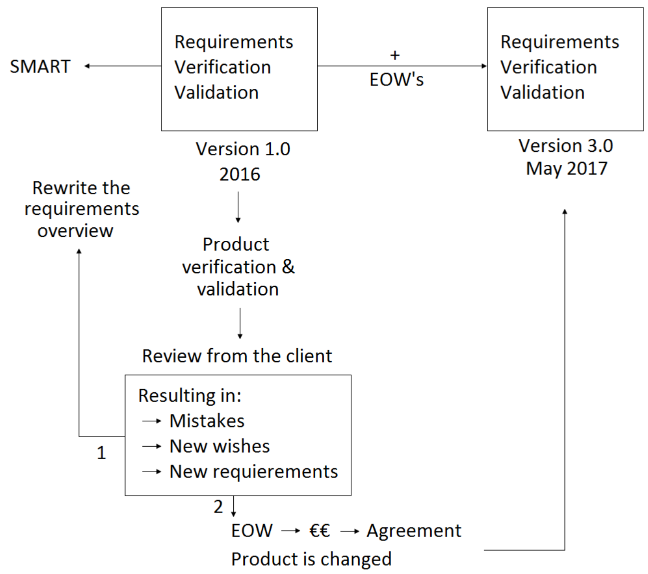


Figure N.2.: Wrong process of reacting and reviewing (Own Image)

N.2.8. The processing of changes

CCM makes a change between CRs and other changes to the system. During this project, there was no distinguishing between these two different changes. They used the procedure of the EOW for both types and also always influenced the contract so can be seen as a contract change proposal. So there was also no difference made between the EOW or a Contract Change Proposal.

CCM states that all changes throughout the system development must be managed by a formal process to ensure that the impact is researched and handled correctly. Till the project manager was replaced at the side of Grontmij, all changes were immediately introduced and there was no formal process for changes. After this many EOWs were afterwards submitted stating only the financial consequences. So, it was tried from that moment on to maintain this till the end of the project.

However, still not all changes were followed by a formal process and there were many changing wishes coming from the reviews. If this would have gone perfectly there would be no scope creep. Small changes and other changes that seemed to have small impact were almost never submitted. There was no distinction made between class 1 and class 2 types, even though this could bring clarity to the changes. It is said by the project manager that changes are only related to a contract. The contract must state exactly what to do, and an additional work outside of the scope is never part of the payment. So, for each change that has financial consequences, the project must receive money. The game around contracts result in not capturing all small changes, because a change to a requirement does not always result in financial consequences.

What must be included in the formal document

When a change proposal is set up, there must be a formal document submitted, requesting and specifying a corrective action to a baseline document. The formal document of an EOW must contain sufficient information to evaluate and approve the proposal. It can be said that this was always the case. However, certain points had to be included but were not:

- It must contain a reason for the change and a statement outlining the change;
  The EOW did always had a statement on the reason for the change and what it withholds and

this was a detailed description. The reason for the changes was not always given. Furthermore, before an EOW is submitted it is already stated that it would become a success or not.

- It must contain the details of the trade-offs, the alternative solutions and the preferred one; This was not always the case as it depends on the initial change proposal and how important it was. Grontmij designed the system and Omexom ordered the needed components. Grontmij needed to help them with this process and this sometimes resulted in trade-offs.
- The preferred detail must show why it can be implemented successfully; This was not named in the EOW.
- An impact analysis must be done to indicate how it impacts the system on its turn; This was not named in the EOW. EOWs would not lead to an improvement, it would correct errors or relate to additional wishes. They were not based on optimization's of the system.
- An impact analysis must be done to indicate which requirements or changes are added; The EOW stated the additional work, not which requirements would be changed.
- To see the impact, knowledge on the trace-ability across the different levels of design is necessary; This was not gained necessarily. They did mostly know the status of some design documents related to the EOW.
- The impact on other CIs and aspects in of the design must be shown; This was not named in the EOW.
- It must contain the impact on interfaces requirements as described in the baseline documentation; This is sometimes named as part of the consequences on the planning. Interfaces are then mostly named in general. The interfaces must be known for the EOW because the interfaces could result in extra additional work that must be part of the formal statement.
- It must contain changes to the baseline documentation; This was not named in the EOW.
- It must contain the requirements that in the specification are adjusted, added or expired; This was not named in the EOW.
- It must contain the likely changes required to the documentation set; Sometimes the documents that needed changing were named but it was never complete.
- It must contain the impact on cost or schedule, if the case; This was always stated.

Results of an EOW

Before an EOW is put into effect, it must first be approved. At the start of the project it resulted in €400.000 of work that was not submitted and approved. After the project manager changed, they started submitting EOWs and they sometimes waited at the approval. Twice they stopped the work due to the long discussions. However, they saw the approval of EOWs as a game. Sometimes they wait on approval and sometimes they work ahead. If it was known in advance that something was seen by all parties as additional work, they did not wait on the assignment. Went the assignment was given, they started negotiating about the payment. The contract stated that Grontmij always had to carry out the work, but this was ignored after a while.

The formal release was a signed EOW form of the RET and this was discussed internally. This could be done because the team was very small. After the approval, changes must be put into the current baseline, but because this wasn't established, this wasn't done. Changes also should be tracked to completion but this was not done. Changes became part of the scope and therefore they did not manage this as a different part of the scope. There is always a risk that there remain faults in the documents due the an overseen integrity. Corrective actions therefore can take place till the end of the project.

N.3. Analysis project Nijmegen Goffert

To conduct a successful project with good use of SE and CCM, the customer demand is important. Within the project of the Nijmegen Goffert, much effort was put into the customer demand. The project team worked closely with the architect and also the Municipality. This so the design would be optimized according to ProRail its wish.

Within the project of Nijmegen Goffert the principles of CM are used, but the theory itself is not mentioned. For example, there is a special work package for the control of changes which could be compared to CCM.

N.3.1. Plan

At the start of the project there must be processes, procedures, tools, files, and databases created for managing the project assets. The project team did set up these aspects in order to manage the project. The distribution of responsibilities was clear which made the management easier.

The CMP plan must be written down in the project management plan. Grontmij worked on a plan, but did not put in the CMP. They did set up a up a planning with certain parts included:

- identifies the required resources, this was not done
- defines the to be performed tasks, this was done and stated in the planning
- describes organizational roles and responsibilities, this was done but was not part of the planning (see J, kick off)
- identifies CM tools and processes, this was not done
- identifies methodology, this was stated in the contract and decided based on expertise, for example the program for the 3D model
- identifies standards and procedures, this was part of the contract, not of the planning

N.3.2. Identify

An important part for CM is setting up the configuration of a project, this means a documented determination of the status of a design at a certain moment in time. Because Grontmij themselves also were included in the plan phase, they already had complete knowledge of the configuration.

In order to set up a configuration, CIs must be selected. Each item must be given a unique identifier so it can be tracked. The selection of a CI must be based on the design. Nijmegen Goffert did set up a SBS and this could be comparable to the CIs. Mutual dependencies were shown there but configuration data was not linked to the items. The configuration of each CI must be managed as a separate item, but this was not done. They things necessary for the system were all part of the design and fell under the management of the scope but not as intended by CM.

N.3.3. Tracking changes

It is seen as needed to understand the baseline for all configuration items. This was not known by Grontmij, because they did not set up baselines and CIs. Another important part is making sure there is always access to accurate data of all available CIs. Because items were not set up, this did not happen, however there was always accurate data. Furthermore, the project team was always open and transparent, also when things went wrong. There was no linking of information, shared database with the client or a structure outside of the project directory.

It is recommended to establish a trace-ability matrix but this was never established. Mailing was seen as trace-ability. Furthermore, there was an action list in excel which was during the project transformed into a sort reporting form where screen dumps from the customer were used. These screen dumps were parts of the model where comments where shown. In an e-mail it was shown that these comments were included. For documents they used the track and trace option of word.

N.3.4. Control records and manage

This section is in line with the section of tracking information. The first point is that configuration records need to be tightly controlled. For the project of Nijmegen Goffert there was no atomized, structured version control. There were versions on the documents, so it was traceable, but it was not put into a system. Furthermore, Grontmij started with putting all history of decisions into their design documents. This then showed the process of decision-making however ProRail asked Grontmij to not include this in the documents any more after a few months.

What can help this process is recording the configuration in a configuration management-database as fast as possible. They had a list of all information but there was no database. This project was a pilot study for using 3D models and at first the intention was to also set up an information management database. These databases were not common back then, so they eventually decided not to start with this and only focus on the 3D model.

Setting up integrity in the project

To establish product and system integrity, enough information must be maintained. It must be ensured that product functional, performance, and physical characteristics are properly identified, documented, validated and verified. The identification and documentation is done using the WBS, SBS, SRS (see J, functieboom, WBS, SRS) and the verification and validation was based on the requirement specification (see J). Furthermore, changes to these product characteristics must be properly identified, reviewed, approved, documented, and implemented. This will be discussed in N.1.6.

It can be said they worked by the use of a WBS, but also by the SRS and SBS. The WBS was set up by ProRail and was the guideline for the integrity of the project. It contained the work needed for the design, development, integration and testing of the requirements. The separate work packages are integrated into the final system by the use of the WBSbut also by the SRS. CM also prescribes that the physical design is documented using an allocation matrix and the subsystem or CI list, but this is not done. They only established a document list that was used for the design.

N.3.5. Audit

Auditing involves validating that the actual configuration elements at any given time are the same as what was expected. During the validation it was checked if these were the same as the original document with requirements plus any change requests. Furthermore there were some internal audits, but never form an external party.

N.3.6. Using Configuration Change Management for changes to the system

In order to deal with all changes, it is recommended to establish a CCB, but this was not done. Grontmij delivered the products to ProRail and they checked and approved them.

N.3.7. Baselines

A baseline is a snapshot representing the current state of a system or technical work product. The freezing of the configuration should be the baseline of the system development and CRS. They started with a baseline but this is released after the architect started getting involved (see J, Motivation). There was an intention of doing so, but they were not consistent enough throughout the project. the activities were going so fast that they did not take the time to maintain the baselines. So they needed to give approval first. So, it can be said that baselines are not correctly established, controlled or maintained. Furthermore, Grontmij was facing the consequences for not reaching the deadlines with the model, while the architect was continuing introducing changes. This was a hard position, because the architect was not a contract party, only ProRail is. The spatial structure of the station was an easy decision and the details were the hardest. ProRail did not interfere with the details, and they said that the architect could be followed.

The first baseline was the project requirement specification that was written down into the contract and specifications. After this, a baseline must be updated with each iteration. The baseline was not frozen in Relatics or in another way. Nonetheless, the model can be seen as a baseline. The 3D model was kept up-to-date to changes, but there was no documentation. During the design and implementation process there were moments to freeze data and starting points. This is deliberately done aimed at milestones and the versions of the models served for this. This is not done by the use of lists or iterations. There were several adjustments per iteration but these were not written down. This because changes can be too little or the iterations go too fast.

When changes occur, it can only change the baseline through a documented change management process. This was not done at all the times, due to the large involvement of the architect and the many wishes. When it was done, this was not for the purpose of changing the baseline, but to remain control of the scope. Small changes were not formalized, because the process would then be at the expense of the content. It must be in proportion to each other.

