SCOPE MANAGEMENT

IDENTIFYING POSSIBILITIES TO IMPROVE SCOPE MANAGEMENT OF DUTCH INFRASTRUCTURE PROJECTS

FINAL MASTER THESIS REPORT F.M. REIJNDORP
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Colophon

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Preface

This is my final thesis which I hereby proudly submit in partial fulfillment of the MSc program Construction, Management & Engineering. With this thesis I obtain the degree Master of Science at the Delft University of Technology.

During my graduation research I researched how scope management in practice can be improved. I am happy to present this thesis which provides the first steps to improve this specific area of project management. I think the result of the research, an implementation guide for scope management, is valuable for professionals participating in Dutch infrastructure projects, which was the initial aim of the research.

Reflecting on the past seven months it can be said that I experienced many challenges. Hereby, I want to thank the many people that were there to help me overcoming these challenges.

I would like to start by thanking my graduation committee consisting of Maedeh Molaei, Hans Bakker, Rob Stikkelman and Vincent van der Meijden. I am thankful for your time and patience during our meetings, and for intensively reading all the versions of the thesis I submitted. Vincent, thank you for giving me the opportunity to graduate in collaboration with PACER, it was a valuable experience.

Furthermore, I would like to thank all the professionals that I interviewed. Without your cooperation I would not have been able to conduct this research. A special thanks to the professionals from PACER, who not only participated in the interviews but also helped me with brainstorming about the topic, reviewed parts of the report and made me feel very welcome.

To my dear friends, family and Sven: thank you for being there for me during this research. Aside from reviewing parts of the report, I am mostly thankful for the evenings and weekends we spend that distracted me from this thesis.

Enjoy reading!

Florine Reijndorp
Rotterdam, March 2018

Summary

Introduction
Executing an infrastructure project is subject to multiple necessities required to deliver a good quality result. Project scope is one of those necessities, which is defined as the activities that must be executed to reach the intended result. Project managers aim to reach their project objectives within the defined scope by applying scope management. Literature demonstrates that a routine of steps is performed when it comes to scope management. Professionals from PACER, a consulting company specialized in infrastructure projects, indicated that there are several bottlenecks hampering scope management in practice.

In literature, bottlenecks are not identified nor described. In this research, bottlenecks were identified with the aim to improve the process of scope management by providing solutions for these bottlenecks. For achieving this objective, the main research question was stated as follows:

How can the execution of the scope management process in Dutch infrastructure projects be improved?

Research methodology
A qualitative research was performed to answer the main research question, including a literature study and empirical research. In the literature study, scope management literature was reviewed. The empirical research consisted of a quick scan in which 12 professionals from the company PACER were interviewed. Besides, three case studies have been performed. In the case studies, project documentation such as the project management plan and the requirement specification was examined, and interviews with 4 case experts were performed.

Results
First, the literature study results pointed out that the available literature mostly focuses on two aspects: 1. scope management steps and 2. managing scope change.

1. The five scope management steps from PMBOK were selected as the basis for the empirical research: 'collect requirements', 'define scope', 'create work breakdown structure', 'verify scope', and 'control scope'.

2. For managing scope change several control systems were proposed including boundary conditions for performing scope change management. Such a control system must at least contribute to identify, analyze, implement and review scope change. For Dutch infrastructure projects the formal procedure for handling scope change seems lengthy. However, this has not been indicated as a problem.

Second, the empirical research provided insight in the scope management steps executed in practice, and the bottlenecks hampering scope management.

A comparison of the results of the quick scan and three case studies with the theoretical findings from the literature study showed that the provided scope management steps by PMBOK do not adequately describe the situation in practice. Because of this, bottlenecks are likely to appear in Dutch infrastructure projects which can be prevented by applying the following set of lessons learned:

i. *Project managers must be aware that scope management requires seven steps instead of five.*

In practice, 'create system breakdown structure' and 'validate scope' is added to the five steps from PMBOK. The scope definition does not automatically result in the work breakdown structure, but first the system is decomposed. In addition, verification and validation cannot be seen as one scope management step because the steps have a different aim and they are executed by a different actor.

ii. *The responsibility structure needs to be clearly defined in the project documentation.*

Both the client and the contractor have a certain amount of responsibility in the scope management steps. However, this is currently not defined nor documented in the project documentation. In addition, it is not defined in which parts of the process the stakeholders need to be involved in the project. Table 1 presents the responsibility division of the client and the contractor in each of the scope management steps.

Table 1 Responsibility charting scope management steps

Scope management steps	Responsible actor defined in practice
Collect requirements	Client
Define scope	Client
Create SBS	Client
Create WBS	Contractor
Verify scope	Client
Validate scope	Contractor
Control scope	Client & Contractor

A further responsibility division needs to be created within each organization, by assigning the tasks within the scope management tasks to specific managers. The RACI chart proposed in literature can be used to assign the responsibilities to roles within the project team.

iii. *Scope change must be managed proactively.*

In the last step 'scope control' scope is monitored and if needed, scope change is processed. Scope change is currently reactively managed: managers take action after a scope change occurs. In combination with the lengthy formal scope change procedure, reactive scope change management causes problems. The lead time of handling scope change is long and is perceived as a bottleneck

A proactive management style must be adopted by predicting patterns in previous scope changes. This means evaluating patterns in previous projects and hereby predict patterns. Monitoring the scope proactively prevents scope change. If scope changes occur, applying proactive management speeds up the process. The scope change procedure is started in an earlier stage, which saves time.

iv. Insight in bottlenecks is needed to prevent them from occurring again.

During the project lifetime the bottlenecks must be identified and documented to serve as input for future projects. In this research, several bottlenecks were identified. However, most of them were project specific. The following bottlenecks were collected:

- Decision-making within the steps takes too much time;
- Lack of information due to different composition of the team in project phases;
- Knowledge shared among project team members of different project teams is not correctly documented;
- The stakeholders are not involved sufficient in the beginning of a project;
- Team members do not see the importance of a tool to track the scope state;
- Lack of overview of possible risks that can result in scope change;
- Not everyone in the project team agrees with the process approach.

Two bottlenecks were identified in all of the researched projects;

a. The stakeholders are not involved thoroughly in the process;
b. Information is lost between the scope management steps due to bad communication and different project teams working on different steps.

The described lessons learned are visualized in the design of the scope management implementation guide, presented in Figure 1. This guide forms an addition to the steps and tools defined by PMBOK by providing the seven process steps including the responsible actor and the lessons learned in each step.

Conclusion

To conclude, to improve scope management in practice, awareness is required concerning the steps to be followed, the roles incorporated and the bottlenecks hampering the scope management process. Using the scope management implementation guide as presented in this thesis, this awareness is created. The guide hereby provides the means to improve scope management by overcoming the bottlenecks currently hampering the process.

Practical recommendations

Systems engineers, contract managers, risk managers, project managers and stakeholder managers play an important role in the steps of the scope management process. That is why this guide is applicable for most of the professionals working for PACER in different disciplines. It is recommended to use the implementation guide in projects to add value to the process of scope management.

Moreover, when using the implementation guide in practice, it is advised that the professionals focus on regular meetings between the client and the contractor when executing scope management steps. Since good communication seems to be lacking in current scope management processes it is also advised to focus on communication, both verbal and documented.

Recommendations for future research

Future research might strengthen the results of this research by;

1. Studying more cases;
2. Researching the benefit of assigning a scope manager overseeing the whole scope process;
3. Examining the possibility to design a separate implementation guide for the client and the contractor;
4. Testing the guide in practice, with the aim to quantify the benefit of using the guide to the overall project success.

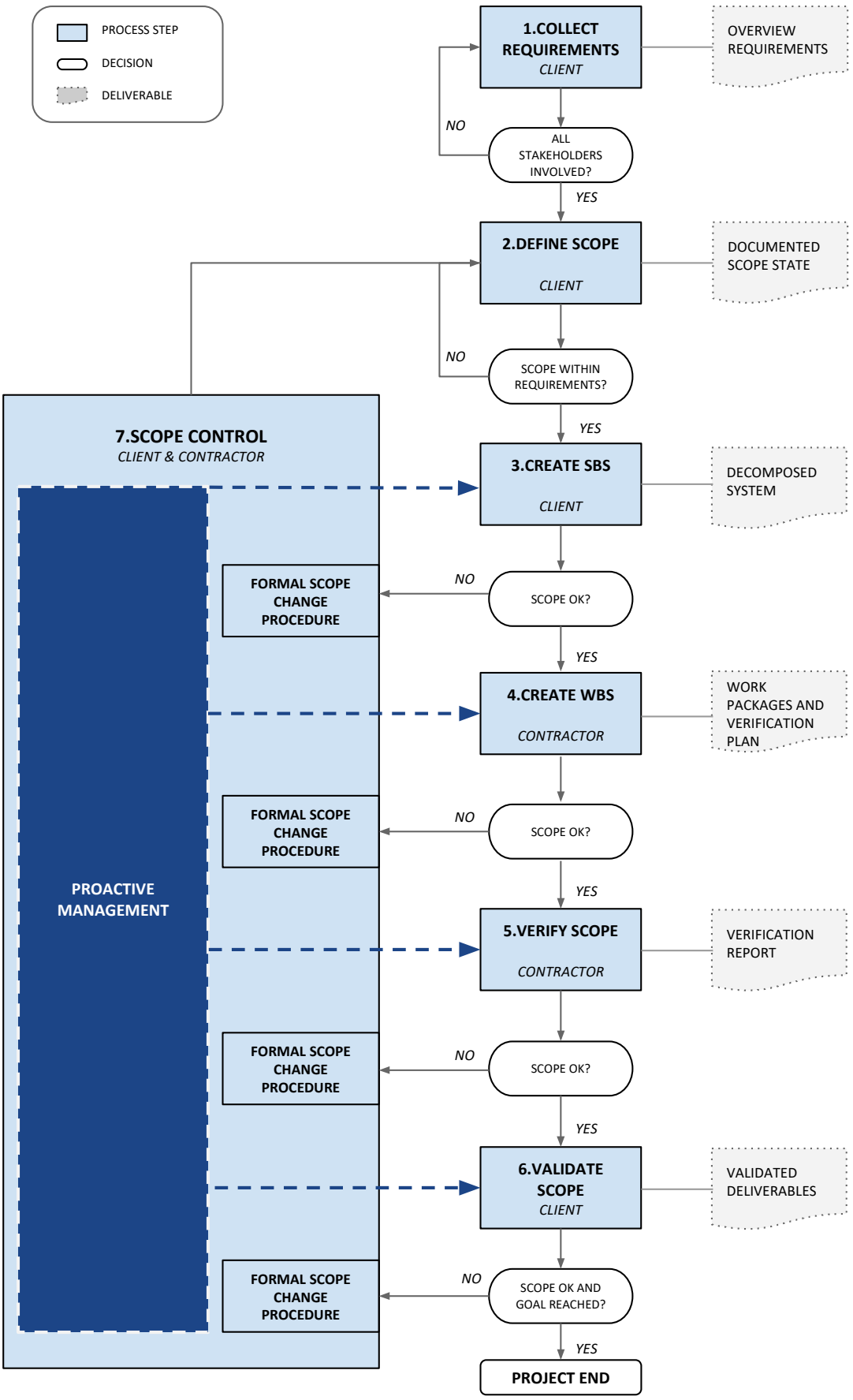

Figure 1 Scope management implementation guide – the flow char

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1.

Introduction

Project managers aim to execute projects within the defined scope. This scope may be subject to change during execution which has an impact on the project output such as schedule, cost and quality. Hence, scope management plays a crucial role in the success of the project realization and therefore receives attention in this research. This research aims to identify the aspects that complicate the scope management process with the aim to improve it.

This section presents the motivation of this research by providing an introduction to the problem field. The research objective, research questions and methodology will be elaborated. The section ends by presenting the demarcation of the research and reading guide of this report.

1.1. Introduction to the problem field

Executing an infrastructure project, is subject to multiple necessities needed to achieve a result with good quality *(Lau & Kong, 2006; The British Standards Insitution, 2013)*. One of these necessities is the scope definition of a project, which is defined as the activities that need to be executed to achieve a project with intended result (*Turner, 2009)*. This result refers to reaching the project's end goal by delivering an end product with the right quality that fulfills the client's requirements within budget and time (*Project Management Institute, 2000; Heldman, 2009; The British Standards Insitution, 2013; Turner, 2009; Meredith & Mantel, 2009*).

Scope together with cost and schedule form the basis for the "*iron triangle*", a project management visualization that presents how a project of good quality can be reached, see Figure 2 (*Atkinson, 1999*).

Figure 2 Iron Triangle based on Atkinson (1999)

The iron triangle shows that scope is a specifically important area within project management that needs to be controlled in regard to the baseline during the project lifetime *(Project Management Academy, 2017; Koskela & Howell, 2002*).

Scope management is defined as the function of developing and managing the project scope throughout the project from a given goal to product delivery (*AWE Services, 2006*). It was indicated by experts from PACER, a consulting firm specialized in Dutch infrastructure projects, that the process of scope management can be improved since there are bottlenecks that hamper the process of scope management.

A preliminary literature study into scope management, which has been performed at the start of this research, indicates that most attention is given to scope management steps, and on managing scope changes. Ways to improve scope management or explicit bottlenecks within the scope management process are not described in the reviewed literature.

The problem is therefore stated as: bottlenecks are present in the scope management process of Dutch infrastructure projects, but they are not identified in literature.