Furthermore, a baseline must be accompanied by performance requirements and acceptance criteria. The criteria for the validation were stated in the verification report of the SRS (see J). Finally, the management of the configuration and changes can be supported by implementing a configuration control cycle. During the project this was a automatic process not necessarily set up for this purpose and not strongly followed. This due to the many iterations with the architect.

N.3.8. The processing of changes

CCM makes a change between CRs and other changes to the system. During this project, there was no distinguishing between these changes and not between class 1 and 2 types, they only set up EOWs. They also did not make a distinguish between the EOW or a Contract Change Proposal. Not all changes were managed by a formal process and this was based on the idea that the process was seen as subject to the content and that these two must be in proportion. Small changes and changes with small impact were almost never submitted. Some small changes were put into an EOW that was reserved for these kind of changes. The work was based on directory and not on fixed sum and this was based on trust. The changes with small financial consequences were put into this.

What must be included in the formal document

A formal document must be set up for changes and must contain sufficient information to evaluate and approve the proposal. It can be said that this was the case even though certain points were not included:

- It must contain a reason for the change and a statement outlining the change;
  The EOW did always had a statement on the reason for the change. The possible planning consequences were always related to this statement. This statement could be a few lines, but could also be more. When a quotation was submitted, the activities were named as substantiation.
- It must contain the details of the trade-offs, the alternative solutions and the preferred one;
  There were almost no trade-offs. Mostly with the EOW the preffered solution is already known. An EOW shows that during the process something came up that was not foreseen, and it is almost never that the client is given a choice unless he comes up with this himselve.
- The preferred detail must show why it can be implemented successfully;
  For large EOWs this can be necessary, together with a risk or quality dossier. However, Nijmegen Goffert had mostly small EOWs that were the result of a chain reaction.
- An impact analysis must be done to indicate how it impacts the system on its turn;
  Tooling would make this much easier. The legality and the cause and consequences would also be easier due to this. Because there was no tooling based on this, this was not always stated.
- An impact analysis must be done to indicate which requirements or changes are added;
  This was not done. This would ask a large amount of dossier knowledge due to the overload of information and the many requirements.
- To see the impact, knowledge on the trace-ability across the different levels of design is necessary. This was not named in the EOW.
- The impact on other CIs and aspects in of the design must be shown;
  This was not named in the EOW.
- It must contain the impact on interfaces requirements as described in the baseline documentation;
  The interfaces were named globally.
- It must contain changes to the baseline documentation; This was not named in the EOW. There was no baseline documentation next to the design report with choices. The history of the made choices were tracked at the start of the project, but as said before, ProRail did not want to receive those anymore.
- It must contain the requirements that in the specification are adjusted, added or expired;
  This was not named in the EOW.
- It must contain the likely changes required to the documentation set;
  This was not named in the EOW.
- It must contain the impact on cost or schedule, if the case;
  This was always stated.

Results of an EOW

Before an EOW is put into effect, it must first be approved. This depends on how large the EOW is, what the impact is and what the client relation is. During this project there was a large amount of trust and therefore it was easier to not wait for approval. They did many times not wait for approval. The formal release of an approval was the assignment in ORACLE. The project manager did not tell all team members formally about an approval. Corrective actions were sometimes done to the EOW when the client want to change an EOW. After the approval of a change, it became part of the scope management.

O. Analysis Information Management

This chapter analyzes whether information management is used in all three projects as intended. The analysis is based on the checklist in F. The completion of the analysis follows from two different things. First, documents lay a basis for this analysis together with the lessons learned from the analysis of scope creep. Second, different interviews were hold based on the checklist. The main interviewee is the project manager and the lead engineer of the different projects.

O.1. Analysis project Geldermalsen

During the project there was nothing demanded by the client related to having a information system. During the project of Geldermalsen the project directory was used as system to store all information and documents.

O.1.1. Change management

One of the important parts to have good control over a project, is implementing change management. During the project of Geldermalsen, changes were managed following the formal procedure of setting up an EOW. However, as already analyzed in 9, not all changes followed the formal procedure. Furthermore, when a change was discovered, it was recorded but not consistently evaluated, because after approval it became part of the scope.

It is important to make reimburse the party responsible for carrying out the change, when the change is an addition to the original scope. During this project, as already shown in K, this didn't always happen. Sweco took the risk of starting to work before the formal approval of an EOW. This resulted in not always getting the full amount, or not getting approval.

O.1.2. Reviewing and approving design documents

This part focuses on improving situations that often happens. However, these points are mostly interesting for the client. One thing is improve the review and approve any delay caused by the consultant engineering in checking, reviewing and approving the design. This is not the task of Sweco, but that of ProRail. However, Sweco can focus on decreasing their delays. The client should also consider minimizing change orders to avoid any delays, just as they need to avoid delay in reviewing and approving design documents. Sweco can not change this situation. They can only exert pressure on ProRail to receive reviews earlier. Another important focus point they can choose, is formalizing pre-design procedures, guidelines, responsibilities and deliverables. This is a collaboration between the client and contractor. Currently this is found in the WBS and the organization structure.

O.1.3. Information management

Information management is important. Key for this is managing the information instead of only the documents. This mindset was not followed by Sweco. They did not necessarily manage information, they and did manage documents.

It is needed to focus on having relevant and up-to-date and accurate information instantly and always available for the project members. Organizing all documents is important for this just as having the information not stored in a rigid data structure but as a collection of relationships. This would result in a coherent network of explicitly described information. However, not all documents were always up-to-date and the version numbers of documents weren't centrally managed and therefore not always clear. The work attitude of the employees is also part of this shortcoming. The basis must be laid out correctly but the team members must also put effort in keeping up with the agreed structure. The basis of having a collection of relationships wasn't used and therefore there was a rigid data structure. It could be concluded that there was lack of a coherent network of information. Also e-mails and other documents were not integrated with other documents. Some of these e-mails were collected and put in a collection folder.

O.1.4. Tool for information mangement

A tool is not used and therefore the concept remains important to consider for this project. An information management tool is based on four different aspects:.

1. All data in hands

All data was in hands of Sweco and they stored project information. However, integrating information in a structured and traceable way did not happen. This is a difficult process due to the large amounts of information. Another aspect that is important here is having the project changes and requirements directly visible. The work packages and requirements are linked just as the responsibilities and work packages. However, a place where this information came together wasn't present.

2. Adapts to information needs

The information needs must be in control of the end user. This was the case for project Geldermalsen, however an improvement could be made in this. For example information could have been changed simultaneously with working on the project. This wasn't the case during the project due to lack of a good system. A system would help project managers have control of the scope from the start and throughout the entire project. The system could also be changed during the course of the project to adhere to changing needs. This also didn't happen due to lack of a system. Data was stored in the project directory that was set up in a certain structure which is used for each project. This resulted in many folders without documents. The directory is structured but not adapted to the information needs of the project.

3. Simple and intuitive

A system must be simple, intuitive, flexible and scale-able. The project directory was used with some spreadsheets that gave structure to documents. This was simple in using, but less for the daily use. It was not necessarily flexible and scale-able.

4. Collaboration focused

The system of project Geldermalsen was stable but not web-based or providing a stable platform. The system was always accessible on the laptop having a Sweco network. The information was not integrated into an external system like Share point. Finally, there were numerous spreadsheets which made the clarity of the overview harder.

O.1.5. Managing information according to System Engineering

To start, three things are important for managing according to SE, namely; manage and structure complex projects, meet the requirements and wishes of the customers, and manage the requirements, tests, risks, tasks and other project objects. Sweco used a structure of work packages that was set up by ProRail and managed by Sweco. The WBS was set up by financial decisions based on technical functions and structured the complexity of the project. The wishes and requirements of the client became clear by having the CRS and using this for the validation of the products. The other parts were all managed and written down when it was part of the scope of the assignment. The list of requirements was written down but wasn't changed when changes appeared to these. The tasks and risks were updated throughout the project.

To support these processes, information must be captured for different parts, for example the requirements, functions, design components and interfaces must be captured. It could also help to look at information from different perspectives. The information was captured at the start of the project, however, they didn't look at the information from different perspectives and did not manage the information at a central place. Additionally it is important to organize information in an explicit, coherent network which was not done.

To have accurate, complete and consistent information, the documents must be checked. This happened regularly at the start of the project. For example there were contradictions in the different CRS documents. This was found and raised to the attention of the client. It is also recommended to have a comprehensive trace-ability, but as already discussed in 9 it can be stated that this was lacking.

Relations can be set up between the different parts of the project throughout the life cycle. However, as said before, the relations were only established between the work packages and requirements, and there were relations between responsibilities and work packages. Therefore this could have been improved. What was established correctly was the providing of each user with custom roles related to the information he is responsible for.

The last point is that high quality deliverables must be generated such as complete requirement specifications, test plans, risk registers, contract documents and interface reports. Because Sweco is certified and has a quality system, it can be said that the deliverables were of high quality. The aspects that were part of the scope were generated. For example the verification of the product was part of Sweco's scope.

O.2. Analysis project energy supply Hoekse Lijn

During the project RET wanted that Relatics was used as information system. They would send their Relatics system, however this was never send. During the project also the project directory was used as system to store all information and documents.

O.2.1. Change management

Changes were managed following the formal procedure of setting up an EOW. However, as already stated in 9, not all changes followed the formal procedure. After it is approved it becomes part of the scope and is managed like that.

It is important to make sure that the party responsible for carrying out the change is reimbursed. Grontmij was at the start of the project not reimbursed for their work and therefore this was straitened by a new project manager. After that the focus lay more the financial consequences.

O.2.2. Reviewing and approving design documents

The points regarding this, are mostly interesting for the client and for Omexom. The client should consider minimizing change orders to avoid any delays, just as they need to avoid delay in reviewing and approving design documents. This did not happen in the project of Hoekse Lijn. There were many changing wishes and many delayed reviews. So, this situation was far from optimal.

O.2.3. Information management

Key for information management is managing the information instead of only the documents. Hoekse Lijn did both have a tool for information management and that they did manage documents. They stopped with updating the tool and therefore document management became more important again.

A focus is needed on having relevant, up-to-date and accurate information instantly and always available. Organizing all documents is important for this just as having the information not stored in a rigid data structure but as a collection of relationships. This would result in a coherent network of explicitly described information. As said this was done at the start of the project but afterwards not maintained due to the bad document control of Omexom and Grontmij. Keeping up-to-date became hard due to the late reviews and reviews on old versions.

O.2.4. Tool for information management

Information management can be implemented by using a tool based on four aspects:

1. All data in hands

Not all data was in hands of Grontmij, because Omexom was in control of the project. They were responsible of storing project information. However, both Grontmij and Omexom did not integrate information in a structured and traceable way. This is a difficult process due to the large amounts of information and the many late reviews. Another aspect that is not established is having the project changes and requirements directly visible.

2. Adapts to information needs

The information needs must be in control of the end user. This was not the case in project Hoekse Lijn because Omexom had control over the information. The tool Relatics that Grontmij had set up was not adapted to the information needs.

3. Simple and intuitive

Relatics, the project directory and Share Point were used. Individually they were simple in use, but combined not especially because they were not kept up-to-date.

4. Collaboration focused

The system was web-based as is recommended, only it was not providing a stable platform. The system was always accessible on the laptop having a Grontmij network. The information was integrated into an external system like Share point. However, there were still numerous spreadsheets with sometimes missing information which made the clarity of the overview harder.

O.2.5. Managing information according to System Engineering

To start, three things are important for managing according to SE namely; manage and structure complex projects, meet the requirements and wishes of the customers, and manage project objects. Grontmij used the structure of work packages and this was set up by RET and Omexom. The WBS was split up into different system parts and responsibilities were related to this. The wishes and requirements of the client became clear by having the project requirements and having the many reviews. The project requirements and changes were used for the validation of the products. The other parts were all managed and written down when it was part of the scope of the assignment. The list of requirements was written down but wasn't changed when changes appeared to these. The tasks and risks were updated throughout the project.

Process information must be captured for different parts. The information was captured at the start of the project but wasn't looked at from different perspectives. Additionally, the information was captured and first brought into Relatics, but because it was not maintained throughout the project there was not a coherent network.

To have accurate, complete and consistent information, the documents must be checked. This happened at the start of the project but was the responsibility of Omexom. It turned out that there were many inconsistencies. Furthermore, they were forced to start checking inconsistencies due to the fact that Omexom was very late with ordering components and it turned out that these did not match the requirements.

The last point is that high quality deliverables must be generated such as complete requirement specifications, test plans, risk registers, contract documents and interface reports. Because Sweco is certified and has a quality system, it can be said that quality was maintained. However, it did turn out to be not satisfying enough, because the engineering is still continuing.

O.3. Analysis project Nijmegen Goffert

During the project there was nothing demanded by the client related to having a information system. It was discussed, but as the project was a pilot for 3D modelling, they decided to not to also try setting up an information system. The project directory was used as system to store all information and documents.

O.3.1. Change management

Changes were managed following the formal procedure of setting up an EOW. As already analyzed in 9, not all changes followed the formal procedure.

It is important to make sure that the party responsible for carrying out the change is reimbursed. This happened most of the time except for the things you can't anticipate. These were mostly small things that were not predicted, and these were not always put into an EOW.

O.3.2. Reviewing and approving design documents

This part focuses on improving situations that often happens. However, these points are mostly interesting for the client. The client did not try to introduce less changes. ProRail on the contrary made Grontmij work closely together with the architect who had a continuous input of changes. Furthermore there were still delays in reviews and EOW. These did not have serious consequences. The delays became longer when the project reached it end.

O.3.3. Information management

Information management is important, however, the mindset of having control of the information instead of the documents was not followed by Grontmij. It is also needed to focus on having relevant and up-to-date and accurate information instantly and always available for the project members. Organizing all documents is important for this just as having the information not stored in a rigid data structure but as a collection of relationships in a coherent network. All documents were always up-to-date due to the open and transparent way of working. But, the version numbers of documents weren't centrally managed and therefore not always clear.

O.3.4. Tool for information management

An information management tool is not used but important to consider. A tool is based on four different aspects:

1. All data in hands

All data was in hands of Grontmij and they store all kind of project information. However, integrating information in a structured and traceable way did not happen. This is a difficult process due to the large amounts of information and because not all information is automated yet. Another aspect that is important here is having the project changes and requirements directly visible. The work packages and requirements are linked just as the responsibilities and work packages, but this information was not stored together.

A problem is that projects still think in the project directory structure. Another approach would be needed to get all data in hands. For example meta data must be linked to information packages and relations between this must be established. Then it does not matter in which folder the information stands, it only matters that the information is accessible.

2. Adapts to information needs

The information needs must be in control of the end user. This was the case for this project but could still be improved. For example that information can be changed or enriched simultaneously with working on the project. Data was stored in the project directory and in an 3D model. The project directory was set up in a certain structure resulting in many folders without documents. The directory is structured but not adapted to the information needs of the project.

3. Simple and intuitive

A system must be simple, intuitive, flexible and scale-able. The project directory and some spreadsheets gave structure to the documents. This was simple in using but not necessarily flexible and scale-able. The 3D model was harder to use when not having the expertise.

4 .Collaboration focused

The system was not web-based, just as that it did not provide a stable platform. The system was now always accessible and not integrated into an external system. Finally, there were numerous spreadsheets which made the clarity of the overview harder.

O.3.5. Managing information according to System Engineering

To start, three things are important for managing according to SE namely; manage and structure complex projects, meet the requirements and wishes of the customers, and manage the requirements, tests, risks, tasks and other project objects. The project was managed, the end result was good and a WBS, SRS and SRS were leading which made managing the objects possible.

To support these process information must be captured for different parts. It could also help to look at information from different perspectives. There was information available on the requirements, stakeholders, functions, design components, work packages, interfaces, and risks. So this was done thoroughly. The client kept contact with stakeholders but Grontmij also worked with them.

To have accurate, complete and consistent information, the documents must be checked. This did not really happen because all documents were set up by Grontmij themselves in the plan phase. Another important thing is setting up relations between the different parts of the project throughout the life cycle. This is done because Grontmij was working on all phases of the project eventually. They also had good ownership of their tasks.

The last point is that high quality deliverables must be generated such as complete requirement specifications, test plans, risk registers, contract documents and interface reports. Because Sweco was also involved in the execution phase, they could be closely involved by controlling the completeness of their products. Furthermore, the project was a pilot for 3D modeling and SE and for both subjects this project is presented as leading.

P. Analysis Partnering

This chapter analyzes whether partnering is used in all three projects as intended. The analysis is based on the checklist in G. The completion of the analysis follows from two different things. First, documents lay a basis for this analysis together with the lessons learned from the analysis of scope creep. Second, different interviews were hold based on the checklist. The main interviewee is the project manager and the lead engineer of the different projects.

P.1. Analysis project Geldermalsen

First it is important that both parties must recognize that the behaviours that may facilitate trust in the different parties are not necessarily the same factors. This was was seen by the different parties. Second, economic conditions could be established based on calculus-based trust, which encourage clients and contractors to work together towards a common purpose. However, there was no incentive for this, just the fixed price of the contract.

Mindset for partnering

The establishment of a conflict resolution strategy is important and this was done by setting up an escalation model. This was never used even though discussions took very long. There was a clear establishment of responsibility and it was always tried to ensure the highest standard of project and relationship management.

There was not a clear commitment to a win-win attitude, but there was also not necessarily a win-lose attitude. They all wanted to finish the project, however the discussions on the EOWs, the FIS, and the CRS were disturbing this process. The team members were seen as equal and solutions were found by brainstorming. However, during arguments there was a defensive manner which was difficult. They wanted to generate innovative ideas but this was hard due to time pressure.

There was a willingness to eliminate non-value added activities and to reduce duplication. They tried to optimize their process also due to time pressure. There was also a willingness to share resources among project participants.

There was not necessarily regular monitoring of the partnering process or evaluation of the team performance. Still there was mutual respect for the partners and their goals. Even though this was established, it cannot be said that there was mutual trust.

Needed for partnering

Adequate resources are needed for good partnering. This include knowledge, technology, information, specific skills, and capital and these were established and shared. The support from the top management was present because they also wanted this project to become a success. There was no long term commitment next to this project. There was search for improvements because the FIS product is in the basis an optimization. Also the workshops with the architect and Bureau Spoorbouwmeester were reason for optimization.

The communication was not always effective. Informal communication took place just as formal communication. They worked together with the architect and Bureau Spoorbouwmeester. There was room to ask question about certain assumptions which was seen as necessary for good collaboration. During the monthly session many things were discussed and risks were shown. The contact intensified at the end of the project when a higher frequency was needed.

Practical sessions

There was no pre-project team building session or workshops. There was a start up and a kick-off. They agreed on mutual objectives and goal formulation which was finishing the project successfully. Quality management was set up based on validations. There was no shared database.

Trust

System based trust was established. The process of having EOWs is an example. Also organizational policies must specifies priorities and explains business procedures. This was part the work packages (see H, Annex 1). Part of this was the establishment of a communication plan. This was all established and tried to be followed. There were internal meetings but also meetings with the client. The contract showed expectations but these were different interpreted by Sweco than meant by ProRail. This was a difficult situation and led to many discussions.

For example the discussion of EOW 44, submitted on 14-10-2016, violated the trust (see H, VGR Dec). ProRail has requested that this EOW be canceled, and Sweco regrets that they must have drawn up this EOW at all, while ProRail never intended to award it. Another example is that of EOW 18 where the assignment letter is missing for a few months (see H, VGR). The work has been carried out in a fully demonstrable manner and Sweco wants to receive the performance statement.

Cognition based trust was also established. There were many moments were knowledge was exchanged and they knew from each party what their expertise was. Affect based trust was also partly established. The emotional bond was found between for example the RSE and the lead engineer of Sweco. However, there were not many relationships based on this trust.

P.2. Analysis project energy supply Hoekse Lijn

First it is important that both parties must recognize that the behaviours that may facilitate trust in the different parties are not necessarily the same factors. This was was done. Only the project manager of Omexom thought that Grontmij was responsible for a certain part of the design, where Omexom was responsible for. He was not been present during the tender phase and therefore there was wrong communication on this point.

Economic conditions could be established based on calculus-based trust, which encourage clients and contractors to work together towards a common purpose. However, there was no incentive for this, just the fixed price of the contract.

Mindset for partnering

The establishment of a conflict resolution strategy was done by setting up an escalation model. This was used once during the in default. Next to this there were clear responsibility and but not every party tried to ensure the highest standard of project management.

There was no commitment to a win-win attitude. Omexom asked questions at the lead engineer instead of the project manager and in this way the contractual consequences were sometimes overseen. Off the record there was additional work done. They said many times that Omexom should not have done this. Furthermore there was no sign of equity. In the collaboration with Omexom there was, but in the relation to the client RET there wasn't. They did have during arguments a non-defensive manner and a focus on solving this together. Furthermore there were brainstorm sessions for finding solution. However, they tried to get Grontmij doing additional work. Grontmij let this escalate once and after that the relations were better and based on collaboration. Omexom made changes at the side of their project management due to this.

There was no strong focus on bringing the design to a higher level and generate innovative ideas, because the focus of many EOWs was on solving mistakes or inconsistencies. Some things were both innovative and financially stirred. Grontmij did also took additional work to help Omexom and this can be seen as a focus on helping to get the project to a better final result.

Grontmij tried to focus on eliminating non-value added activities and reducing duplication. Grontmij did this to their own process but only sporadic because of the problems they already had to encounter and the time pressure. They always shared resources and knowledge. At the start there were days of collaboration with Omexom, where Omexom came to the office and team sessions with the entire team took place. However, after the large amount of EOWs in July, this was stopped.

There was a regular monitoring of the partnering process. In October 2015 the project was started. January 2016 the first monitor took place, in June the second, in October the third and in March 2017 the fourth. In January the project manager at Grontmij changed. In June Omexom had a second design manager. October was defined by a meeting of the managing board to align goals and this also happened in March. In March Omexom placed again two extra managers on the project. This all happened because the project was not going well.

There was no mutual trust during the project. However, there was an understanding of the other party. Omexom was low in capacity and that was partly due to the strict budget they had. This was hard to work with for the project manager and Grontmij understood this. Omexom was not allowed to not make profit and Grontmij accepted that but also had their own financial situation. So there was respect and understanding but the business attitude of both parties disturbed the relation.

Needed for partnering

Adequate resources like knowledge, technology, information, specific skills, and capital are needed for good partnering and were present. The support of the top management was in place but is always a hard position when a project faces many problems. There was a intention for long term commitment. After this project Omexom and Grontmij would work together again. A collaboration took already place at an earlier work.