1.2. Research objective and research questions

The objective of this research is to contribute to an improved scope management process by identifying the bottlenecks that hamper this process and provide solutions for these bottlenecks, by comparing literature findings with practical experiences.

The development of an implementation guide for proper scope management provides the means to contribute to this improvement of the scope management process in practice. This guide will be developed in this research.

The research questions are derived from the problem statement and the research objective.

The main research question is stated as follows: *How can the execution of the scope management process in Dutch infrastructure projects be improved?*

To answer the main research question, four sub research questions are identified:

1. What are the steps in the scope management process based on literature?
2. How are the scope management process steps executed in practice?
3. What are the experienced bottlenecks in the scope management process steps in practice?
4. Which lessons can be learned in each of the scope management process steps?

1.3. Research methodology

The research methodology follows the path of a qualitative research based on a literature study followed by empirical research. The empirical research consists of a quick scan and three case studies which will be conducted in collaboration with PACER, a Dutch consulting firm specialized in infrastructure projects, see appendix A for more information about PACER.

The literature study provides findings from theory that will be used in the questions for the first round of interviews. The first interview round forms a quick scan aimed at discovering the main topics which are perceived as frustrating the success of scope management by 12 interviewed experts from the company PACER. In the second part of the empirical research, three cases will be studied. During the case studies, interviews will be performed as well. The questions zoom in on the project processes in practice and provide in-depth findings of the bottlenecks from round one.

The findings from theory and practice will be used to make an integral analysis in light of the research questions. The conclusions that are the output of this step form the basis for validation after which the end result is developed: a scope management implementation guide.

A visualization of the described research methodology can be found in Figure 3. The following sub sections elaborate on this methodology.

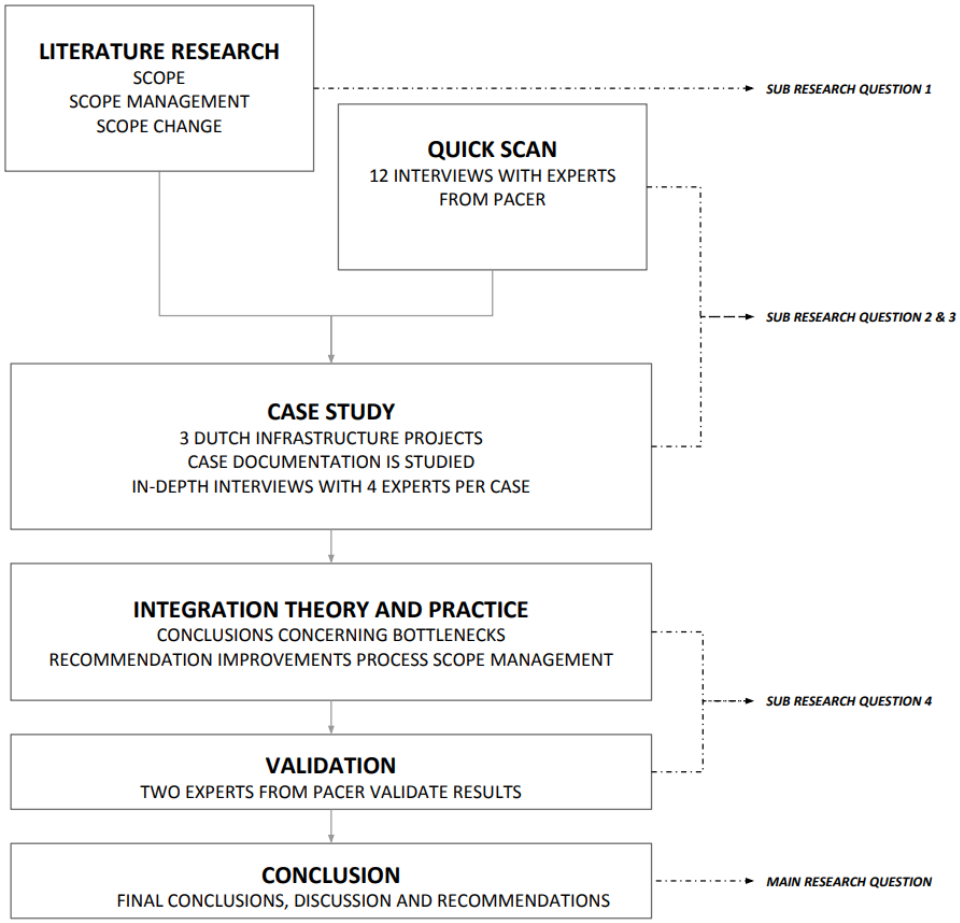


Figure 3 Research methodology

1.3.1. Literature study methodology

A literature study is performed with the aim to create insight in the topic scope management. The result of this study provides a framework that includes defined scope management process steps and recommendations to manage changes in the scope. Literature is chosen based on their applicability in the infrastructure context and process approach. A quick interview with project professionals has led to the desire to research the steps from PMBOK more in-depth, therefore this project management guide gets substantial attention in the literature study. To gain a broad overview and be able to connect and compare existing knowledge about the topic different disciplines and sources are used *(Verschuren & Doorewaard, 2010; Groat & Wang, 2013)*. With the findings of the literature study sub research question 1 will be answered.

1.3.2. Empirical research methodology

The empirical research consists of two parts: a quick scan as part of the preliminary research and a comparative design of in-depth case studies. The method for analyzing the interviews is presented in this section as well.

Quick scan
Exploratory interviews with 12 experts from the company PACER are conducted with the aim to form a baseline for the case studies. The aim of the quick scan is to identify a first direction of bottlenecks hampering the scope management process. The direction for the quick scan interviews is based upon the literature study findings, so scope management process steps and managing scope change receives attention in the exploratory interviews. The result of the quick scan aims to smoothen the transition from the theoretical point of view to the in-depth analysis of three cases.

Case studies
To get a deeper insight in the bottlenecks hampering the scope management process steps and to be able to provide a set of solutions to overcome these bottlenecks, three cases are studied. The reason for studying three cases is summarized in the following;

1. Studying multiple cases increases generalizability, this way results can be transferred to other projects in the same context
2. They help strengthen the results from the quick scan by using the similarities and differences across the cases *(Miles, Huberman, & Saldana, 2014)*
3. Case studies give the opportunity for intensive data generation that can be used to generalize the empirical findings to theory *(Groat & Wang, 2013; Flyvbjerg, 2006; Verschuren & Doorewaard, 2010)*

Method for analyzing the interview results
Each interview is recorded in order to make a transcript, a written version of the interview recording, afterwards. This transcript is sent to the interviewee for approval.

The interview transcripts are organized and evaluated by coding them in Excel to draw conclusions on basis of the interviews results *(Clifford, French, & Valentine, 2010).* First reoccurring patterns within the interviews are detected and combined in key categories, in a three steps method, see appendix B. The selected codes as a result of this first step are combined in the second step, where segments of data from the different interviews are clustered and summarized. For the final result of the case studies, the data is visualized systematically in a matrix in order to simplify the amount of data and compare variables in a proper way *(Miles, Huberman, & Saldana, 2014).* The result of the empirical research will answer sub research question 2 and 3, and contribute to answering sub research question 4.

1.3.3. Integration theory and practice

The literature findings and empirical results are combined to draw conclusions and provide solutions to improve scope management. The steps in the process as defined in the literature are compared to the steps executed in practice which leads to defining lessons learned.

The lessons learned are operationalized in the implementation guide for scope management. This practical tool shows the most important aspects that need to be taken into account when managing the scope, including the responsible actor and recommended tools & techniques for each step. The visualization of this integration of theory and practice is validated by two experts in the field of scope management.

The result of the defined lessons learned visualized in the implementation guide will contribute to answering sub research question 4.

1.4. Validation of the findings

Applying method validation in this research aims to achieve two objectives. First, it aims to prevent the theory findings are subordinate to the interview findings. This is achieved by constantly integrating theory and practice. Second, applying validation aims to guarantee that the research conclusions are labeled as true and practical by the project professionals (Feinberg, Boulanger, Dewé, & Hubert, 2004). In other words, a review of project professionals aims to validate the research output as means to improve the scope management process in practice. To achieve these two aims two ways of validation, internal and external validation, are considered here:

1. To guarantee the reliability and accuracy of the results, the theory and practical findings need to be considered as equivalent. The interview results are based on the literature findings and are tested against the case documentation that will be analyzed. At last, the literature findings and practical findings will be compared, this increases the internal validity of the results (Godwin, et al., 2003).

2. To be able to generalize the results and to use the findings in real-life infrastructure projects, the external validity should be guaranteed (Rothwell, 2005). Safeguarding the external validity is achieved by two experts that validate the end result of this research to guarantee it is useful in projects executed in the demarcated context: Dutch infrastructure projects working according the UAV-GC contract.

1.5. Demarcation

This research focusses on Dutch infrastructure projects, executed according the UAV-GC contract. In addition, it concentrates on the scope management process steps executed by the project team members. It does not focus on the day-to-day activities within these processes executed by each individual. Aside from the project manager, scope management also is of concern to the project team members and third parties. Given these points, the roles of both the contractor and the client in the scope management process are researched. The research is commissioned by PACER, which means project management consultants from PACER are interviewed during the quick scan. In addition, the three cases are chosen in consultation with the professionals from PACER.

1.6. Relevance

Theoretical relevance

This research adds insight to the current literature by researching the whole process of scope management. Insight in the bottlenecks concerning scope change is partly researched by others. However, details about bottlenecks in the other steps of the scope management process are lacking. Therefore, insight in bottlenecks within the complete process of scope management provides the first step in improving this process.

Practical value

This research creates value to the company PACER by creating awareness of the bottlenecks in the scope management process steps and by providing practical means for improvement.

1.7. Reading guide

The theoretical framework for scope management in Dutch infrastructure projects is presented in section 2. The framework is set up using available literature to define scope and explain scope management.

Section 3 presents the result of the quick scan reflected upon literature concerning these results. Section 4 describes the set-up of the interviews and results of the case studies. The result from the empirical research, including quick scan and case studies, is reflected upon the literature findings in section 5. The lessons learned drawn in section 5 form the basis for the design of the implementation guide for scope management, as presented in section 6.

In section 7 the research is discussed, followed by the conclusion. Furthermore the recommendations for the company PACER and future research into this topic are presented in this section.

Last, a personal reflection is provided in section 8.

2.

Scope management: a theoretical framework

Scope management is studied and described by many authors. The combination of available and relevant literature findings concerning this topic provides input for the theoretical framework the empirical research is based on. In this section, scope management literature is studied that serves as input for this framework, with the aim to contribute to answering the first sub research question as presented in section 1.2.

2.1. Scope management: definitions and processes

Several definitions of scope are found in literature;

- The Project Management Body of Knowledge *(2013)* divides the term scope in project and product scope. Project scope involves managing the work that must be done to deliver a product with specified features and functions which can be visualized by creating a Work Breakdown Structure (WBS). Product scope concerns the characteristics of the product, service or result of the project.
- Meredith & Mantel *(2009)* argue that scope can be defined as the requirements and expectations set by the client combined with time, cost and quality.
- Pettman (*2017)* states that scope includes objectives, goals, tasks, phases, resources, budget and schedule of a project.
- According to Turner (*2009*) scope is an initial, high-level description of the way in which the goal of a project will be reached. This description or statement of scope should include the work required to solve the problem and achieve benefits, the work that falls outside the project and also interface with other projects.

In this research the focus lies on the processes important to manage the scope of the project, not on the product scope. Therefore the following scope definition is used;

> The scope of the project is defined as the activities executed during a projects lifetime in order to reach the intended end result of the project.

Management of scope is described by several authors:

- It was argued by Nahod (*2012)* that scope management deals with the analysis and approval of changes in construction projects.

- Scope management is defined by Rijkswaterstaat (*2015*) as effective management of changes and controlling the project to ensure the assignment is up to date.

- Turner (*2009)* states that performing scope management includes ensuring that an adequate amount of work is done, unnecessary work is not done and the work which is done delivers the desired performance improvement. Turner (*2009)* defined four main steps:

1. Developing the concept through the objectives of the project
2. Defining the scope of work through the WBS
3. Authorizing and executing the work, and monitoring and controlling the progress
4. Commissioning the facility to obtain the desired benefit

Scope management, like every area of project management consists of several processes. This is described in three standardized approaches: the PMBOK guide (*2013*), the ISO 21500:2012 *(2017),* and the PRINCE2 method *(2016)*.

- In the PMBOK guide (*2013*), 5 phases are distinguished in which activities throughout the project are described: Initiation, Planning, Implementing, Closing and Monitoring & Control. During monitoring and control the scope is tracked, reviewed and if needed adjusted (*Heldman, 2009)*. This does not occur sequentially like the other processes but happens during the planning, closing and implementation stage, see Figure 4.