The communication inside Grontmij was effective. However between Omexom and RET it was not. Grontmij was not in direct contact with RET and this made the communication difficult. Still they could ask questions about assumptions made. There was no increase in contact points, after June the number of contact points even decreased.

Practical sessions

There was no pre-project team building session or workshops. There was a kick-off were agreements were made, however, there were no team building sessions. They agreed on mutual objectives and on finishing the assignment. The management of quality and the goal was largely the responsibility of Omexom. There was a shared database which was together with Omexom and RET.

Trust

System based trust was established. The process of having EOWs is an example. Another thing that must be done is that the organizational policy specifies priorities and explains business procedures. This was part of the work packages (see I, Annex 1). Also agreements were made based about communication and a plan was made for this. However, the project manager of Omexom had expectations based on his experience, but did not know the contract. This made the process harder even though the contract clearly stated the expectations.

Cognition based trust was established. There were many moments were knowledge was exchanged and they knew each others competence. Also affect based trust was established. The emotional bond was found with multiple team members. However, the relationship was hindered by the problems of the project.

P.3. Analysis project Nijmegen Goffert

First it is important that both parties must recognize that the behaviours that may facilitate trust in the different parties are not necessarily the same factors. This was seen as logically. During this project the management of expectations was important for this. Additionally, economic conditions could be established based on calculus-based trust, however, there was no incentive for this, just the fixed price of the contract.

Mindset for partnering

A conflict resolution strategy was established by setting up an escalation model based on putting the discussion on a higher level. Instead of the content, the process is then discussed and how to solve the issue. This model was ever used. Next to this there were clear definitions of responsibility and they tried to ensure the highest standard of project and relationship management.

There was a clear commitment to a win-win attitude. All parties shared the same goal and the project needed to become a success by the effort of all parties. This was clearly communicated. They worked together in a 3D model and wanted to show the possibilities of this. The different team members were all equal, solutions were found by brainstorming and during arguments there was a non-defensive manner and a focus on solving together. There was a strong focus on bringing the design to a higher level and generate innovative ideas. There was not necessarily communication on sharing of risks or rewards.

There was an always present willingness to eliminate non-value added activities and to reduce duplication. Grontmij made themselves sometimes even problem owner when they were not responsible. This was a risk they took. An example of reducing duplication were the monthly reports. These would formally take place each month, but after a time it turned out that the weekly informal updates were enough. The reports decreased in size and referred to the mailing conversation. This reduced duplication and resulted in a pleasant experience.

The partnering process and team evaluation was evaluated twice and each quarterly there was an assessment. Furthermore, because Grontmij worked on different phases of the project, each phase they were evaluated. They did not keep track of the value-add to each partner. There was still a bit of friction on the competition and therefore they focused mostly on their own value. They did have ownership of their own value and communicated this. Even though there was some competition, they started the project with willingness to share all resources. They did not have a history with architect StudioSK or Movares, so they decided to share everything.

The project was characterized by great mutual trust. Even though products were not always delivered on time, they communicated clearly on this and this established trust. The early implementation of the partnering process in an earlier phase made the trust even bigger. They knew their partner and respected them.

Needed for partnering

Adequate resources like knowledge, technology, information, specific skills, and capital are needed. The 3D model was chosen based on the skills and knowledge of the team of Grontmij. The resources were therefore adequate. The support from the top management was present because they also wanted this pilot project to become a success. Eventually the long term commitment worked good for this project. After this project the same project team also worked on project for a tunnel of slow moving traffic in Zevenaar.

The communication was always effective. Informal communication took place on multiple levels. For example the architect and the engineer responsible for the construction worked closely together. There was always room to ask question about assumptions which was necessary for the collaboration and finding a good result together. During the monthly session with the clients irritations and other things were discussed where-after they made a plan of action. There was an increase in contact points to the end of the project. The process became more intense, the detail-level became larger and the frequency of contact increased. However, it was stated that it would have been better if this intense contact also took place at the start of the project. That is when the SRS is established and the requirements. Then they could have focused on setting up the project correctly.

There was a continuous search for improvements together with the architect. Improvement must always be point of focus, but now it took a long time because the iterations did not stop which was not desirable. ProRail had the authority for this.

Practical sessions

There was no pre-project team building session or workshops. There was a kick-off, but no team building sessions. They agreed on mutual objectives and goal formulation. The assignment was finishing this project successfully. Both the architect and ProRail and Grontmij wanted to get a design that was leading and make profit if possible. The quality management that must be set up was also done as part from the scope and all products were reviewed internally before sending to ProRail. Finally there was no information technology or shared databases.

Trust

System based trust was established. The process of EOWs and quarterly assesments are examples of this. Another thing that must be done is that the organizational policy specifies priorities and explains business procedures. This was part of the work packages (see J, Annex 1). A clearly defined system of communication procedures and approaches must be established which was agreed on during the tender phase. The kick-off was a moment were this was discussed and adjusted. When less information was needed the frequency of communicating decreased. Finally the contract showed the expectations, however, if this would have been perfect there would have been no changes. Contracts are never perfect.

There was a movable scope but it was applied as a fixed scope. The project tried to outline the situation as good as possible, but they did not know what they would encounter because some things cannot be foreseen. This must be accepted. A project remains a work with humans and not everything can be solved through tooling and structure.

Cognition based trust was also established. There were many moments were knowledge was exchanged, sometimes even in much detail. For example the architect wanted a hood with a overhang of 20 meters which was not possible and started a long discussion and based on many sharing of information and possibilities. Furthermore they knew which partner was competent in what aspect and they used this kind of information.

Affect based trust was also established. The emotional bond was found between multiple team members. For example the RSE of ProRail was someone with whom there was strong affect based trust. They all put effort into coming forth from the need to make this project a success.

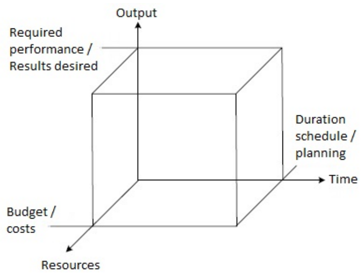
Q. Analysis Factors

The analysis in chapter 9, 10, and 11 is based on how the situation would have changed if the theory would have been followed correctly. Four criteria costs, quality, integrity and planning are used to give structure to the analysis. For each criteria it is reasoned which cause or effect is influenced.

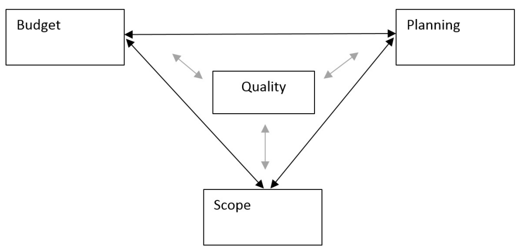
This appendix will first explain why the four different criteria are chosen in section Q.1. Then the criteria are discussed further in section Q.2 so they can be used for the analysis in chapter 9, 10, and 11. The causes and effects of each criteria are related to scope creep. Finally in section Q.3 the factors are compared with each other on the basis of the four criteria. This eventually leads to factors with high potential to control scope creep. To gain the latter, it is important what is considered as the most important criteria for both client and engineering company.

Q.1. Criteria

Scope is related to different aspects of a project. The three main factors considering the success of a project are the costs, the planning and the quality. These are stated in the triple constraint, see Q.1a. The project value is converted into the required performance and this is supplemented with a budget and a time schedule (de Ridder, 2009). Therefore it can be said that changes in scope directly influence the quality, and has impact on the budget and planning. All aspects influence each other, but quality is the most important aspect for success. In figure Q.1b it is therefore placed in the middle.



(a) Triple Constraint (de Ridder, 2009)



(b) Aspects in relation to quality (Own image)

Figure Q.1.: Success factors in projects

Additionally, the integrity of a design is strongly positively related to the quality of a product. Integrity is based on the process of a design, where quality is the end result of the process. The integrity of the design is a factor related to scope creep because it can be a cause for scope creep when not correctly managed. Therefore this is also taken as criteria for the research. Four criteria are thus used for the analysis of the approaches in chapter 9, 10 and 11:

- Costs
- Planning
- Quality
- Integrity

Q.2. Criteria for the analysis

Literature thus states that scope is related to three aspects of a project, namely the costs, planning and quality of a project. Furthermore, the integrity of a design is strongly positively related to the quality of a product and on its turn negatively related to scope creep. If the integrity is bad in a project, there will be higher chance on having scope creep.

The different criteria can be assessed by looking at the relation between the factors and causes and effects related to the four different criteria. The causes and effects are based on literature, partly stated in chapter 5, and the findings in chapter 6. The different causes of scope creep that are found in both chapters are now again classified but then related to the criteria.

A factor can be related to a cause in a way that it will support the existence of a cause, or that it can decrease the chance on having a cause. A factor can be related to effects in different ways. First, scope creep can have its effect on the criteria. Second, the different causes can have effects that can lead to scope creep on its turn. Both are taken into consideration.

The analysis in chapter 9, 10, and 11 are based on how the situation would have changed if the theory would have been followed correctly. The four criteria costs, quality, integrity and planning are used to give structure to the analysis. For each criteria it is reasoned which cause or effect would result or be taken away by a factor.

Q.2.1. Costs

The factors can have certain costs as result and are therefore a reason to implement or not. Furthermore, costs can be accompanied by choosing to take or not take certain actions, which can eventually result in scope creep. The different causes related to costs are (Mirza et al., 2013), (Hwang & Low, 2012), (6):

1. Investment and the maintaining costs
2. The final project costs tend to be higher when boundaries are not appointed due to changes that interrupt the project process
3. Increase in overhead expenses, which can result in not formalizing changes or starting without approval
4. Having uncertainty at the start of the project resulting in strategic behaviour
5. Having a moving scope while the project is tendered as a fixed scope
6. Not having agreed on what is seen as rational for the project
7. Seeing the project as a game with a focus on costs instead of scope and quality

Effects are financial costs, loss of earnings and changes in cash flow (Sun et al., 2006).