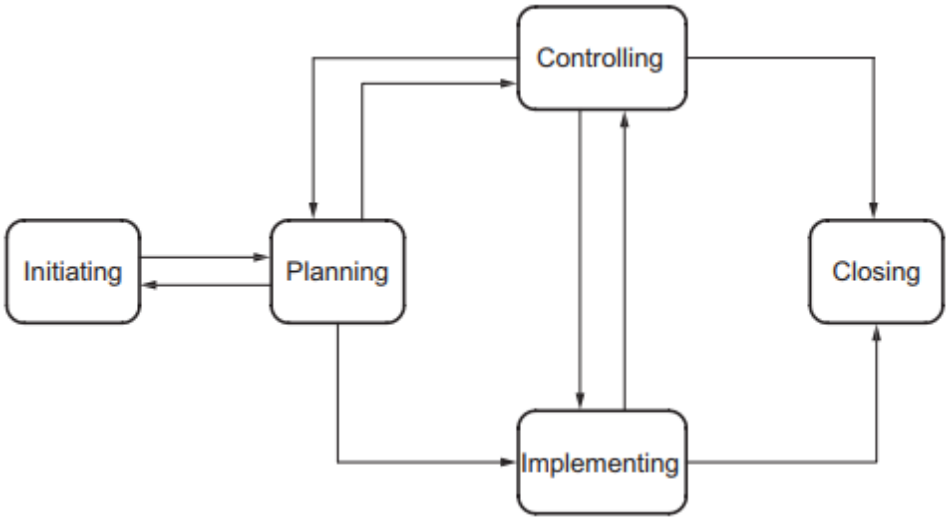


Figure 4 Process groups interactions (The British Standards Insitution, 2013)

The following steps are defined by PMBOK *(2013);*

1. Collect requirements
2. Define scope
3. Create Work Breakdown Structure (WBS)
4. Verify scope
5. Control scope

- PRINCE2 is a methodology required for all projects executed by the UK government but can also be used for all types of projects outside the UK *(Siegelaub, 2004)*. The method presents 7 principles, 7 themes and 7 processes. It focuses on the intended end product of the project, decisions concerning the business case and the project team. It presents roles and responsibilities, product descriptions and stages (*Skogmar, 2015*).

  The seven themes are: progress, business case, organization, quality, plans, risks and change. Scope is not specifically mentioned as one of the themes but some advice for scope management is provided. PRINCE2 advises to start with an overview of the product including quality criteria and expectations which forms the basis for the product breakdown structure (*Skogmar,* 2015).

- ISO 21500:2012 is an internationally agreed standard with the focus on processes that are important for, and have an impact on the projects performance *(The British Standards Insitution, 2013; International Organization for Standardization, 2017)*. It is similar to the PMBOK guide since it uses the same process groups; initiating, planning, implementing, controlling and closing. Several aspects are distinguished that receive attention here such as the stakeholders, resources, time, scope, quality and risks.

The three presented approaches all describe scope management in a different way. In PMBOK it is explained including process steps, tools & techniques. PRINCE2 distinguishes themes within project management, scope management is not one of these main themes but some advice for scope management is provided. This gives the impression scope management is not seen as a highly important project management aspect in this approach. Last, ISO 21500:2012 provides the same processes as PMBOK, and describes scope as one of the several aspects important within these processes. Overall, it can be concluded that PMBOK pays the most attention to scope management when comparing the three presented approaches.

Hence, comparing PMBOK guide (*2013*), PRINCE2 method *(2016)* and ISO 21500:2012 *(2017)* led to the insight that PMBOK fits best to describe scope management process steps. Even though scope management is one of the aspects described in ISO 21500:2012 and PRINCE2, it is not that in-depth as in PMBOK and no steps were identified.

PMBOK

The provided in-depth overview of the scope management steps with their input, tools and techniques by PMBOK *(2013)* can be found in appendix C. Other authors also added insight to these steps, for example Khan (*2006)* who points out that the five steps are connected to the WBS and interact with each other through this WBS. Combining the additional insight of several researchers with the information provided by PMBOK gives the following insight in the scope management steps:

Step 1: Collect requirements

The business need is aligned with a company's objectives and a project is initiated, being aware of project feasibility criteria. The project feasibility is a combination of technical, economic and financial feasibility. The technical feasibility explores the availability of technological knowledge and materials. The economic feasibility explores the rates of return for the project and evaluates the cost-benefit of different scenarios. Last, during the financial feasibility evaluation, the availability of necessary funds and credit rating of the organization is checked *(Khan, 2006)*.

Step 2: Define scope

Scope definition is an iterative process. In this step, the beginning of the scope statement is made along with a set-up of the Work Breakdown Structure (WBS). According to Cho & Gibson *(2001)*, a helpful tool in scope definition is the Project Definition Rating Index (PDRI) tool. This is a weighted checklist, developed by a research team from the Construction Industry Institute. It helps the project team determining which steps are necessary to follow in defining project scope. And besides, it can be used as a benchmarking tool for organizations to use in evaluating completion of scope definition versus the performance of previous projects *(Cho & Gibson, 2001*).

In Dutch infrastructure projects it is often the case that at the start of the project a requirement specification is present. Within this requirement specification, the requirements are already collected. However, there is a slight difference between the collected requirements and turning them into the functional requirements. This is usually done by the contractor or the contractor and the client together. Specification of the requirements is an iterative process and contains feedback loops concerning the requirements and design, as showed in Figure 5 *(Alsem, et al., 2013).*

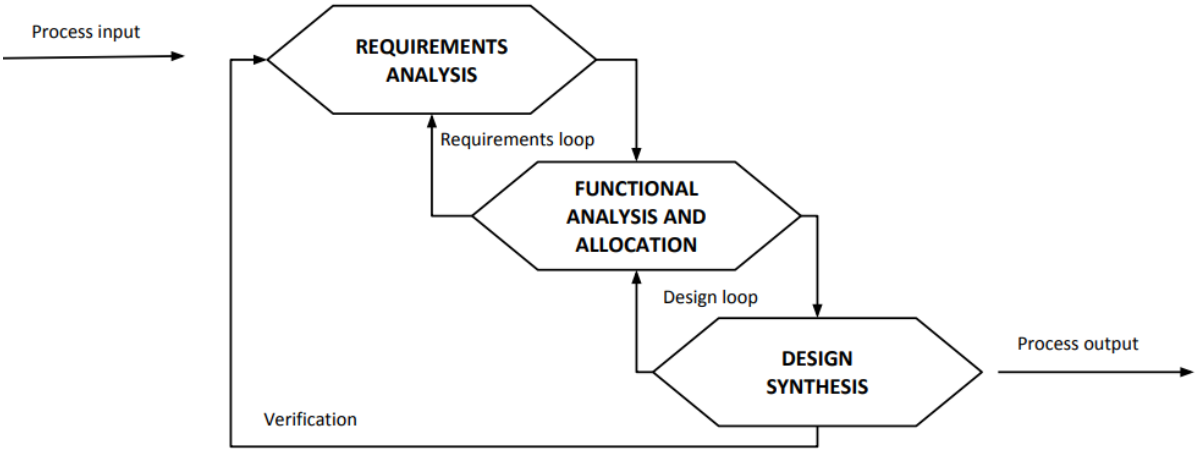


Figure 5 The iterative character of requirements specification based on Alsem et al. (2013)

Step 3: Create Work Breakdown Structure (WBS)
The goal of creating a WBS is to create work packages that decrease the complexity of a project. These smaller work packages are easier to manage and to execute *(de Boer, Bruinsma, Elich, van Luling, & Wemeijer, 2009).* Each work package contains the activities that must be executed along with the requirements, information and identified risks.

Step 4: Verify scope
A continuous feedback loop provides verification of the scope of all the work done within the project. It involves checking the design and engineering deliverables required as part of the scope planning and definition phase. The work has to be in accordance with the regulations and design documents. To check the project's progress, the earned value technique can be used. This technique evaluates indices to measure cost and schedule progress. It compares the planned work against the actual performed work. During the project this process of verification should happen continuously, with the aim to check whether the executed activities meet the demands from the client *(de Boer, Bruinsma, Elich, van Luling, & Wemeijer, 2009).*

Step 5: Control scope
During this step the project team monitors the scope and processes possible changes. Monitoring the scope and keeping it within the defined boundaries is the key activity, but if during scope verification it seems that there are problems, the scope needs to be changed. It can also be the case that undesired changes arise which need to be managed.

It should be noted that the described process steps are not sequentially following each other, they overlap in the project. Also, sometimes processes are merged together. Figure 6 presents the feedback loop and interactions between the scope management elements as defined by Khan (*2006)*.

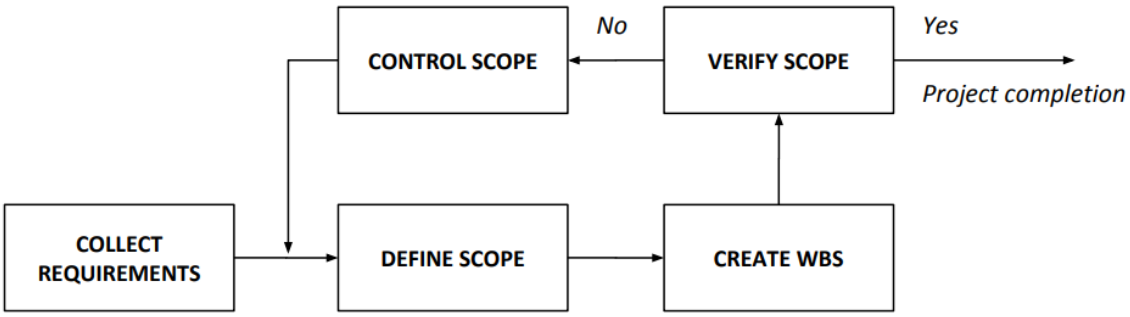


Figure 6 Feedback loop scope management process steps (Khan, 2006)

To summarize, investigating different definition of scope, the following definition is chosen; the activities executed during a projects lifetime in order to reach the intended end result. To monitor and control this scope, scope management is applied. The chosen approach from PMBK describes five steps to manage scope. It is chosen to give substantial attention to a part of the last described step of scope management: control of among other things scope change. The reason for this is because researched literature largely emphasizes on this last step of scope management and because Dutch infrastructure projects are often subject to scope change.

2.2. Scope change

This section zooms in on scope change, starting with the definition of scope change. Second, it is explained why scope change must be managed and third it is presented which ways of scope change management are proposed in the reviewed literature.

2.2.1. Scope change definition

A scope change is defined as an alteration or a modification to the defined conditions, assumptions or requirements as stated in the beginning of a project, which lead to a change in activities *(Gokulkarthi & Gowrishankar, 2015; Nahod, 2012).*

Two categories of scope change are defined; rework and change orders *(Huang, Kong, Guo, Baldwin, & Li, 2007; Hao, Shen, & Neelamkavil, 2008; Sidney, 2006*).

- Rework refers to re-doing a process or activity because of quality defects, variance, poor design or on-site management. The baseline requirements are still satisfied by the new alternative. The process of rework is relatively simple, but the costs can be very high since it is most of the time accompanied by the demolition of what has already been built *(Hao, Shen, & Neelamkavil, 2008)*.

- A change order refers to a change generated by an unanticipated cause that cannot easily be replaced by an alternative. It has to be negotiated case by case and requires a common agreement on paper between all involved actors. Dealing with these changes includes coordinating all aspects relating to the change orders such as documentation, drawings, processes, information, costs, schedule and personnel *(Hao, Shen, & Neelamkavil, 2008).*

2.2.2. Why must scope change be managed?

It is important to manage scope change because it can negatively influence the quality of the end result of a project *(Ndihokubwayo & Haupt, 2009; Sweis, Sweis, Hammad, & Shboul, 2008; Hwang & Low, 2012)*. The need for managing scope change is researched by several other authors. A set of negative consequences found in literature is presented in Table 2.

Table 2 Overview scope change consequences (Arain & Low, 2005; Charoenngam, Coquinco, & Hadikusumo, 2003; Gokulkarthi & Gowrishankar, 2015; Ndihokubwayo & Haupt, 2009)

Consequences of scope change
Additional works
Cost – and time overruns
Disputes between actors
Need to hire additional specialist equipment and personnel
Lowering professional reputation actors
Degradation of quality standards
Adjustment in contract duration
Delay in payment contractor
Schedule delay
Poor professional relations
Decrease in productivity
Decrease in quality end result
Delay of material & tools

2.2.3. How must scope change be managed?

The process of scope change management was defined extensively in the reviewed literature. This sub section gives insight in these approaches. Second, the boundary conditions for a good scope change management process are defined. Third, the UAV-GC procedure for handling scope change in Dutch infrastructure projects is presented.

2.2.3.1. Process of scope change management

Scope change management need to consist of forecasting possible changes, identifying changes that occurred, plan measures to prevent negative impact and coordinate changes throughout the entire project *(Hao, Shen, & Neelamkavil, 2008; Voropajev, 1998; Motawa, Anumba, Lee, & Pena-Mora, 2007)*.

It was emphasized by Schatteman et al. (2006) that since scope change brings risks to the project, project risk management must be applied in any scope change procedure. They stated that an integrated risk methodology is therefore needed for planning construction projects executed under high uncertainty. This needs to be taken into account when performing scope change management.

Three scope change management procedures are reviewed briefly here, first the five stage model from Hao, Shen and Neelamkavil *(2008)* is considered. Second, the change management procedure defined by Ibbs et al. *(2001)*. And third the change control system presented by Hussain (*2012)* is examined. What they all have in common is the need for identification of change, analyzing and implementing it and learning from changes.