Integrity

Scope changes directly affect the integrity of the design and puts pressure on maintaining a good integral design. This has multiple causes and all these can individually result in new causes, therefore many causes are related to each other. The design-generated causes include (Sun et al., 2006), (Khan, 2006), (Kuprenas & Nasr, 2003), (Hwang & Low, 2012), (see 6):

1. The lack of good pre-design is the most common cause for scope creep and pressure on integrity
2. An incomplete or partial scope
3. Design errors

4. Design changes
5. Omissions
6. Operational improvements
7. Communication flaws
8. Bad trace-ability
9. Having to change the design into the use of new starting points
10. Recruiting of new professionals
11. Decrease in labour productivity
12. Faults due to bad team composition
13. Changes that must be implemented across many disciplines which are linked and the responsibility lies with different people
14. Parties that are involved with strong opinions
15. Other parties with flaws in their project management
16. Changes till the last moment
17. Uncertainties that make construction dynamic and unstable and force the use of assumptions
18. Incorrect assumptions
19. Revising of decisions
20. Products set up in the wrong order
21. Bad scope control process
22. Not anticipating changes correctly
23. Working in too much detail
24. Wanting to work too good
25. Time pressure
26. Not having consistency in the products that are delivered by the client
27. Receiving reviews without integrity

These causes can have multiple effects that are all related to the integrity. Furthermore, an incomplete or partial scope and scope changes have effects related to integrity of the design. These effects are (Mirza et al., 2013) (6) (Hwang & Low, 2012)(Sun et al., 2006):

- Rework and re-engineering
- Addition of work or requirements throughout the project
- Revisions to project reports and documents
- Reorganization of schedule and work methods
- Risks for the interfaces
- Loss of rhythm
- Loss of productivity as a result of reprogramming
- Disputes and blame among project partners
- Lower morale of the work force
- New recruited professionals that are not familiar with the integrity of the design
- An increased risk of coordination failures and errors

Q.2.2. Quality

The factors can influence both the product and the process quality. Scope creep or scope changes can lead to a design that is not fit for purpose which is the product quality. As said before in Q.1, quality and integrity are related to each other. Negative impact on the integrity eventually can have a negative impact on the end quality. The different causes related to quality are (Kuprenas & Nasr, 2003), (6), (Mirza et al., 2013):

1. An unclear definition of scope. Scope definition is linked to project failure and therefore correlate negatively to project performance
2. An incomplete or partial scope
3. Missing consistency in the documents
4. Changes to the scope till the last moment
5. Not formalizing changes
6. Not anticipating changes
7. Rework and re-engineering
8. A decrease in optimization due to rework
9. Addition of work or requirements throughout the project
10. Not having the best team in place
11. Uncertainties conditions that force making decisions based on assumptions
12. Incorrect assumptions
13. Decisions that need to be revised
14. Not including stakeholders in the scope definition
15. Decrease in labour productivity
16. Not being able to grasp the complexity

Q.2.3. Planning

Scope changes can result in planning consequences. There are different causes for delays and these can eventually result in scope creep when acting on these causes, they include (see chapter 5 and 6):

1. Financial problems
2. Delay in the decision making
3. Delay or long waiting times in approvals of EOWs
4. High costs involved with setting up an EOW
5. Long waiting times on reviews
6. Difficulties in obtaining work permit
7. Coordination and communication problems
8. Discussions on EOWs that take long and are arduous
9. Optimism bias and strategic misrepresentation are reasons for inaccuracies of estimations and forecasts
10. Scope control process in too much detail
11. Changes till the last moment
12. Limited capacity in the project team
13. Time pressure, that can have as result not formalizing scope changes

Effects can be (Sun et al., 2006):

- Much time spent on the management of scope
- Planning not good substantiated
- Decisions of the planning of low quality
- Decisions that are not mutually understood
- Rework and re-engineering
- Time loss
- Addition of work or requirements throughout the project
- Loss of productivity
- Reorganization of schedule and work methods
- Loss of rhythm
- Loss of float and thus an increased sensitive to further delays

Q.3. Comparing factors

The fifteen factors of the three optimal scope control approaches are compared with each other. This is done to answer sub-research question 5: *What would be the result if the optimal approaches would have been followed correctly as stated by theory?*. The results in this section is on the analysis on how the situation would have changed if the theory behind the factor would have been followed correctly, shown in chapter 9, 10, and 11. The four criteria costs, quality, integrity and planning are used to give structure to the analysis and will all be discussed. Each criteria is analyzed on cause or effect that would result or be taken away by a factor. Finally the four criteria together give input for the analysis on the factors with high potential to control scope creep.

Q.3.1. Methods

To compare the different factors by the use of the four criteria costs, integrity, quality and planning, a paired comparison is used. In science, factors with different ratio scales are combined by the use of formulas based on variables and their relations with a scale with a zero and an origin. However, intangible properties, like the factors in this study, have no scale of measurement. The value for each factor depends on what other factors it is compared with. Relative scales of measurement can be made by using pairwise comparisons using numerical judgment from an absolute scale (Saaty, 2008).

	A	B	C	D	E	Total
A		1	0	0	1	2
B	0		0	1	1	2
C	1	1		0	1	1
D	1	0	1		0	2
E	0	0	0	1		3

Figure Q.2.: Paired comparison example

So, when we deal with the factors in the case study, which have no scale of measurement, they can be compared in pairs so the preferred factor can be indicated. (Saaty, 2008). The method of paired comparisons thus provides a basis for comparing the factors in the form of pairs to obtain ranks (Hussain & Muhammad, 2013). The numbers that are used are defined in a 1 or 0, where a 1 is for the preferred factor. Finally the scores can be added up and this results in the most optimal factor. In figure Q.2 an example is given, that shows that factor E is the most optimal one. The ranking derived from this analysis is specific to this situation and represents the dominance of one element relative to the others (Saaty, 2008).

The paired comparison is followed for all four criteria. The results of this are combined in a multi-criteria analysis. The multi-criteria analysis is a scientific evaluation method to make a rational choice between various alternatives based on more than one distinguishing criterion. Criteria can be added up to rank the alternatives. The goals of this analysis is organizing data, making decision processes transparent and supporting decisions (Janssen, van Herwijnen & Beinat, 2003). The multi-criteria will be based on the four criteria and the alternatives will be the different factors. Finally the best factor can follow from this. This is based on ranking the four criteria in importance for both the client and the engineering company and by taking these two together.

Q.3.2. The paired comparison for costs

Table Q.1 shows the results of the analysis of the different factors. The investment costs and maintaining costs are shown together with the number of causes each factor influences.

Maintaining costs are making the most harm, therefore high maintaining costs makes a factor very unattractive. However, when the factors scores high on decreasing the chance of causes, it can still be preferred. Furthermore, investment costs are seen as less important to consider than causes. What must also be considered is that the investment costs will only be chosen by middle to large project. The €8.400 will be on a project of €50.000 be 17% of the total costs. In large projects therefore the investment costs are becoming feasible. It is recommended to keep investment costs of factors between 2 - 10 % of the total costs.

Table Q.1.: Paired Comparison for Costs

Factor	**Investment costs**	**Maintaining costs** (week)	**Causes**
Set up the configuration and the CMP	€8.400-€4.200	€400	1
Identifying Configuration Items	€1.680-€4.200	€400	0
Accurate data and clarity on version and status of documents	€400	€0	1
Configuration Control Board	€1.600	€300	1
The establishment of baselines	€15.000-€4.200	€400	1
The processing of changes	€2.100	€840	2
Distinction between types of changes	€200	€400	0
EOW approval	€0	€0	2
Information management	€4.200	€400	3
Check documents on accuracy, consistency and completeness	0	€210	1
Partnering	€0	€100	4

When combining two factors, the preferred factor receives a 1 and the other a 0. Eventually this adds up to the most preferred factor for this criteria. This is shown in figure Q.3.

Costs	Configuration and the CMP	Identifying CIs	Accurate data and clarity/status on versions	Configuration Control Board	Baselines	The processing of changes	Distinction between change types	EOW approval	Information management system	Check on accuracy, consistency and completeness	Partnering	**TOTAAL**
Configuration and the CMP		1	0	0	1	1	0	0	0	0	0	3
Identifying CIs	0		0	0	0	0	0	0	0	0	0	0
Accurate data and clarity/status on versions	1	1		1	1	1	1	0	1	0	1	8
Configuration Control Board	1	1	0		1	1	1	0	1	0	0	6
Baselines	0	1	0	0		1	0	0	0	0	0	2
The processing of changes	0	1	0	0	0		0	0	0	0	0	1
Distinction between change types	1	1	0	0	1	1		0	0	0	0	4
EOW approval	1	1	1	1	1	1	1		1	1	1	10
Information management system	1	1	0	0	1	1	1	0		0	0	5
Check on accuracy, consistency and completeness	1	1	1	1	1	1	1	0	1		0	8
Partnering	1	1	1	1	1	1	1	0	1	1		9

Figure Q.3.: Paired Comparison for costs

Q.3.3. The paired comparison for integrity

Table Q.2 shows the results of the analysis of the different factors. The number of causes together with the number of effects each factor influences are shown.

Table Q.2.: Paired Comparison for integrity

Factor	Causes	Effects
Set up the configuration and the CMP	6	3
Identifying Configuration Items	7	3
Accurate data and clarity on version and status of documents	4	3
Configuration Control Board	7	4
The establishment of baselines	6	5
The processing of changes	5	2
Distinction between types of changes	1	-1
EOW approval	0	-4
Information management	8	6
Check documents on accuracy, consistency and completeness	2	3
Partnering	5	2

When combining two factors, the preferred factor receives a 1 and the other a 0. Eventually this adds up to the most preferred factor for this criteria. This is shown in figure Q.4. Decreasing the chance on having causes is seen as more important than decreasing the effects, because there will be no effect when a cause is taken away. Therefore the factors that affect the most causes is preferred.

Integrity	Configuration and the CMP	Identifying CIs	Accurate data and clarity/status on versions	Configuration Control Board	Baselines	The processing of changes	Distinction between change types	EOW approval	Information management system	Check on accuracy, consistency and completeness	Partnering	**TOTAAL**
Configuration and the CMP		0	1	0	0	1	1	1	0	1	1	6
Identifying CIs	1		1	0	1	1	1	1	0	1	1	8
Accurate data and clarity/status on versions	0	0		0	0	0	1	1	0	1	0	3
Configuration Control Board	1	1	1		1	1	1	1	0	1	1	9
Baselines	1	0	1	0		1	1	1	0	1	1	7
The processing of changes	0	0	1	0	0		1	1	0	1	1	5
Distinction between change types	0	0	0	0	0	0		1	0	0	0	1
EOW approval	0	0	0	0	0	0	0		0	0	0	0
Information management system	1	1	1	1	1	1	1	1		1	1	10
Check on accuracy, consistency and completeness	0	0	0	0	0	0	1	1	0		0	2
Partnering	0	0	1	0	0	0	1	1	0	1		4

Figure Q.4.: Paired Comparison for integrity

Q.3.4. The paired comparison for quality

Table Q.3 shows the results of the analysis of the different factors. Quality only decreased causes of scope creep related to the design being fit for purpose. Therefore only the number of causes that each factor influences are shown.

Table Q.3.: Paired Comparison for Quality

Factor	**Causes**
Set up the configuration and the CMP	6
Identifying Configuration Items	2
Accurate data and clarity on version and status of documents	2
Configuration Control Board	6
The establishment of baselines	7
The processing of changes	4
Distinction between types of changes	2
EOW approval	0
Information management	5
Check documents on accuracy, consistency and completeness	2
Partnering	3

When combining two factors, the preferred factor receives a 1 and the other a 0. Eventually this adds up to the most preferred factor for this criteria. This is shown in figure Q.5. When two effects have the same amount of causes, then the effect on the integrity was taking into account.

Quality	Configuration and the CMP	Identifying CIs	Accurate data and clarity/status on versions	Configuration Control Board	Baselines	The processing of changes	Distinction between change types	EOW approval	Information management system	Check on accuracy, consistency and completeness	Partnering	**TOTAAL**
Configuration and the CMP		1	1	0	0	1	1	1	1	1	1	8
Identifying CIs	0		1	0	0	0	1	1	0	1	0	4
Accurate data and clarity/status on versions	0	0		0	0	0	1	1	0	1	0	3
Configuration Control Board	1	1	1		0	1	1	1	1	1	1	9
Baselines	1	1	1	1		1	1	1	1	1	1	10
The processing of changes	0	1	1	0	0		1	1	0	1	1	6
Distinction between change types	0	0	0	0	0	0		1	0	0	0	1
EOW approval	0	0	0	0	0	0	0		0	0	0	0
Information management system	0	1	1	0	0	1	1	1		1	1	7
Check on accuracy, consistency and completeness	0	0	0	0	0	0	1	1	0		1	3
Mindset for partnering	0	1	1	0	0	0	1	1	0	1		5

Figure Q.5.: Paired Comparison for quality

Q.3.5. The paired comparison for planning

Table Q.4 shows the results of the analysis of the different factors. The number of causes together with the number of effects each factor influences are shown.

Table Q.4.: Paired Comparison for Planning

Factor	Causes	Effects
Set up the configuration and the CMP	2	4
Identifying Configuration Items	0	1
Accurate data and clarity on version and status of documents	0	4
Configuration Control Board	2	3
The establishment of baselines	4	2
The processing of changes	0	5
Distinction between types of changes	2	1
EOW approval	-5	-4
Information management	3	4
Check documents on accuracy, consistency and completeness	0	2
Partnering	3	3

When combining two factors, the preferred factor receives a 1 and the other a 0. Eventually this adds up to the most preferred factor for this criteria. This is shown in figure Q.6. Decreasing the chance on having causes is seen as more important than decreasing the effects, because there will be no effect when a cause is taken away. Therefore the factors that affect the more causes are seen as more preferred.

Planning	Configuration and the CMP	Identifying CIs	Accurate data and clarity/status on versions	Configuration Control Board	Baselines	The processing of changes	Distinction between change types	EOW approval	Information management system	Check on accuracy, consistency and completeness	Partnering	**TOTAAL**
Configuration and the CMP		1	1	1	0	1	1	1	0	1	0	7
Identifying CIs	0		0	0	0	0	0	1	0	0	0	1
Accurate data and clarity/status on versions	0	1		0	0	0	0	1	0	1	0	3
Configuration Control Board	0	1	1		0	1	1	1	0	1	0	6
Baselines	1	1	1	1		1	1	1	1	1	1	10
The processing of changes	0	1	1	0	0		0	1	0	1	0	4
Distinction between change types	0	1	1	0	0	1		1	0	1	0	5
EOW approval	0	0	0	0	0	0	0		0	0	0	0
Information management system	1	1	1	1	0	1	1	1		1	1	9
Check on accuracy, consistency and completeness	0	1	0	0	0	0	0	1	0		0	2
Partnering	1	1	1	1	0	1	1	1	0	1		8

Figure Q.6.: Paired Comparison for planning

Conclusion

The highly potential factors follow from comparing the different factors to each other. Fifteen factors are compared with each other and this is shown in appendix Q. For each criteria the most promising factors can be derived:

- Costs: EOW approval, Partnering and Check on accuracy, consistency and completeness
- Integrity: Information management system, Configuration Control Board and Identifying Configuration Items
- Quality: Baselines, Configuration Control Board and Establishing the configuration and the Configuration Management Plan
- Planning: Baselines, Information management system, Partnering

Q.3.6. Factors with high potential

The four criteria can be prioritized for the client and the engineering company. Both parties are important to consider for finding the most optimal and realistic factor for the control of scope and anticipating scope creep. Prioritizing criteria results in highly potential factors for both parties. Combining the potential factors for both parties on its turn result in the most realistic and optimal factors to implement in a project.

The prioritizing of criteria for the engineering company is based on a discussion with project managers of Sweco. It is argued that the costs is the most important criteria. This is followed by the integrity because that can influence the process negatively and can cause failure costs and errors. The planning in almost every project is ignored after a while, or revised many times. Therefore the planning is the least important factor. This results in having the CCB as most important factor, followed by an information management system, and finally partnering, see figure Q.7.

		Configuration and the CMP	Identifying CIs	Accurate data and clarity/status on versions	Configuration Control Board	Baselines	The processing of changes	Distinction between change types	EOW approval	Information management system	Check on accuracy, consistency and completeness	Partnering	
Costs	4	12	0	32	24	8	4	16	40	20	32	36	
Integrity	3	18	24	9	27	21	15	3	0	30	6	12	
Quality	2	16	8	6	18	20	12	2	0	14	6	10	
Planning	1	7	1	3	12	10	4	5	0	9	2	8	
		53	33	50	81	59	35	26	40	73	46	66	

Figure Q.7.: The best factors for the engineering company

For the client it is argued that the end quality of the product is the most important criteria. The integrity on the other side does not matter, when the design is fit for purpose, therefore the integrity is seen as the least important factor. The client will find it both important to have a product that costs as less as possible and finishing a project on time. The costs are argued to be the most important of these two. This results in having the CCB as most important factor, followed by establishing baselines, and finally by having an information management system, see figure Q.8.

		Configuration and the CMP	Identifying CIs	Accurate data and clarity/status on versions	Configuration Control Board	Baselines	The processing of changes	Distinction between change types	EOW approval	Information management system	Check on accuracy, consistency and completeness	Partnering
Costs	3	9	0	24	18	6	3	12	30	15	24	27
Integrity	1	6	8	3	9	7	5	1	0	10	2	4
Quality	4	32	16	12	36	40	24	4	0	28	12	20
Planning	2	14	2	6	24	20	8	10	0	18	4	16
		61	26	45	87	73	40	27	30	71	42	67

Figure Q.8.: The best factors for the client

In figure Q.9 this is combined and then it follows that having an CCB is the best factor to implement, followed by implementing information management system. Establishing partnering is the third best option and establishing baselines the fourth. These four factors are therefore seen as the most promising factors to solve scope creep.

Configuration and the CMP	Identifying CIs	Accurate data and clarity/status on versions	Configuration Control Board	Baselines	The processing of changes	Distinction between change types	EOW approval	Information management system	Check on accuracy, consistency and completeness	Partnering
57	29,5	47,5	84	66	37,5	26,5	35	72	44	66,5

Figure Q.9.: The best factors combining the client and the engineering company

R. Survey results

The survey was introduced by:
My research focuses on managing scope changes in projects. My research will lead to a recommendation to better anticipate these changes and to make scope creep less common. These are changes that are not formalized and are often implemented quickly as a result of, for example, a request from the customer. However, they are never officially part of the scope. It is often small changes whose benefits are overestimated and the disadvantages are underestimated. The consequences are often not investigated, although they often have a negative impact on planning and costs, on the integrity of the design and possibly on the quality of the end product.

You must choose a project that is used as a starting point for these questions. This must be a project that has focused on engineering in the design phase. The project must at least be of medium size (at least € 200,000 and a minimum lead time of 6 months). This questionnaire is anonymous and will cost approximately 5 minutes per project. He can be filled in several times.

My research has focused on investigating control measures for scope. In the end I fined this up to 4 factors that came out the strongest to be able to anticipate scope creep better. I would like to present this to you in this survey.

The survey was filled in by Dutch employees of Sweco. There were thirty-three (N=33) participants who took the survey. The participants had to fill in a project which they took in mind for filling in the survey. Projects like the redesign of the emplacement of Coevorden, junction of Joure, dyke reinforcement Marken, and the SAAL project. Optional was filling in the department within Sweco. 32 participants answered this question resulting in:

- Rail: 43.8% (N=14)
- Roads: 34.4% (N=11); Civil works is part of this department, therefore probably many participants are from the department civil works, 2 actually stated this.
- Hydraulic Engineering: 12.5% (N=4)
- Assetdata/management: 6.2% (N=2)
- Technique Randstad: 3.1% (N=1)

Each factor was introduced by a small description of the factor. This was based on the description in chapter 12. The questions regarding value, seeing it as realistic and trust are expressed in a five point Likert scale. Number 1 of value says that there is no value at all, number 5 says that there is a large value for scope management. Whether a factor can be implemented realistically is given a 1 for not and a 5 for highly realistic. If trust is given a 1 there was no trust established and with a 5 there was much trust established.

Configuration Control Board

Figure R.1 answers the question: "Was there a Configuration Control Board (CCB) in this project?". It shows that in 25 projects there was a Configuration Control Board established.

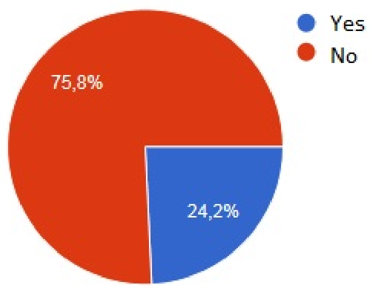


Figure R.1.: Configuration Control Board implemented or not

Figure R.2 shows the answers to the question: "How much value do you see in the establishment of a CCB for keeping the scope in control?". It shows that there is a small division in opinion, with a standard deviation of 1.149 around the mean of 3.52.

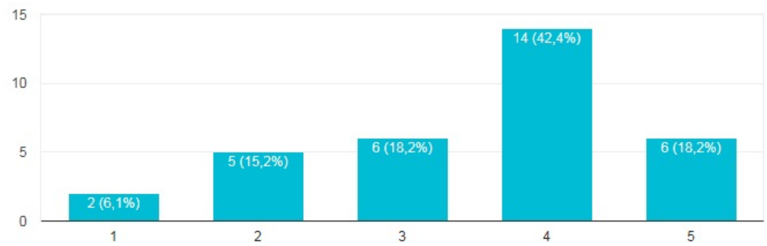


Figure R.2.: Configuration Control Board value

Figure R.3 shows the answers to the question: "How realistic do you see the introduction of a CCB in projects?" In general it is favourably graded but it doesn't meet full satisfaction. This leaves room for improvement. It has a mean of 3.12 and a standard deviation of 0.960.

Participants who filled in 1 or 2 stated multiple reasons like not seeing the added value compared to the project team or that consultation with an aim on managing the integrity already exist. Additionally, some never had problems that would need a CCB, for relatively small projects keeping track of changes takes more time than it will deliver, the function of the CCB is the role of the Project Manager in combination with his Lead engineer, the effect is not visible in the short term, and it is difficult to convince the customer of the usefulness and necessity of this. The customer often does not understand that these kinds of "small" changes can have a large impact.

Participants with a score of 3 also gave multiple reasons. One stated that a CCB happened already in the chosen project but under a different name. The project has a framework agreement and this results in many questions from the client. The Project leader and coordinator took these into account, scrutinized them and assessed if it is an EOW. The project and/or the client often gives insufficient room and time to make a thorough assessment and impact determination and therefore a CCB is only something to aim at, and that it still does not happen enough while it should be done. Additionally, one thinks it is a good tool to communicate transparently, and another participant states that it could work for projects with many 'fuss' about the final to be delivered product. It is seen as valuable for multi-disciplinary projects to ensure an integral alignment, and to manage the interfaces between disciplines.

Other arguments are that they cannot imagine this in a project, or that it depends partly on the nature and scope of the assignment. They would want to know if the investment will be paid back. There is consensus on that it will be an overkill in small projects and that it is essential in large projects, but that for the medium sized projects there will be a challenge for implementation. In line with this is the argument that it will lead to paper tigers, harming the process. One state that the discussed changes must often be implemented in the short term and that waiting until the CCB comes together would take too long.

One participant gave a 5 and said that this is needed to keep the project manageable. The participants who stated 4 also stated that it depends on the project and that the added value is only seen in large projects. However, it is said that they see it already as part of every team consultation where both technical and financial aspects are discussed. One sees it as contract management where currently technical management is insufficiently taken into account.