1. Five stage model

Hao, Shen and Neelamkavil *(2008)* identified five stages within a good scope change management process; identify, evaluate and propose, approve, implement and review scope change.

i. Identify change

To identify changes including their source, cause and possible actions an effective system is needed to define the relationships between requirements, malfunctions and various aspects of change. Several researchers studied the causes of scope change. Examples are: poor definition of requirements, lack of integration of projects parts and technological uncertainty *(Sharma, 2016; Meredith & Mantel, 2009)*. An overview of researched causes can be used in this step. In appendix D an overview is given of the causes found in this literature study.

ii. Evaluate and propose changes

Based upon defined criteria, the impacts of changes are predicted in this stage. Change options are optimized and the outcome of this stage is a proposal change order, which summarizes the change and the impacts including an action plan with costs, schedule, personnel etc.

iii. Approve changes

All involved actors must agree on the proposed change of work written down in the proposal change order. A change review process facilitates this, involving decisions on acceptance, improvement or rejection of changes.

iv. Implement changes

If needed, documentation, coordination, designs and drawings are modified in this step. An operational system is needed to ensure that all aspects are updated during the project's lifetime. All documentation is linked to each other in the end to make change analysis possible.

v. Review changes

The information from the implementation stage is the input for this analysis. System performance is reviewed after changes are processed *(Hao, Shen, & Neelamkavil, 2008)*. In addition, the changes itself are reviewed with the aim to learn from them.

2. Change management procedure

Ibbs et al. *(2001)* described a change management procedure. The aim is to minimize undesired changes and promote beneficial changes within projects by executing five steps;

i. Promote a balanced change culture
ii. Recognize changes in projects
iii. Evaluate changes
iv. Implement change
v. Learn from changes by improving lessons learned

3. Change control system

A third way to control scope change was presented in the form of a change control system including the following steps *(Hussain, 2012; Clarity Consultants, 2017)*:

i. Set-up a clear communication system, which is used both during routine activities as well as during negotiation processes.
ii. Analyze impact of scope change.
iii. Document changes in writing.
iv. Ask management to approve changes.
v. Embed approve changes in project plan.
vi. Learn from previous experiences by documenting changes and their process of management.

To sum up, it is possible to control changes on the condition that a good system or procedure is used. A proper change management system should first identify change proactively, analyze them and evaluate possible risks. Implementing changes and dealing with the consequence is an important part of scope change management. Learning from previous changes should be the last step of a proper change management system.

2.2.3.2. Boundary conditions for a good scope change process

According to studied literature, a scope change management procedure must be used within several boundaries:

- A good front-end planning
  To effectively expect, prepare and manage change, project managers have to undertake detailed planning including incremental review options; to integrate the work activities of the consultants, the subcontractors and the suppliers *(Love, Holt, Shen, & Irani, 2002; Baker & Greer, 2011)*. A good front end planning can avoid many high risk change orders in projects *(Taylor, Uddin, Goodrum, & McCoy, 2012; Faniran, Love, & Smith, 2000)*.

  Figure 7 shows that in the front end development phase the uncertainty of the project is the highest. If change orders occur in the beginning of the project, the costs are relatively low *(Olssen, 2005)*. At the end of a project, there is less uncertainty but the costs of changes are very high, this should be taken into account in the planning *(Olssen, Project Flexibility in Large, 2006)*.

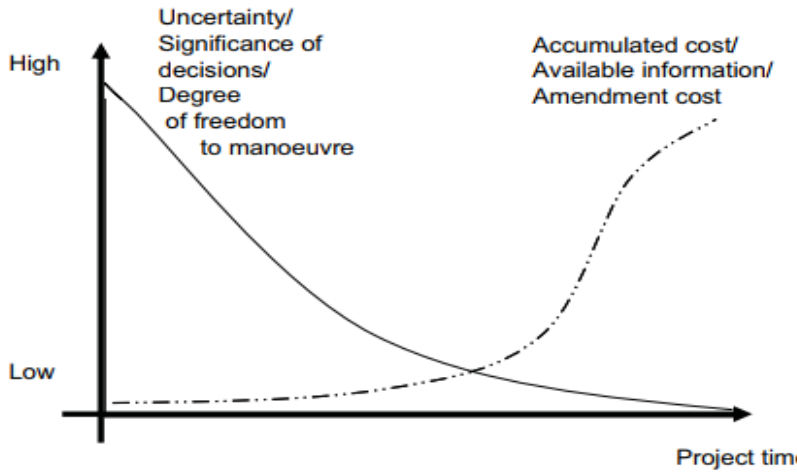


Figure 7 Uncertainty and costs over project lifetime (Olssen, Project Flexibility in Large, 2006)

- All project team members are accountable for scope management
  The steps of the scope management process must be encountered by everyone in the project team, not only the project manager. This way, an increase of the success rate of the scope management process steps is reached. If the processes are understood by the project team members, this increases the performance (Palmetto Document Systems Inc., 2016).

- The use of a change control board
  This board is created by identifying a core team of change agents. The work capacity, availability and capability of change agents should be carefully considered *(Lines, Sullivan, Smithwick, & Mischung, 2015)*. Especially when multiple organizations are part of the project it is advised to incorporate them in the decision-making. The idea is that the project team determines the impact and cost to the project. The control board considers the impact and value to the project and the timing. In addition, the control board decides whether the change request is approved. In this way, the costs and other impacts are valued by different actors and this way an objective comparison is made.

- Increase understanding of roles within project team
  To increase the speed of the decision-making process concerning scope change, it needs to be be clear which roles and responsibilities are assigned to which actor. It should be clear who gives the approval for a change *(Palmetto Document Systems Inc., 2016).*

- Low resistance to implement scope change within project team
  Lines et al. *(2015)* state that proper implementation of scope change procedures is only possible on condition that there is low resistance to embed scope change among the project team members. In case the decision to implement a scope change is made, the project team needs to have a low resistance to involve the consequences of this change. This does not mean the project manager nor project team should be open to any possible scope change.

- Involvement of the right representatives
  Each stakeholder group must assign a representative. It is essential that these representatives are involved at the appropriate moment in the change process *(Baker & Greer, 2011)*.

2.2.3.3. Change procedures in the Netherlands

Most of the projects in the Dutch infrastructure industry are working according the UAV-GC contract. This UAV-GC presents guidelines concerning the procedure for changes within projects *(Centrum voor aansprakelijkheidsrecht, 2005)*. There are two possibilities; changes come from the contractor, or changes come from the client. In both cases, a change procedure should be followed.

Two change procedures are distinguished and described in the UAV-GC, a change procedure when the change is initiated by the client, and a procedure when the change is initiated by the contractor. What the procedures have in common is the lengthy formal procedure. Many steps need to be followed to reach consensus and to be able to implement a change. An explanation and visualization of the procedures can be seen in appendix E.

2.3. Conclusion literature study

The reviewed literature shows that the PMBOK guide describes scope management most adequately in 5 steps:

1. Collect requirements;
2. Define scope;
3. Create WBS;
4. Verify scope;
5. Control scope.

Besides the identified scope management steps it is found that scope change receives a substantial amount of attention in the reviewed literature. This section therefore largely focused on managing scope change as well. To properly manage scope change a control system must be in place to identify, analyze and review changes. For Dutch infrastructure projects, the UAV-GC formal scope change procedures are lengthy. However, it has not been indicated in literature as a problem.

The assumption that in practice bottlenecks hamper the scope management process is not supported by the reviewed literature. No bottlenecks are described: a literature gap is identified. Therefore, this research focuses on identifying bottlenecks in practice, in order to provide solutions how to overcome these bottlenecks.

3.

Quick scan

The literature study in section 2 provided insight in the scope management process steps defined by PMBOK (*2013)*. Literature emphasizes that managing scope change is an important aspect of scope management and requires therefore attention from the project manager. A literature gap was identified; bottlenecks hampering the scope management process are not yet described in researched literature. Providing insight in these bottlenecks helps improving Dutch infrastructure projects.

The quick scan provides the start of the empirical research, with the aim to identify these bottlenecks, of which insight is currently lacking in the reviewed literature. This section gives an overview of the quick scan results. Moreover, these results are reflected upon literature in order to provide a solid basis for the case studies.

3.1. Quick scan results

In the quick scan exploratory interviews are performed with 12 project management experts from the company PACER. The aim is to determine the research direction for the case studies, in which an in-depth analysis of scope management in practice is performed.

To increase the validity of the interview results the interviewees are selected in such a way that their roles differ. This also minimizes biased answering because experts with different interests are interviewed. The profile of the interviewees is presented in appendix F. Semi-structured interviews are conducted, of which the standardized interview questions can be found in appendix F.

The interviews are analysed applying the methodology defined in section 1.3, and an example of this analysis is provided in appendix G. It is concluded from the analysis that in practice the scope management steps are executed by several project team members. It is indeed identified that bottlenecks are present that hamper the scope management process.

Based on a score card, the most mentioned bottlenecks by the interviewees are derived. This led to the list of elements as presented in Table 3.

Table 3 Ranking elements mentioned during quick scan

Most mentioned elements	Score code
Involvement many roles and responsibilities	9
During initiating and planning phase scope was changed a lot	2
Time pressure	4
Unclear documentation	3
Procedure was not followed	4
Communication	5
Reactive scope change management	6

This score card indicates that the two elements: 'involvement of many roles and responsibilities' and 'reactive scope change management' were mentioned most by the interviewed experts.

1. **Involvement of many roles and responsibilities**

   From the project manager, the contractor manager, the technical manager to the change manager; many roles are involved in executing the scope management process. Monitoring and controlling the scope can be a difficult tasks, especially in combination with the many roles involved. It is perceived as difficult to monitor which information is brought up by which team member and to be able to communicate the state of the scope with the entire project team.

2. **Reactive scope change management**

   Scope changes have a potentially great impact on project progress and therefore follows a precise administrative procedure. The procedure described in UAV-GC is used, which is perceived as a time consuming procedure, which supports the reviewed literature in section 2. A good relationship between the client and the contractor is key but it does not simply speed up this administrative process. The overall management style to manage scope change is defined as reactive; action takes place after scope change arise, which is not beneficial especially because the procedure is so time consuming and lengthy.

It can furthermore be concluded that other bottlenecks are perceived to be present hampering the scope management process. For a successful process the following examples of bottlenecks need to be overcome;

- Incomplete administration
- Difficult budget decisions in case of scope changes
- Unfamiliarity of the contractor with the contract form
- Unmeasurable quality checks
- Bad internal communication and documentation within the project team

This quick scan results point out that in practice three aspects require in-depth analysis: roles and responsibilities, reactive management and other, not categorized, bottlenecks. The aspects 'roles and responsibilities' and 'reactive management' are reflected upon literature in sub section 3.2 to provide a solid basis for the case study, taking both empirical results and literature findings into account.

3.2. Quick scan results reflected upon literature

1. Roles and responsibilities in project teams

Dekkers and Pekka *(2008)* introduced an experienced project manager as the responsible actor for scope in project teams. This manager is critical in the stakeholder involvement and must possess a multi-disciplinary set of skills. The project manager manages scope by use of regular reporting of the project progress. After completion of the project, the project manager collects data and reviews the delivery with the stakeholders and reflects with them on the project *(Dekkers & Pekka, 2008).*

It is stipulated in literature that being responsible for scope management is different from being accountable. Responsibility is defined by the individual that is responsible for an action or implementation and can be shared among individuals. There is only one individual accountable, which means he or she answers for the activity or decision *(Smith & Erwin)*. Accountability might also be interpreted as the provision of information, linked to the justification and explanation of an organization's behavior for its stakeholders *(Swift, 2001)*.

Project managers can use responsibility charting as a way to ensure the right responsibility of tasks is in the hands of the right person. Using the RACI chart is a way of assigning roles within the project team, and helps charting responsibility. An example of the RACI chart is provided in Figure 8.

RACI Chart	**Person**				
Activity	Ann	Ben	Carlos	Dina	Ed
Create charter	A	R	I	I	I
Collect requirements	I	A	R	C	C
Submit change request	I	A	R	R	C
Develop test plan	A	C	I	I	R

R = Responsible A = Accountable C = Consult I = Inform

Figure 8 RACI Chart (Project Management Institute, 2013)

As can be seen, four types of responsibilities are distinguished;

- Responsible (R); the one performing the work and responsible for fulfilling the activity until the work is finished and approved by the accountable person.
- Accountable (A); the one approving the activity that another person is responsible for. There can only be one person accountable for an activity.
- Consulted (C); during execution of the work, different persons are asked for their opinion. This means there is communication in two ways.
- Informed (I); persons that are kept up to date about the progress of the work and the results. This means there is just one way communication *(Cabanillas, Resinas, & Ruiz-Cortés, 2011)*.

The many roles involved in the scope management process can be defined clearly using this RACI chart. This will increase the mutual understanding of each other's responsibilities in the process and hereby decreases the negative influence of the many roles involved in the scope management process.

2. Reactive and proactive management

Reactive management is defined as a management style in which the project manager takes action after a situation occurs. In case of crisis situations, fast decision-making is required which is characterized by creative and innovative way of thinking. This leads to creation of new solutions instead of solid procedures *(Reh, 2017)*. In case of scope change there is a solid procedure, which makes fast decision-making and creation of non-procedural solutions difficult. Managers often try to avoid changes instead of predicting and expecting them *(Lee & Ryu, 2013).*

The opposite of reactive management is proactive management which requires the ability to think in patterns. Future problems can be prevented by analyzing previous ones. Managers must ask 'why' something happens instead of what needs to be done to solve it. In proactive scope management the cause of changes is researched *(Reh, 2017*). By predicting and analyzing external threats, project team members are able to change a possible scope change into an opportunity *(Lee & Ryu, 2013).*

The combination of the lengthy procedure described in UAV-GC and a reactive management style were perceived as a bottleneck by the interviewees. Applying a more proactive management style, helps reducing the long lead time of this lengthy formal procedure. This implies experiences from previous projects are used to proactively manage scope in current or future projects.

3.3. Conclusion quick scan

To conclude, the scope management process is hampered by:

1. The many roles involved

   The roles involved in executing the scope management steps are not defined or documented. Using the RACI chart contributes to a clear role and responsibility division, and hereby decreases the negative influence of having many roles and responsibilities.

2. A lengthy and time consuming scope change procedure

   In practice a reactive management style seems to be applied when managing scope change. This is characterized by 'a manager taking action after a situation occurs', according to literature. To apply a more proactive management style, a project manager must predict patterns by analyzing previous projects and hereby prevent negative situations from occurring.

3. Other, not categorized, bottlenecks

   These bottlenecks are project specific but are needed to overcome. Examples of bottlenecks derived from the quick scan are: incomplete administration, unmeasurable quality checks and bad internal communication.

As shown above, the quick scan presents that these aspects frustrate the success of the scope management process. Consequently, a solution is needed to overcome these aspects.

4.

Case studies

This section describes the second part of the empirical research, in which three cases are studied in-depth. The aim is to provide insight in the scope management steps in practice and the bottlenecks hampering scope management.

The case study analysis is based on the aspects derived from the quick scan and literature review;

1. Scope management steps;
2. Many roles and responsibilities;
3. Reactive scope change management;
4. Proactive scope change management.

The case study analysis is furthermore based on the theoretical framework from PMBOK *(Project Management Institute, 2013)*.

In this section the interview setup and case selection are discussed, followed by the case study results. The section ends with presenting the cross case comparison, which led to the conclusion of the case studies.

4.1. Interview set up

Prior to the interviews case documentation is reviewed such as the requirement specification and project management plan. This forms the basis for the case study interviews. Subsequently, in each case study, four experts are interviewed, all fulfilling a different role in the project, to ensure different perspectives of scope management in the project team are studied.

The conducted interviews are semi-structured which means a set of standardized questions was asked. These questions are based on the aspects derived from the researched literature presented in section 2, section 3 and the quick scan: the scope management steps, roles and responsibilities, and reactive versus proactive management of scope change.

For each of the aspects several indicators were defined based on the literature reviews and quick scan. The questions are based on these indicators, in order to ensure the right information is gathered concerning the four aspects. Table 4 presents the indicators identified for each of the aspects. An elaboration of the definition of the aspects and the list of standardized interview questions based on the literature reviews is provided in appendix H.

Besides the literature study and quick scan results, the case study interviews are based on the theoretical framework from PMBOK *(Project Management Institute, 2013)*.

Table 4 Aspects and their indicators

Aspect	Indicators
Scope management steps	• Procedure is set up and well known • Process steps are followed • Definition of 'good scope management process' available
Many roles and responsibilities	• Several managers execute scope management tasks • Clearness responsibility scope management tasks
Reactive management of scope change	• Changes are seen as a bottleneck in scope management process • Action occurs after change • Procedure not always followed; creative solutions brought up
Proactive management of scope change	• Previous changes are analyzed to search for patterns • Initiative to change current situation • Changes are seen as an opportunity

4.2. Case selection

Cases are selected on the expectation of available information concerning the four presented aspects. To be able to get an overall view of scope management, three cases are chosen that vary in their circumstances. The cases are chosen based on strategic selection, with the aim to be able to generalize the findings *(Flyvbjerg, 2006).* The cases are chosen on basis of the following criteria;

- The projects take place in the Netherlands

- Each project is commissioned by a different organization
  This research focuses on scope management as a part of project management. This does not include the application of company specific procedures but requires a more general view. Therefore, the projects chosen to research are executed commissioned by different organizations and executed by different organizations.

- There is both relevant documentation and people available to interview
  Since the interview results need to be validated, they need to be compared to the case documentation. Therefore access is needed to information about the defined scope and scope management steps, roles and responsibilities and procedures concerning scope management. Besides the documentation, four project team members with different roles need to be available to participate in the case study interviews.

- The UAV-GC contract is used in the projects
  The procedures written down in the UAV-GC contract form the baseline for the process of scope change management in projects using this type of contract. To be able to compare the cases, only projects using UAV-GC are chosen.

- The projects are all infrastructure projects
  Because of the time constraint of this research and availability of data and experts from PACER, only infrastructure projects is researched.

- Availability to access data in time
  This research has a time constraint of 6 months, therefore data needs to be received within that time. The case documentation is preferably received before the interviews take place.

- Enough information and expertise about the variables presented in the previous section
  Since the focus will be on the aspects: scope management steps, roles and responsibilities, and reactive versus proactive scope change management. Enough expertise is required concerning these aspects, both regarding the availability of documents and the knowledge of about the interviewees.

On the basis of these criteria the following three Dutch infrastructural projects are chosen.

Case 1
This project is executed by an infrastructure contractor. The project concerns activities within the electricity sector and takes place in the south of the Netherlands. The project management plan describes that regarding scope management, the contractor is obliged to make a WBS and an object tree. The expert from PACER participating in this project is hired by the infrastructure contractor.

Table 5 presents the interviewees profile for case 1, working for the contractor. This includes their role, background and the abbreviation that is used in the analysis.

Table 5 Profiles of the interviewees case 1

Role	Abbreviation	Background
Project manager	PM 1	Technical
Process coordinator	PC 1	Architecture
Manager process and quality	MPQ 1	Civil Engineering
Technical coordinator	TC 1	Systems Engineering

Case 2
Case 2 concerns a project executed by a consortium of three contractors together: an infrastructure contractor, a road construction company and an offshore contractor. The project concerns repair- and maintenance activities of a Dutch weir. In the requirement specification, it is stated to be the contractor's responsibility to decide which activities are needed to repair and maintain de weir. Scope management is not included as a specific area of interest in the requirement specification. However, in the technical management section, several activities to manage the scope of the work are mentioned. This concerns validation & verification and constructing the work breakdown structure.

Table 6 presents the interviewees profile for case 2, working for the infrastructure contractor. This includes their role, background and the abbreviation that is used in the analysis.

Table 6 Profile of the interviewees case 2

Role	Abbreviation	Background
Project manager	PM 2	Agricultural
Process coordinator	PC 2	Civil engineering
Project leader	PL 2	Mechanical engineering
Technical coordinator	TC 2	Mechanical engineering & business administration

Case 3
This case concerns a long term maintenance of a set of tunnels in the Netherlands. The requirement specification states that within a contract of three years, the contractor needs to live up to several goals. The tunnel functions need to be maintained to ensure it keeps working in a good condition and sustainability and public values need to be taken care of. Scope management tasks are described. It is pointed out that a WBS should be made by the contractor.

Table 7 presents the interviewees profile for case 3, working for the client. This includes their role, background and the abbreviation that is used in the analysis.

Table 7 Profile of the interviewees case 3

Role	Abbreviation	Background
Contract manager	CM 3	Mechanical engineering & management
Technical coordinator	TC 3	Mechanical engineering
Asset manager	AM 3	Hydraulic engineering & business administration
Coordinator changes	CC 3	Science & innovation management

4.3. Results case studies

Analyzing the cases provides insight in the process of scope management in practice and the bottlenecks arising when executing this process. This section presents the results of each case. The findings are categorized as follows:

1. A comparison between the project documentation and interviewees answers to test the knowledge of the interviewees concerning the scope definition and the scope management procedure;
2. The scope management steps;
3. The roles and responsibilities involved in the process;
4. Reactive scope change management;
5. Proactive scope change management;
6. The identified bottlenecks.

Case 1

1. Documentation scope definition & scope management steps

As can be seen in Table 8, all the interviewees mention the same scope, which gives the impression that the scope is clear among the project management team. The scope is defined in the requirement specification which is accessible for everyone in the project team. The requirements part of the scope are accessible and up-to-date in the tool *Relatics.* Not every project team member understands the importance of using this tool the right way since the focus is more on technical aspects instead of the processes. Also, the scope management tasks belonging to the contractor are not adequately described in the project documentation.

Table 8 Comparison documents and interviews case 1

Topic	Case documents case 1	Interviews case 1
Scope definition	The contractor will design and construct high voltage electricity lines at two locations A and B. Furthermore high voltage electricity lines will be connected to electricity station Y.	- "Designing, preparing and executing construction of electricity lines in the south of the Netherlands" (PC1, 2017) - "Responsible for realization of electricity lines" (MPQ1, 2017) - "Officially responsible for design and construct, in practice only for constructing electricity lines" (PM1, 2017) - "Providing electricity power lines" (TC1, 2017)
Scope management	The contractor needs to execute the following activities concerning scope management; constructing a work breakdown structure (WBS) and an object tree. The work breakdown structure needs to have at least a hierarchical structure of activities and work packages and there needs to be an unambiguous relation with the objects from the object tree.	Besides translating the requirements from the client into a good scope definition, the contractor also makes a verification and validation plan connected to the requirements. A System Breakdown Structure (SBS) and Work Breakdown Structure (WBS) are made.

2. Scope management process steps

The following process steps are performed; collect requirements, define scope, create WBS, create SBS, verify and validate scope, and control scope. Collecting the requirements and creating a first definition of the scope was performed by the client. The client uses the System Breakdown Structure (SBS) to define which subsystems are present, which serves as a basis for the WBS made by the contractor. The contractor creates a detailed version of the scope, creates the WBS, performs verification and validation, and controls the scope. Scope management could be improved by connecting the WBS to roles and responsibilities in the project team. Predicting and handling scope change could be improved using a tool to provide an up-to-date overview of changes. The current formal process of scope change management is criticized due to the long lead time.

3. Roles and responsibilities

The interviewees are unanimous about the fact that one person needs to be fully responsible for scope management. This person should have full knowledge about the content of the activities and about the contractual agreements. It is stated that instead of the project manager, a contract manager must be responsible for scope management since it comes down to managing the requirements and therefore, knowledge about contractual agreements is required. Besides the project manager and contract manager the following roles need to be involved in the scope management process; technical manager, site manager and process manager.

4. Reactive scope change management

According to the interviewees, scope change is managed reactively. Bringing up scope change can give the contractor a negative image. Processing scope change is a challenge because of the long lead time of the formal process.

5. Proactive scope change management

Proactive management means experiences from previous projects should be used to anticipate future change. These experiences currently emerged in the form of tacit knowledge, which means experts do have the knowledge but the documentation is lacking. By improving the documentation changes might be predicted. In addition, a continuous verification and validation between the contractor and the client smoothens the scope change process and create a pro-active attitude.

6. Identified bottlenecks

The bottlenecks mentioned by the experts from this case are presented in

Table 9.

Table 9 Summary bottlenecks interviewees case 1

Identified bottlenecks case 1
Team members do not see the importance of a tool to track scope
There is no common understanding of the roles within the project team
A project team member fulfilling the role of a contract manager is missing
The lead time of the documentation procedure of scope change is too long
A lack of information due to different composition of the team in different process steps
Changes coming from the contractor create a negative image, which creates fear to bring them up
The responsibility for designing is assigned to the contractor on paper, but in practice the client is responsible

Case 2

1. Documentation scope definition & scope management steps

Scope definition is clear among the project management team as presented in Table 10, but not to the workers carrying out the activities on site. Those workers are aware of a part of the scope, not the complete context. Memo's in which scope is documented are however accessible to everyone in the project. The tool *Vise* is used to document all the requirements and they are connected to the parts of the scope. The scope management tasks are not described in the project documentation. However, the tasks are known by the interviewees.

Table 10 Comparison case documents and interviews case 2

Topic	Case documents case 2	Interviews case 2
Scope definition	The contractor is asked to execute repair work with the aim to maintain functioning of weir X. Way of executing activities can be decided by the contractor.	- "Execution of repair activities of weir X" (PC2, 2017) - "Repair activities on location A" (PL2, 2017) - "Technical implementation of repair activities" (TC2, 2017)
Scope management	No information provided	The contractor collected requirements. Scope definition was done by the contractor with the help of another maintenance contractor and the client. Constructing Work Breakdown Structure (WBS) and preparing a verification and validation plan was also part of the scope management process.

2. Scope management process steps

The following process steps are performed; collect requirements, define scope, create the WBS, verify and validate scope, and control scope. Collecting the requirements and defining the scope is done by the client and the contractor together with help of a maintenance contractor that is aware of the current state of the project. The WBS and verification set up is created by the contractor. Scope control is present in the form of validation of requirements throughout the project. It is suggested that the sequence of the steps might be changed if necessary, for example in case of a different project type or in case of time pressure.

3. Roles and responsibilities

One person needs to be responsible to ensure clear communication with the client. Insight and support given by the technical manager is necessary. The responsible project manager must be aware of all the contractual matters. Another role important to execute the scope management steps with sufficient substantive knowledge is the environmental manager. In addition, the stakeholders influenced by or can influence the project need to be taken into account to safeguard the requirements. In case of large projects, it is recommended to assign a scope manager.

4. Reactive scope change management

The attitude towards scope change is rather reactive instead of proactive because of the use of 'stelposten'. Stelposten are defined in the start-up phase of the project and contain information on possible changes including the estimation of financial consequences in case they occur. The official way of documenting scope changes is through a request for change (RFC). A list of RFC's contains the most up-to-date version of the scope status. In case there is time pressure, the formal procedure is not always followed but verbal agreements are made to achieve fast consensus. Overall scope change is seen as a disruption to the scope management process.

5. Proactive scope change management

Besides the use of 'stelposten' as part of proactive management there is a desire for a system that helps seeking for patterns. Use of experiences can be beneficial in some cases. It can also make a project team anxious and reserved in taking chances. Changes coming from the client are seen as an opportunity. To improve ways to anticipate on changes expectations must be managed by documenting experiences. Also, the client and the contractor need to discuss possible scope changes regularly.