Some say that it ensures clear scope management for the entire project, it makes clear for both client and Sweco what the consequences could be of a relatively small change, and that it can prevent many discussions during the project because Sweco and the client can discuss changes at an early stage and determine the impact. This could also be combined to a project where changes are added in Relatics and scope changes are shown in excel. However even though it is seen as realistic, necessary, and in everyone's interest, the question is whether the client sees it this way, and the phenomenon prevention is better than cure is not generally recognized yet which makes it more unrealistic.

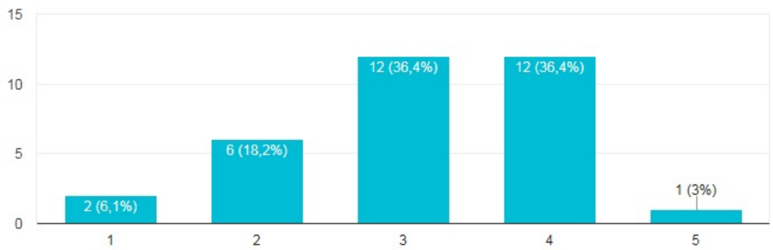


Figure R.3.: Configuration Control Board realistic to implement

It is researched with the Pearson Chi Square test in SPSS whether there is a relation between having a CCB in place and what is seen as the value of CCB for scope management, however, with a asymptotic significance of 0.422, there is no significant relation. Also the relation between having a CCB and whether it is shown as realistic to implement shows no significant relation (0.411).

It is also researched whether the value and rated as realistic is related to each other. From the paired sample T-test it follows that there is a significant correlation (0.003) of 0.508. This is a positive correlation, which means that if the value is ranked higher, the realistic character is mostly also ranked higher. However, there is a significant (0.040) difference between the means of these two variables, where there are significant higher scores on the value of a CCB. This means that it is seen as valuable, but that this does not necessarily leads to a higher realistic character.

Information management system

Figure R.1 shows three pie charts. Pie chart 1 answers the question: "Was there a document structure set up and stored in the project directory in this project?". It shows that many projects still used the project directory. Pie chart 2 answers: "Was there an information management system such as Relatics entered in this project?". This shows that only half of all projects established this. Pie chart 3 answers the question: "If yes to the previous question, was this information management system kept up to date?" 21 persons answered the question instead of the 15 of the previous question. Looking at the individual scores, the accurate percentiles are shown in pie chart 3.

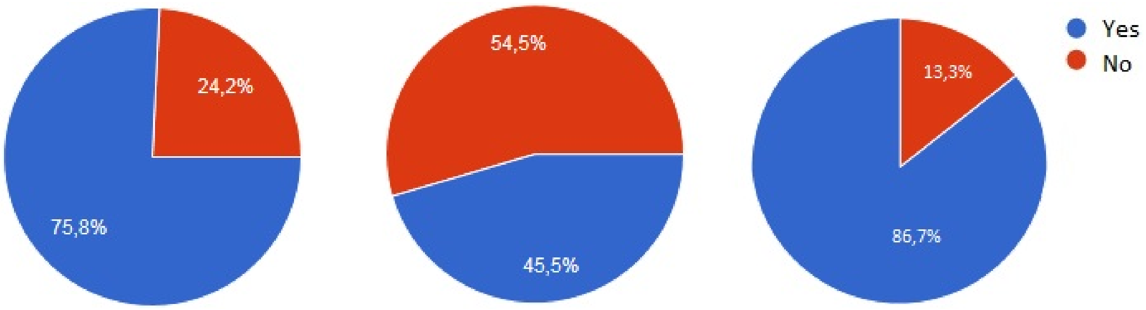


Figure R.4.: Information Management System implemented or not

Figure R.5 shows the answers to the question: "How much value do you see in the establishment of an information management system for keeping the scope in control?". It has a mean of 4.36 and a standard deviation of 0.822. This means that there is a tendency to see it as adding value.

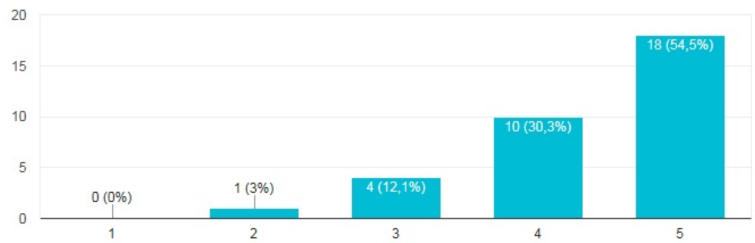


Figure R.5.: Information Management System value

Figure R.6 shows the answers to the question: "How realistic do you see the introduction of an information management system?" In general it is seen as realistic with a mean of 4.06 and a standard deviation of 1.059.

The participants who rated the IMS as not highly realistic mostly said that it would be an overkill for small projects, the effort to set up and maintain the system would be too much, but for larger projects it can work. One states that the correct system is still missing and that BIM could have been of more value than Relatics. Finally one states that he finds Relatics cumbersome and generic, he prefers a simple but effective system in Excel which is much easier to adjust if necessary.

Ten participants who scored a 4 gave a statement. It is stated that Sweco sees the advantages of organizing things properly at the front, to ensure that things are not forgotten and failure costs can be reduced. It also contributes to good information provision, it keeps track of the integrity between disciplines and it forces a project team to work more explicit. Accessibility and trace-ability of documents are important for scope management. An IMS also helps for the other control measures proposed during the survey. Therefore such systems should be used more often also because the market is asking for it. However, even though Sweco has been talking about it for a long time, it does not kick off due to a lack of people who control the implementation and because employees are not able to handle the system properly. Setting up a system is possible but maintaining it and using it properly is a challenge because it is forgotten in the issues of the day. It takes time, which is often considered not to be earned back. In addition, the system that is applied must be project-wide applied. Only if that is the case, it actually adds something to the project. In line with this it is said that the basis of such a system works very well, but not all things, like risk management and actions lists, can be properly arranged in these systems. Still, Sweco has several systems at its disposal, so it is a question of choosing and applying while having budget and capacity available.

A 5 was given because participants simply stated that it must be implemented and it showed its benefits. To set up the Relatics environment takes time, but it is an investment that pays out later. It is important for fast retrieval of documents and thus makes scope management easier. Improvement is needed in taking away the ignorance of employees with the system. One project was used as pilot project for a document management system in Relatics, to easily record version management, document flow and changes, and this worked well. Finally, it is stated that in the case of a complex multi-year project such as OV SAAL, many employees coma and go (with project-specific knowledge), and central registration then becomes key for trace-ability through the years.

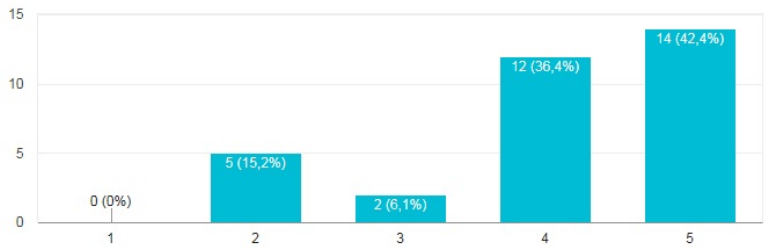


Figure R.6.: Information Management System realistic to implement

It is researched with the Pearson Chi Square test in SPSS whether having a document structure or an IMS is related to the value for scope management. With a asymptotic significance of 0.276 and 0.207 it can be said that there is no significant relation. Also the relation between these two and seeing it realistic to implement is not significant (0.499 and 0.258).

It is also researched whether the value and rated as realistic is related to each other. From the paired sample T-test it follows that there is a significant correlation (0.001) of 0.548. This is a positive correlation, which means that if the value is ranked higher, the realistic character is also ranked higher. There is not a significant (0.067) difference between the means of these two variables.

Partnering

Partnering was researched by looking at the most important parts of establishing partnering. These are a focus on collaboration, having a win-win situation with equal goals and trust. Figure R.7 shows three different pie charts. Pie chart 1 answers the question: "Was there a focus on collaboration in this project?". It shows that in 23 projects this gained focus and this is most of the projects. Pie chart 2 answers: "Was there a win-win situation in which the goals of both partners were equal in this project?" Only 17 projects had this situation, which means that there is much room for improvement. Pie chart 3 in R.7 shows that only 48.5% of all projects had partnering established.

Figure R.8 answers the question: "How much mutual trust was there in this project?" This is one of the most important factors for having a mindset for partnering. Unfortunately there are still 3 projects with very low levels of trust. It has a mean of 3.52 and a standard deviation of 0.972.

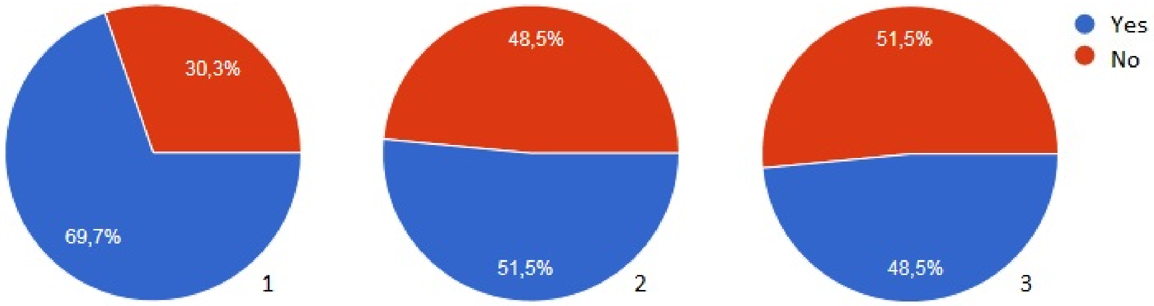


Figure R.7.: Partnering implemented or not

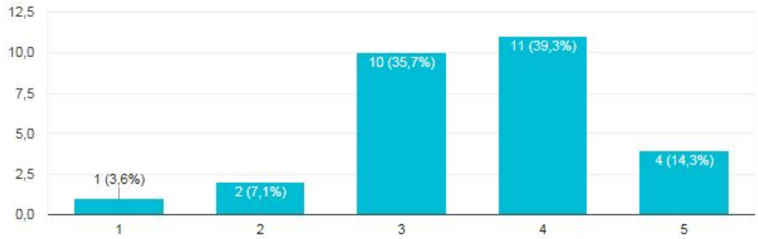


Figure R.8.: The amount of trust in the project

Some participants provided explanation with their answer. Some who said that they had partnering stated that there was good collaboration or collaboration between the client, contractor, sub-contractor and Sweco as consultant with the same project goals. This was also the case in another project, however, additional work become a difficult topic to discuss because the contractor thought differently about this. In one project partnering was realized by a follow up session with the client and two mentors where the aspects of partnering were discussed. One things that an ideal win-win situation is not realistic, however a 80% win-win situation is achievable.

Some projects however stated that trust was present at the start together with a striving for cooperation, but this changed due to mutual failure, Sweco who does not meet her obligations, or due to lack of clarity regarding scope, goals and finance. In one case partnering mainly existed between the ProRail RSE and the Sweco lead engineer. Finally in one project there was sharing of risks between parties.