6. Identified bottlenecks

The bottlenecks mentioned by the experts from this case are presented in Table 11.

Table 11 Summary bottlenecks interviewees case 2

Identified bottlenecks case 2
Not everyone in the project team agrees with the process approach
There is a lot of discussion concerning scope change
A system for keeping track of changes to seek for patterns is not used yet
Expectations concerning scope change are not identified nor managed correctly
The stakeholders are not considered throughout the complete scope management process
A person fulfilling the role of a scope manager is missing in large projects

Case 3

1. Documentation scope definition & scope management steps

The scope is defined in the contract and accessible to every project team member. The experts are aware of the general scope, but not of the exact information per tunnel, which can be seen in Table 12. The provided scope management documentation does not describe the scope management tasks completely. For example, creating the SBS is part of the client's tasks, but not described in the documentation.

Table 12 Comparison case documents and interviews case 3

Topic	Case documents case 1	Interviews case 1
Scope definition	The contractor is responsible for perennial maintaining, monitoring and informing about the status of the tunnels in area A.	- "Fixed and variable maintenance required to ensure a tunnel is safe and available" (CM3, 2017) - "The contractor executing maintenance activities of tunnels in the contract from point A to point B" (TC3, 2017) - "There is a tunnel and it needs maintenance" (AM3, 2017)
Scope management	The contractor needs to execute scope management activities to ensure the functioning of area A will continue. A WBS needs to be made and showed to the client. The contractor needs to start preparation of activities within the scope before the maintenance contract starts. If any change within the given area A characteristics arise, the contractor needs to notify the client as soon as possible.	The client stated the requirements and scope definition, and made a System Breakdown Structure (SBS). These together formed the guidelines for the Work Breakdown Structure (WBS). The WBS and verification and validation plan is made by the contractor.

2. Scope management process steps

The client is responsible for collecting the requirements and defining the scope. The complete scope is split up in subsystems and is defined in the System Breakdown Structure (SBS), created by the client. This serves as a guideline for the WBS, created by the contractor. The contractor is obliged to come up with a verification plan. It is mentioned that between the steps important information get lost because different teams work on different scope management steps. Also, the decision-making within the steps takes too much time.

3. Roles and responsibilities

The client is mainly responsible for managing the scope. The project manager does not have enough specific knowledge to execute all the scope management steps. Therefore the following other roles are needed; portfolio manager, environmental manager, technical manager and a contract manager. The knowledge of the managers fulfilling these roles is combined to reach an adequate project result.

4. Reactive scope change management

The interviewees are not unanimous if overall a reactive or proactive management style is used. What is mentioned without exception is in case scope change comes without extra capacity, it is experienced as a bottleneck. Mostly, a large scope change requires a lot of focus, which impairs the focus on the rest of the project. A scope change without proper information increases the negative attitude towards scope change among the project team members. In case of emergency, the process of scope change is not always followed.

5. Proactive scope change management

Currently there is knowledge exchange among project teams that execute the same type of projects. However, it is not documented yet. The tool *Relatics* is used to keep track of changes and their impacts. It is possible to include other risks in this tool, but this is not done.

6. Identified bottlenecks

The bottlenecks mentioned by the experts from this case are presented in Table 13.

Table 13 Summary bottlenecks interviewees case 3

Identified bottlenecks case 3
Detailed scope is not known by team members because they work on several contracts
There is loss of information between process steps
The responsible actor of each step is not documented
A scope change does not come with extra capacity in terms of employees or budget
The lead time of the scope change procedure is too long to follow, especially in case of safety matters
There is no clear overview of possible risks
Knowledge shared among project team members of different project teams is not correctly documented
Stakeholder involvement is not done thoroughly in the beginning of the project
Decision-making within the steps takes too much time

4.4. Cross case comparison

The findings of the three cases are combined and visualized in one matrix to provide input for the cross case comparison, Table 14 shows this result. The results are explained for each of the four aspects:

1. The scope management steps;
2. The roles and responsibilities involved in the process;
3. Reactive scope change management;
4. Proactive scope change management.

TOPIC	INDICATOR	CASE 1 FINDINGS	CASE 2 FINDINGS	CASE 3 FINDINGS
Scope management process steps	**Procedure is followed**	Collecting requirements done by client, scope definition, WBS, verification & validation and scope control present	Collecting requirements & scope def client, contractor and input maintenace contractor	Collecting requirements and definition scope done by client
			WBS and verification present	WBS and verification done by contractor
			Scope control done as validation requirements	Guidelines for WBS set by client in SBS
	Definition good process	When initial plan is executed	Execution initial steps	Within time and budget execution
			Realistic plan	Meeting inital requirements
			Fast consensus changes	
	Possible improvements to process steps	WBS should be connected to roles	Sequence steps dependent on project & timepressure	Less information loss
		Use of a tool for changes		Faster decisions
		Faster proces		Verification and validation not only afterwards
Roles and responsibilities	**Responsible party for managing scope**	Project manager	Project manager with technical manager	Portfolio manager internal
		Also responsibility for the whole team	Also responsibility for the whole team	Project manager external
	Roles invovled in scope management	Project manager	Project manager/contract manager	Project manager external
		Technical manager	Technical manager	Contract manager
		Site manager	Manager environment	Manager environment
		Manager project processes	Stakeholders	Technical manager
			Bigger projects; scope manager	
	Reponsibility structure	One person responsible	One main responsible	One responsible internal
			Necessary support by technical manager	One responsible external
Reactive scope change management	**Scope change is seen as bottleneck**	Overall acceptance	Depends on timing and prospect	Yes when focus impairs
		Sometimes negative image and process of documenting difficult	Overall seen as disruption instead of bottleneck	More work against same capacity
	Creative solutions instead of procedure	Not doable to not follow formal process	In case there is timepressure, yes	In case of emergency; yes
			Verbal agreements instead of documentation	Procedure afterwards when timepressure
	Reactive action; after changes appear	Yes, but sometimes proactive way of reporting towards client	Use of 'stelposten' creates proactive attitude	Interviewees undecided
Proactive scope change management	**Anticipate on changes by seeking for patterns**	Not in current project, sometimes experiences from previous ones	Necessary but not done in this project	Use of programming tool
			Use of experience sometimes beneficial	Exchange of knowledge among projectteams
	Initiative to turn change into opportunity	Yes but mostly to help client	Yes, a change is a opportunity by definition	Yes, to reach extra goals
		Sometimes bargening for better execution	Sometimes financially, sometimes for good evaluation	
	Seeking for new ways to anticipate on change	Verification and validation together with client	Managing expectations by impactanalysis	Better documentation of knoweldge exchange
		Better documentation of evaluations	Use of good documented experiences	
			Stay in touch regularly with client	

Table 14 Overview case study findings

Cross case comparison findings

1. Scope management steps

In practice, scope management consist of the following steps: collect requirements, define scope, create System Breakdown Structure (SBS), create Work Breakdown Structure (WBS), verify and validate scope, and control scope.

A system breakdown structure is an additional step compared to the theory from PMBOK *(2013)* and is defined as: 'a decomposition of the main system in subsystems with the aim to gain insight in large amount of information. It is hereby important to consider what way the systems are designed, what the systems do and how critical interfaces of the system should be managed' *(Rich, 2015)*. The ouput of the SBS is a list of elements and tasks necessary to accomplish the objectives of a project *(IEEE, 2005)*.

It is stated that the verification and validation of scope need improvement. In the start-up phase of the project a better verification & validation plan should be prepared and there should be clarity about the task division between the client and the contractor. For the step scope control, it is found that when a scope change must be handled, the lead time of the formal procedure is too long which leads to skipping parts of the process.

Three bottlenecks are identified in the scope management steps:

- The WBS must be connected to roles to increase understanding among project team members of each other's responsibilities;
- Sometimes the WBS is mentioned in project documentation but an overall definition of scope management tasks is lacking;
- Between the steps information gets lost.

2. Roles and responsibilities

The responsibility for the scope management steps is distributed between the client and the contractor. It is stated that within the clients and the contractors organization, preferably one person is responsible for scope management for clarity. The responsibility division between the client and the contractor is as presented in Table 15.

Table 15 Responsibility distribution scope management steps

Scope management step	Role defined in practice
Collect requirements	Client
Define scope	Client
Create System Breakdown Structure	Client
Create Work Breakdown Structure	Contractor
Verify and Validate scope	Client & Contractor
Control scope	Client & Contractor

3. Reactive versus proactive management

Overall there is a reactive management style applied to manage scope change, because of the following reasons:

1. Scope change management is not directly seen as a bottleneck;
2. No documentation concerning previous projects experiences is available;
3. The project team is not familiar with tools to analyze previous changes and seek for patterns.

The long lead time of the formal scope change procedure is seen as a bottleneck. The long lead time of the procedure is in accordance with the findings in studied literature. In the studied literature it was however not perceived as a bottleneck, and therefore no solutions were provided. To overcome this problem, verbal agreements are made in practice, for which trust is key. It Is important to keep in mind that verbal agreements can at the same time be bottlenecks, because verbal decisions are not enforceable. It is possible to use them in order to speed up a part of the process but, in the end a documented version of the agreement is always needed. Discussions about financial decisions concerning scope change are always present.

To better anticipate scope changes the following was mentioned by the interviewees:

1. Use of impact analysis for possible changes;
2. Better documented evaluation of experiences in projects;
3. More client-contractor contact.

4.5. Conclusion case studies

Practice shows that there are seven steps when executing scope management: collect requirements, define scope, create SBS, create WBS, verify scope, validate scope and control scope.

In accordance with the quick scan results, the following bottlenecks are identified;

1. Roles and responsibilities are not known by everyone in the project team.
   In addition, the roles and responsibilities are not defined nor documented in the project documentation. Using a tool such as Relatics or Vise is not used in every project. However, it is indicated to be beneficial.

2. A reactive management style is applied to manage scope change.
   This in combination with the long lead time of the formal procedure is perceived as a bottleneck to the scope management process. Project team members use verbal agreements to overcome the long lead time but this again results in a bottleneck if it is not documented in a later stage.

3. Other, project specific bottlenecks are identified.
   Project specific information is needed to overcome these. Two bottlenecks were identified in all of the studied cases and therefore presented here:
   3.1. Loss of information between the steps;
   3.2. The stakeholders are not involved throughout the complete project.

These bottlenecks are perceived as negative by the professionals when executing scope management steps. This means there are possibilities for improvement of the scope management process.

5.

Lessons learned

The literature study and empirical research provided insight in the process of scope management and the bottlenecks hampering this process. This section elaborates on the results of the empirical research reflected upon the reviewed literature.

The findings from comparing the literature study and empirical research are categorized in the four topics defined as the basis for the case study in the previous section;

1. The overall scope management process
2. Roles and responsibilities
3. In-depth analysis of process steps
4. Reactive versus proactive scope change management

Each topic is analyzed using the same method, with the aim to derive lessons learned. First, the findings from literature are presented. Second, the empirical research results are examined. And last, the lessons learned are derived from the analysis of those literature and empirical findings.

The lessons learned resulting from this integration of theory and practice form the basis for section 6, in which an implementation guide is developed for improving scope management.

1. Scope management process

In the theoretical research presented in section 2, scope management process described in PMBOK guide *(2013)* is determined to be most comprehensive. This guide distinguishes five steps; 1. collecting requirements, 2. definition of scope, 3. create WBS, 4. verify scope and 5. scope control. This research is built on this process.

The empirical research pointed out that in addition to the five steps described in the PMBOK guide two differences are observed. First, creating a System Breakdown Structure (SBS) is also part of the scope management process. Second, verification and validation are two separate steps in practice, while PMBOK only describes verification. This brings the total in practice to seven steps.

A system breakdown structure is a decomposition of the main system in subsystems with the aim to gain insight in large amount of information. It is hereby important to consider what way the systems are designed, what the systems do and how critical interfaces of the system should be managed *(Rich, 2015)*. The SBS is based on the functional requirements retrieved from the first step of scope management; collecting requirements. The ouput of the SBS is a list of elements and tasks necessary to accomplish the objectives of a project *(IEEE, 2005)*. The way these tasks are executed and divided into work packages is defined in the Work Breakdown Structure (WBS). This way, the SBS provides input for the WBS.

The first lesson learned defined is that the scope management consist of 7 steps instead of 5.

The scope management steps defined in literature by PMBOK *(2013)* do not comply with the scope management steps executed in practice. The difference in steps is presented in Table 16. The PMBOK guide is therefore not completely applicable to practical projects. This research adds value with defining those differences and proposing a more adequate scope management implementation guide.

Table 16 Comparison scope management steps PMBOK and practice

Scope management steps	Theory (PMBOK)	Practice (based on case studies)
Collect requirements	V	V
Define scope	V	V
Create SBS	X	V
Create WBS	V	V
Verify scope	V	V
Validate scope	X	V
Control scope	V	V

2. Responsibilities

In theoretical research it is stated that a way to ensure responsibility is in the right hands can be achieved by responsibility charting (*Cabanillas, Resinas, & Ruiz-Cortés, 2011)*. The RACI chart can be used to assign roles to actors within the project and give them a certain amount of responsibility. Four type of roles are defined in the RACI chart; responsible, accountable, consulted, and informed.

Scope management requires a designated responsible actor and Dekkers & Pekka *(2008)* introduced an experienced project manager to fulfill this role. It is however not defined whether this project manager is an employee from the clients or the contractors side.

The empirical research results revealed that in contrast to the theory, in practice a clear division of responsibilities is present, but it is not always clearly documented. Table 17 demonstrates the responsible actor in each of the scope management steps as derived in the empirical research.

In relation to scope control both the client and the contractor are involved, because they have a shared responsibility in monitoring the scope and brining up scope change if necessary. When scope changes occur, the client is responsible for safeguarding that the goal of the project is reached. The contractor is responsible for execution of the required activities as a result of scope change.

Table 17 Responsibility charting scope management steps

Scope management steps	Responsible actor defined in practice
Collect requirements	Client
Define scope	Client
Create SBS	Client
Create WBS	Contractor
Verify scope	Client
Validate scope	Contractor
Control scope	Client & Contractor

The second lesson learned is that the responsibility of actors should be defined and documented.

The many roles involved in the process causes information loss between the steps. The RACI chart proposed in section 3 can be used to assign this responsibility to the actors in the scope management process. Applying this chart brings clarity in the responsibility structure for all actors. In addition, using the RACI chart improves the transition between the process steps by creating insight in which information is in the hands of which actor.

Table 18 gives an example of a RACI chart for scope management. In which: 'A' defines the accountable actor, 'R' defines the responsible actor, 'C' defines the consulted actor, and 'I' means the informed actor. This RACI chart shows the scope management steps and responsibilities of three actors: the client, the contractor, and the stakeholders. It should be noted that a RACI chart should be created for each of the scope management steps in detail, including the tasks that need to be executed and the roles within the project teams that play a role. For example, in the step collecting requirements, the project manager of the client is accountable for ensuring the requirements of the stakeholders are collected. A systems engineer can be assigned the responsibility for keeping an overview of the requirements and ensuring there is an up-to-date list available.

Last, it should be noted that in each project, a group of important stakeholder should be involved. However, in each project the group of stakeholders differ and therefore no specific actors are indicated in this chart.

Table 18 RACI chart applied to scope management

RACI Chart Scope Management	*Actor*	
Activity	Client	Contractor
Collect requirements	A/R	
Define scope	A/R	C
Create SBS	A/R	I
Create WBS	I	A/R
Verify scope	I	A/R
Validate scope	A/R	I
Control scope	A/R	R

3. In-depth analysis of process steps

In the theoretical research 5 scope management steps were described, while in practice seven steps are executed. Besides the finding that in literature 2 steps are missing to describe practice completely, bottlenecks are identified in each of the scope management steps. The steps are described here in Table 19 to Table 25, by presenting:

1. The explanation of the step in literature;

2. The bottlenecks experienced in practice;

3. The lessons learned derived from integrating the literature findings with the bottlenecks. These lessons learned serve as guidelines to prevent bottlenecks currently present in projects from occurring again. These lessons are defined as strategic activities that need to be executed in each of the scope management process steps. The lessons learned presented here are part of the input for the design of the implementation guide, presented in section 6.

Table 19 Analysis step 1 collect requirements

STEP 1 COLLECT REQUIREMENTS	
Literature findings - A project is initiated by aligning business need with company objectives - Feasibility is tested along with gathering the requirements - The stakeholder overview is created	*Bottlenecks experienced in practice* - The stakeholders are informed instead of involved - Responsible actor for scope management not assigned or documented in the project documents
Lessons learned	
• Organizing workshops and interview with the stakeholders will ensure thorough stakeholder involvement, and improve the collection of requirements. • A first identification of scope management steps will create a solid basis for the next step. • In case of large projects, it should be decided whether a specific scope manager is needed.	

Table 20 Analysis step 2 define scope

STEP 2 DEFINE SCOPE	
Literature findings - Defining scope is an iterative process - Tools can be used such as Project Definition Rating Index tool - Requirements are collected in the requirement specification	*Bottlenecks experienced in practice* - Scope management tasks associated with scope are not documented - It is not always possible for the contractor to execute the scope as defined by the client - Project team members are not familiar with the focus on processes instead of the output
Lessons learned	
• Scope should be documented in a comprehensive way and it should be accessible to everyone within the project team. • Scope management tasks need to be defined within the project management plan. • It is required to distinguish processes and the exact content of activities within the scope and explain this to the project team members. • If possible, the contractor should be asked for input to ensure a design can be created that fits within the defined requirements and which is possible to execute.	

Table 21 Analysis step 3 create SBS

STEP 3 CREATE SBS	
Literature findings - Not defined in PMBOK - By other researchers defined as 'a logical decomposition of the system in subsystems with the aim to gain insight in large amount of information. One should consider how the systems are designed, what the systems do and how critical interfaces of the system should be managed' *(Rich, 2015)*	*Bottlenecks experienced in practice* - The contractor is not involved - Information gets lost between step 3 and step 4 since different project teams are working on it, from different organizations
Lessons learned	
• There should be no difference between the scope definition output and the SBS input. Awareness about possible information loss between the steps is therefore important. • Since the SBS provides input for the WBS, it should be documented comprehensible and self-explaining. • If possible, the contractor must be involved when dividing the system in subsystems and defining critical interfaces and elements.	

Table 22 Analysis step 4 create WBS

STEP 4 CREATE WBS	
Literature findings - WBS follows from the scope definition - Deliverable-oriented overview of activities to be executed to reach project objective - Work packages are created that are easier to manage and execute - Within work packages activities, objects, requirements and risks are described	*Bottlenecks experienced in practice* - The WBS is not connected to roles and responsibilities are not assigned to actors within the project - A contract manager is not assigned in every project, but always needed - Information gets lost when translating the SBS into the WBS since different project teams are working on it, from different organizations
Lessons learned	
• Organizing regular meetings between the client and the contractor is required to ensure the SBS is translated properly into the WBS. • It is required to connect the WBS to roles and assign responsibility, to increase mutual understanding of project team members. This can be done using the RACI chart, in which different actors can be assigned different roles. An example is presented in Table 18, explained previously in this section.	

Table 23 Analysis step 5 verify scope

STEP 5 VERIFY SCOPE	
Literature findings	*Bottlenecks experienced in practice*
- Continuous feedback loop provides verification of all work compared to the regulations and design documents - It is checked whether the requirement specification matches the work performed by the contractor - The outcome of verifying scope can be a change request - Project documents should be updated after verification	- No clear agreements between the client and the contractor concerning how to verify that the activities comply with what is stated in the contract - Verification does not take place on a regular basis
Lessons learned	
• The contractor needs to define how each activity will be verified during execution in a document prior to execution. • Regular verification meetings between the client and the contractor will ensure that both actors are up to date about the state of the verification.	

Table 24 Analysis step 6 validate scope

STEP 6 VALIDATE SCOPE	
Literature findings	*Bottlenecks experienced in practice*
- Not defined explicitly by PMBOK but incorporated in the step 'verify scope'	- The stakeholders are not involved in validating the projects deliverables - The client is not completely informed about the state of verification of the contractor's activities which provides the input for validation
Lessons learned	
• Regular meetings between the client and the contractor must be organized in order to be fully aware whether the executed activities of the contractor are in accordance with the requirements • By combining information concerning the verified activities with thorough stakeholder involvement, the client is able to decide whether the project's result meets the intended goal.	

Table 25 Analysis step 7 control scope

STEP 7 CONTROL SCOPE	
Literature findings - Control scope consists of monitoring the scope and keeping it between boundaries, and handling possible scope change - As a result of monitoring the scope, it may be needed to change the scope - In case of scope change a management system should be in place that includes identifying, analyzing, implementing and learning from changes - There should be a change control board, a good understanding of roles and good communication about change - Risk management should be linked to scope change management - Dutch infrastructure projects mostly use the guidelines from the UAV-GC, which is a precise procedure	*Bottlenecks experienced in practice* - The scope state is not always tracked in a tool which makes monitoring difficult - Scope change causes discussion between the client and the contractor - Lead time of the formal scope change procedure is long - A reactive scope change management style is applied - Scope change does not come with extra capacity which makes processing scope change difficult
Lessons learned	
• To monitor scope properly, the scope state should be tracked preferably in a tool. In case changes do arise, these should be documented in this tool as well. For example Relatics or Vise. • Project team members should be aware of the long lead time of the formal scope change procedure. Verbal agreements can speed up the process, but they should only be used in crisis situations. To ensure the agreement is enforceable, a documented version of the agreement is required, but can be made afterwards. For verbal agreements a high level of trust between the client and the contractor is needed. • The contractor is advised to calculate and present risks of scope change to the client to prevent discussion.	

4. Reactive versus proactive scope change management

Aside from the lessons learned described in step 7, specific findings concerning reactive versus proactive scope change management are presented here, because it was derived from the quick scan and case studies as a matter that requires attention.

Literature defines reactive management as a management style in which a manager takes action after a situation occurs. In case of scope change there is a lengthy procedure that should be followed precisely. Fast decision-making is therefore difficult. Reactive management is characterized by managers trying to avoid changes instead of predicting and expecting them *(Lee & Ryu, 2013).*

It is described in the theoretical research that the opposite of reactive management is proactive management which requires the ability to think in patterns. Future problems can be prevented by analyzing previous ones. In proactive scope management the cause of changes are researched *(Reh, 2017*). By predicting and analyzing external threats, project team members can change a possible scope change into an opportunity or prevent changes from happening *(Lee & Ryu, 2013).*

Empirical research pointed out that overall, a reactive management style is used to manage scope change. However, this management style is difficult since the formal procedure for scope change is characterized by a long lead time. Since patterns are not predicted, project team members cannot anticipate scope change and the long lead time of the procedure will never be reduced.

The long lead time of the scope change procedure is seen as a bottleneck, for the reason that it requires more budget and a change of planning. Another bottleneck is project managers that are unfamiliar with tools that help predicting patterns of scope change. Using a tool such as Relatics or Vise, an impact analysis and a better documentation of evaluations of previous projects could improve the application of proactive management.

The last lesson learned is that proactive scope management must be applied.

In the last process step 'control scope', a proactive instead of reactive management style should be applied. As stated in the literature, control scope consists of two processes: monitoring the scope and applying scope change procedures, in case the scope changes. A proactive management style must be used to predict patterns in the lessons learned from previous projects. Hereby, scope change is prevented using proactive management. Applying proactive management in the scope change procedure speeds up the formal scope change process, because using patterns in previous scope changes helps identifying scope change in an earlier stage.

Conclusion lessons learned

Only applying the theory from PMBOK is inadequate in practice since:

1. Only 5 steps are defined and in practice 7 steps need to be executed;
2. In PMBOK the steps are not linked to the roles and responsibilities;
3. Bottlenecks are hampering the process:
    - Information is lost between the process steps since different project teams work on different steps and the communication between the teams is not clear;
    - The described procedure for scope change are lengthy and time consuming;
    - There is not enough focus on the stakeholders which makes identifying ánd safeguarding requirements difficult.

Consequently, it is concluded that applying only the theory from PMBOK creates unclarity about the steps and the roles and responsibilities linked to the steps. In addition, bottlenecks are still present. The lessons learned presented in this section bring clarity concerning these topics to overcome the bottlenecks.

6.

The scope management implementation guide

Section 5 presented the analysis of empirical findings reflected upon the literature study. It was concluded that the scope management guide from PMBOK *(2013)* is not fully applicable in practice because it describes only 5 steps instead of 7. Moreover, the analysis performed in section 5 revealed that awareness is required concerning the responsibilities assigned to the client and the contractor in each of the scope management steps. Bottlenecks are occurring and guidelines to overcome the variety of bottlenecks are missing. This guideline is provided in this section by presenting the aim and visualization of the scope management implementation guide.

Aim of the scope management implementation guide
The aim of the guide is to create awareness of the scope management steps and to bring clarity in the responsibility structure. Using this guide provides insight in the possible bottlenecks and the means to prevent them from happening. The guide is meant to provide information for professionals from PACER, professionals who work for either the client or the contractor, and the guide is therefore developed taking the client and the contractor into account.

Visualization: the flow chart and explanation of the steps
The guide presented in Figure 9 encompasses a flow chart including the overview of process steps, responsible actor and deliverables. The lessons learned that were identified in the previous section form the input for the implementation guide. The lessons learned are partly based on the theory from PMBOK *(2013)*, it is therefore stated that this guide is an extension of the PMBOK Guide. The operationalized lessons learned are validated by two experts, to conclude if they are correct and useful in real-life practice. These experts have more than 10 years of experience in the field of scope management. Each expert is interviewed separately which reduces the chance that they are influenced by each other (in appendix J the first design of the implementation guide along with the validation is presented).

The flow chart presents an overview of the seven scope management steps, the responsible actor and deliverable of each step. The explanation of each step is provided in this section, to ensure they are executed the right way. To apply good scope management all the seven steps presented in the flow chart must be completed.

Step 1 to 6 need to be executed in sequentially: in the ideal situation, collected requirements are input for the scope definition, the scope definition is input for the SBS and the SBS is the starting point for the WBS. The work packages form the basis for the executed activities. After execution of these activities, they are verified by the contractor, and later validated by the client. The seventh step ‘control scope’ hovers over the other process steps because monitoring of the scope is performed throughout the complete project and scope changes are brought up at every moment in time.