The participants who answered that there was no partnering sometimes also had higher trust at the start of the project. Distrust came forth from continuous failure to deliver at agreed deadlines and a client who does not have clear understanding of how requirements have been interpreted. Some participants said to have a close and intensive collaboration, but they did not meet the requirements for partnering. Sometimes there was a focus on cooperation, but Sweco made mistakes on an integral level and the client did not give full room for cooperation because they were tight on the contract. In line with this is one who says that there is much on paper described about cooperation, but in practice a client often returns to traditional roles, this also came forth in another project where there was a strong client - contractor role due to a fixed price project. One participant states that if working good does not get anything in return while at the same time they have to fight for additional work. Finally one project had a municipality that came up with design aspects after the work was finished and they had no understanding for the impact on the work and costs.

Finally, in one international project, in which Sweco Finland was one of the partners in the joint venture, the team members from Finland seemed to have little project experience. The employee of Sweco Nederland brought SE related issues (risk and scope control, sensitivity analysis, cost estimates etc.) to the attention, but nobody wanted to put effort into this. The co-project leader was the director of the Swiss partner and was mainly interested in his own scope. He did not want to introduce modern project management techniques. The major cultural differences made the collaboration difficult and the scope management was not carried out as should.

Figure R.9 shows the answers to the question: "How much value do you see in entering partnering for keeping the scope in control?". It shows that there is a tendency to see it as a approach that can give value for scope management. It has a mean of 4.12 and a standard deviation of 0.696.

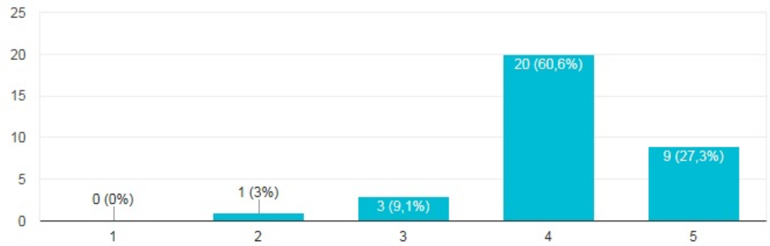


Figure R.9.: Partnering value

Figure R.10 shows the answers to the question: "How realistic do you see the introduction of partnering" In general it is favourably graded but it doesn't meet full satisfaction. It has a mean of 3.39 and a standard deviation of 0.899.

Participants who stated 1 or 2 gave different reasons for this. Firstly, it turns out that the client still finds it too scary to tender work in a different way. Another participant also states that clients are not yet ready for this. Secondly, it is stated that the view on added value is missing and that it does not happen enough. Finally it is stated that it is difficult to be seen as equal if Sweco works for a contractor or a government party like ProRail. Sweco only carries out a small part of the project that is followed up by another party.

Some participants gave a statement on the score 3 of the realistic character of partnering. Some state that requires a change in mindset and successful partnering dependents on the project environment and the mindset of both client, the RSE and the one responsible for the contract on the side of the client. However, not all clients are open to this, not all parties are ready for the change of mindset and there are different interests between parties. Partnering seems essential but becomes hard to realize due to this. It also is dependent on which persons are working together in a project. Partnering must come from both sides and if one of the parties does not fully commit, it is doomed to fail. The way in which partnering in a project should be applied requires good agreements in advance so that the expectations are fully transparent. It does not make sense to only agree on cooperation on paper.

Fourteen participants who gave a 4 as score gave a statement with this. They state partnering ensures good collaboration between client and contractor which is what really matters. Partnering happens more and it is paying off especially for large projects, both internally and between the parties. The advantage of partnering is that a lot is based on trust and a mutual relationship. Scope changes are made in order to achieve the (shared) goal easier and discussions will be easier. Furthermore, it is essential to discuss partnering already at the start of the project and to decide on a fixed agenda and frequencies of meetings, so it can be effective. However, mutual trust and good cooperation are often mentioned in words, but in actions they often remain somewhat behind. Furthermore, the organization and coordination of partnering comes with the necessary costs and the added value of partnering depends on the project size and type.

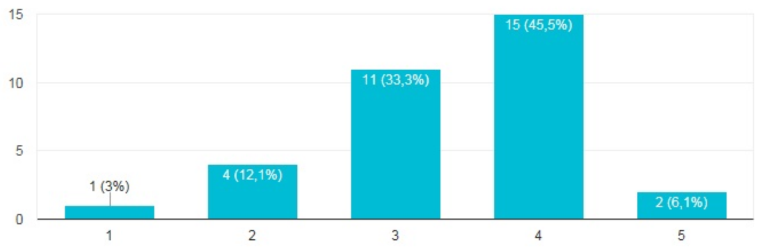


Figure R.10.: Partnering realistic to implement

It is researched with the Pearson Chi Square test in SPSS whether there is a relation between partnering and what is seen as the value for scope management. With a asymptotic significance of 0.073 it can be said that there is no significant relation. Also the relation to if it is shown as realistic to implement is researched. The asymptotic significance of 0.249 shows no significant relation.

It is also researched whether the value and rated as realistic is related to each other. From the paired sample T-test it follows that there is a significant (0.000) difference between the means of these two variables, where there are significant higher scores on the value of partnering than the realistic character. This means that it is seen as valuable, but still many things must be improved to also make it realistic.

Baseline management

Figure R.11 shows two pie charts, where the first one answers the question: "Was there baseline management introduced in this project?". It shows that in 20 projects there were baselines established. Pie chart 2 answers: "Were intermediate baselines drawn up after the design reached a more detailed design level / an iteration was completed in this project?" This shows that this was done in only 48.5% of the projects.

Only 14 of the 20 projects established baselines after an iteration, even though this is also seen as a crucial part of baseline management. 2 projects did not establish baseline management, but did establish baselines after an iteration. One participants did explain why this happened. He states that during the detail phase, a number of optimization's were implemented in the project, in which reference was made to earlier agreements and the consequences were communicated. The other could be explained in the same way as project Geldermalsen. There they did not have a focus on baseline management but did see the products they delivered during the project as freezing the baseline.

Other participants also gave a comment. Three participants said to have baseline management but not new baselines after each iteration. First, one states that the contract was the baseline. Second it is said that a baseline in the form of a CRS was present. However, a number of requirements in this project were not SMART. Finally, one states that the project was too extensive to establish real baselines and that Relatics offered a solution. For each report, the link with the current documents was made in Relatics and the elaboration of the design (all disciplines) was a continuous process.

Two participants answered both questions with a yes, where it is stated that the baselines could have been more explicit, especially in the intermediate phases or after design choices. Furthermore it is said that despite the various baselines and the active attitude of ProRail to manage these, the municipality in question remained elusive. Finally, Three participants gave two no's where one stated that he does not sees the benefit above partnering and a CCB. It is also stated that in one project the work was done in the traditional way. The scope was shared and they tried to work with the same starting points. However, the size of the project did not allow this and as a result integrity errors were made. Finally, in one project the project team had to monitor the CRS. The project manager however did not wanted to put much effort in this and changed his tactic. Therefore financially the project became hard to manage and after three months the project team did not know why certain choices were made by whom.

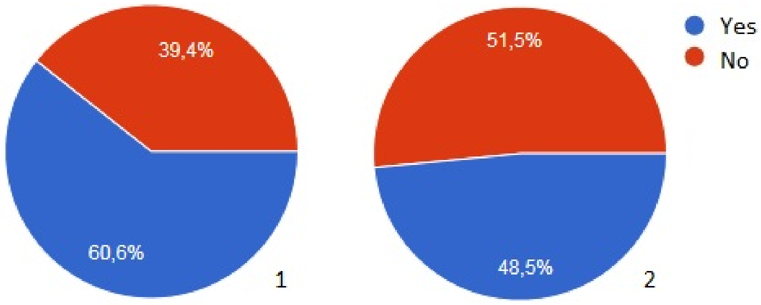


Figure R.11.: Baseline Management implemented or not

Figure R.12 shows the answers to the question: "How much value do you see in entering baseline management for keeping the scope in control?". This resulted in a mean of 4.12 and a standard deviation of 0.740, which means that there is a tendency to see it as an approach that gives value to scope management.

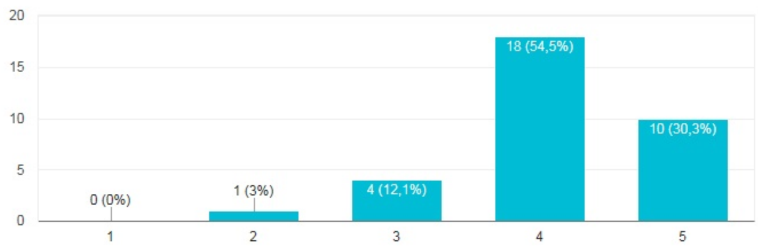


Figure R.12.: Baseline Management value

Figure R.13 shows the answers to the question: "How realistic do you see the introduction of baseline management?" In general it is favourably graded with few participants that score it as not as realistic. It has a mean of 3.85 and a standard deviation of 0.939.

Some participants questioned the use of baseline management. They stated that it is unrealistic for small projects, but it could be useful in larger projects. It is seen as the basis of structured way of collaboration and it is important to manage changes in the starting points. It is seen as a good management concept, but experience shows that it is dependent on the people who work on the project. It was said that someone noticed that the client does not understand what baseline management means and does not understand the importance of it, which makes it unrealistic to implement as the client must also be willing. Some Sweco employees see the benefits but still too much do not see the point or do not know how to organize this, and this follows for example from the fact they notice that it is not a standard way of working at Sweco and at ProRail and it is not expected to become the standard way fast.

Nine participants commented their score of 4. One states that it is inherent in working with work packages and partial deliveries. The others state that the design becomes manageable, in this way they can keep up with the scope, and it keeps decisions with their related deadlines clear. A project can keep track of deviations from the current situation. CRSs are often not or incompletely provided and are also often subject to changes during the design process. Baseline management could frame this, but also reveals who is the cause of the changes. Time and capacity have to be made available just as strict agreements on how to guarantee integrity at the various levels. It would become more realistic if a separate official can be appointed for this.

Nine participants commented on their score of 5. They state that it is crucial for the manageability of the project and scope management and that it should be the basis of every project. It is seen as a good method for the recording of the moments where changes appeared. It is said that it always pays itself back. In one project the aim is always on baseline management, and they always succeeds in this. It is also said that even the most simple method can suffice if used consistently.

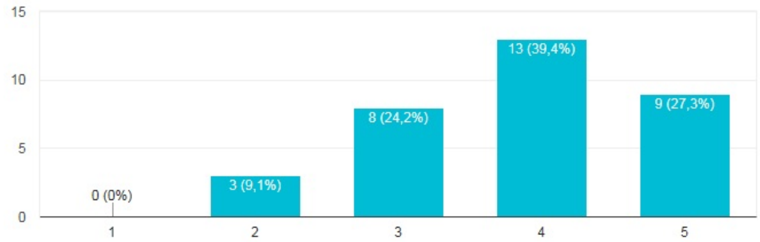


Figure R.13.: Baseline Management realistic to implement

It is researched with the Pearson Chi Square test in SPSS whether having a baseline and updating this after an iteration is related to the value for scope management. With a asymptotic significance of 0.321 and 0.661 it can be said that there is no significant relation. Also the relation between these two and seeing it realistic to implement is researched. The asymptotic significance of 0.237 and 0.083 shows no significant relation.

It is also researched whether the value and rated as realistic is related to each other. From the paired sample T-test it follows that there is a significant correlation (0.000) of 0.657. This is a rather strong positive correlation, which means that if the value is ranked higher, the realistic character is also ranked higher. However, there is not a significant (0.037) difference between the means of these two variables.