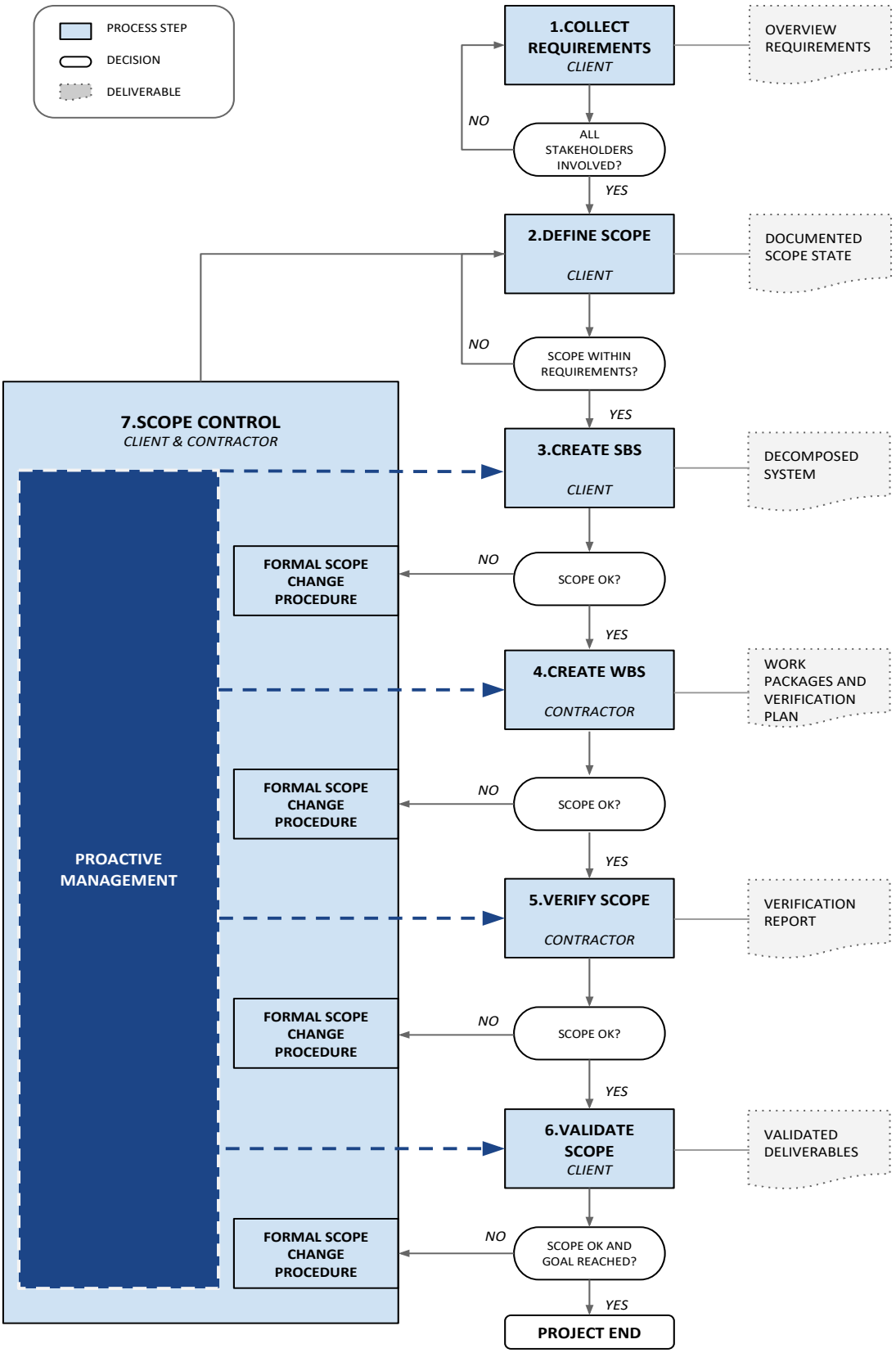


Figure 9 Scope management implementation guide – the flow chart

Table 26 Scope management implementation guide step 1

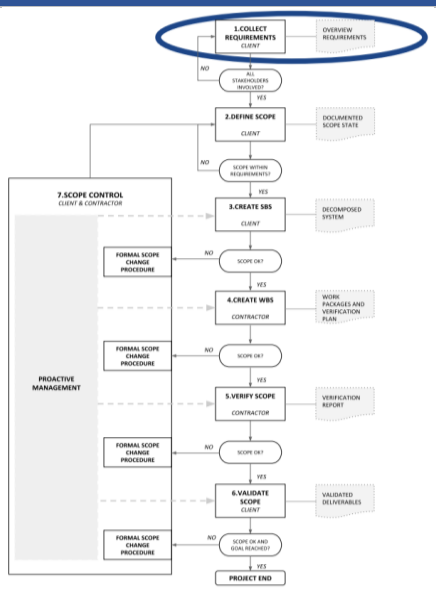
STEP 1 COLLECT REQUIREMENTS - CLIENT		
Actor responsible	Client	
Explanation	To properly define the objective and scope of the project, the requirements of the stakeholders must be collected. This is done by the client. According to the complexity and size of the project, it needs to be determined whether a scope manager need to be assigned. Thorough stakeholder involvement is required for a good scope management process, so it is ensured that all important stakeholders are identified and their requirements are gathered.	
Tools & Techniques	Interviews, focus groups, and workshops. Tools; Relatics or Vise.	
Output	An overview of requirements, preferably in a tool that is accessible for everyone in the client's project team. At the end of this process step it is checked whether all the stakeholders are involved. If not, they are taken into account and the list of requirements is extended.	

Table 27 Scope management implementation guide step 2

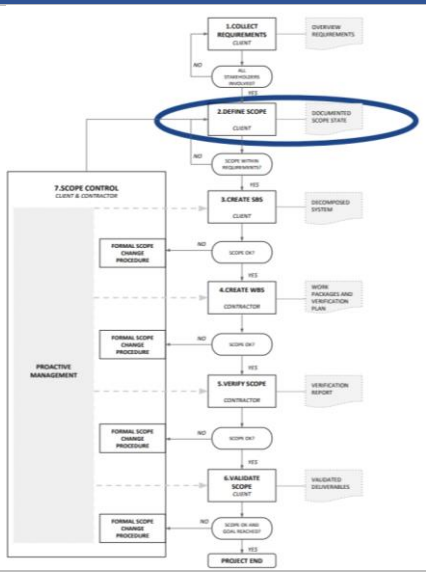
STEP 2 DEFINE SCOPE - CLIENT		
Actor responsible	Client	
Explanation	To ensure it is possible to monitor the scope during the project, documenting scope in a highly accessible format for the complete project team is important. Functional requirements, process descriptions and scope management steps are described. If possible, it is advised to ask the contractor for input to ensure the execution of activities and achieving the project goal is feasible.	
Tools & Techniques	Expert judgement, product analysis, and facilitated workshops.	
Output	A written version of the scope of the project called the project scope statement and an overview of the scope management steps. At the end of this step, a check whether the scope lies within the defined requirements is performed. If not, the scope definition step cannot be finished. It is highly important that the scope state is available for the project team members in order to monitor the scope as part of step 7, control scope.	

Table 28 Scope management implementation guide step 3

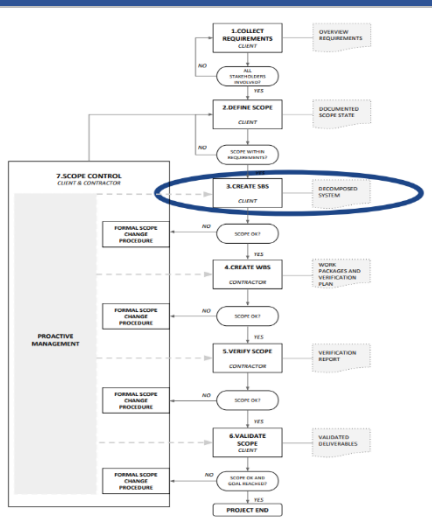
STEP 3 CREATE SBS – CLIENT		
Actor responsible	Client	
Explanation	The main system is decomposed, based on the information stated in the project scope statement. Each subsystem including the goal and elements, are visually represented. If possible involve the contractor to help with defining the elements part of each subsystem. The client must be highly alert to the fact that after this step the responsibility for the next step shifts to the contractor, and information gets lost between the steps	
Tools & Techniques	Visio or Google Draw.	
Output	A visual representation of the decomposed system along with a clear explanation forms the input for the WBS. Besides transferring the document to the contractor, a meeting is recommended to explain the SBS.	

Table 29 Scope management implementation guide step 4

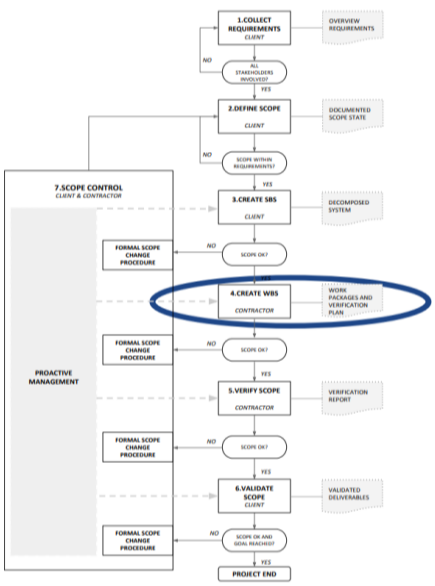
STEP 4 CREATE WBS – CONTRACTOR		
Actor responsible	Contractor	
Explanation	The WBS is created, based on the SBS defined by the client. Within each of the subsystems, work packages are defined. Since every actor has its own interpretation, it is important to have meetings with the client to discuss the right interpretation of the SBS. The work packages need to be linked to roles within the project team, and responsibilities are assigned. It is advised to do this using a responsibility charting method such as the RACI chart. Elements that might change with a large financial risk must be identified and documented.	
Tools & Techniques	Visio or Google Draw, and a RACI chart.	
Output	An overview of the work packages with all the executed activities, linked to the roles in the project team. Also, a list with elements that might change and have a large risk is preferable the ouput of this step. The activities presented in the WBS are executed and verified as explained in step 5.	

Table 30 Scope management implementation guide step 5

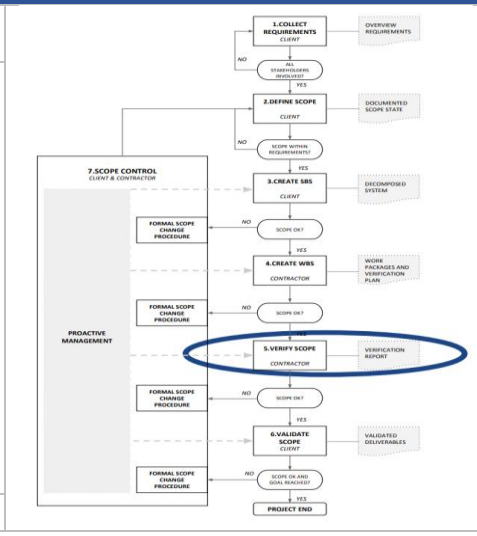
STEP 5 VERIFY SCOPE		
Actor responsible	Contractor	
Explanation	Before execution, the contractor describes the verification process of each activity. During regular meetings with the client, it should be checked whether the requirements are met by performing the activities. The contractor must be highly alert to the fact that after this step the responsibility for the next step shifts to the client, between the steps information gets lost.	
Tools & Techniques	Inspection of activities, a checklist.	
Output	In case the executed activities are verified to be executed the right way, they are assigned to a list with verified deliverables. The client must use this list to check during the validation whether the end result and the desires of the stakeholders are reached. Be careful with the information transfer, possibly information gets lost. Besides transferring the verification documents, it is recommended with both actors to prevent misinterpretation.	

Table 31 Scope management implementation guide step 6

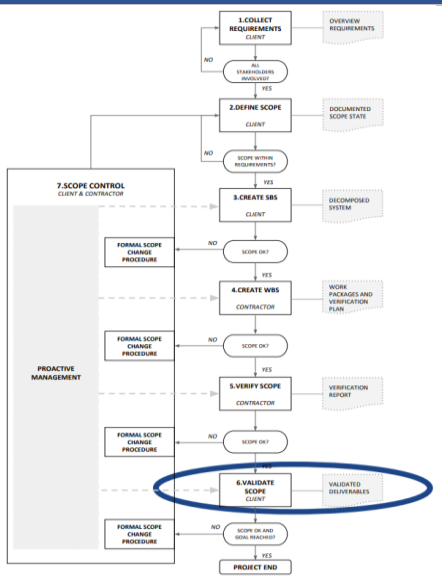
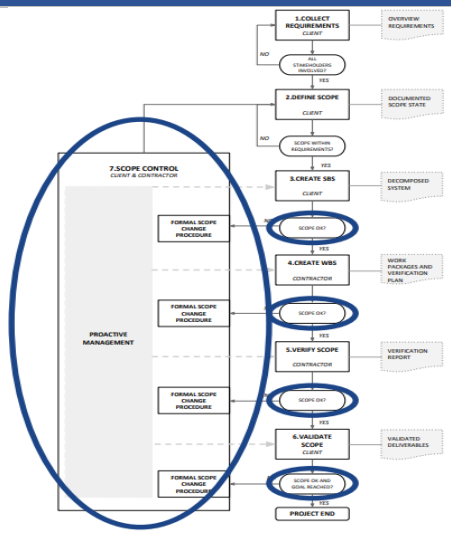
STEP 6 VALIDATE SCOPE - CLIENT		
Actor responsible	Client	
Explanation	The client is responsible for ensuring the end result of the project is as promised to the stakeholders, and fulfills the function as defined in the requirement specification. This is done by regular checks. It is important to check during execution if the requirements are up to date and still feasible.	
Tools & Techniques	Stakeholder meetings.	
Output	A list with validated deliverables is presented to the stakeholders at the end of this step. The validation step is finished at the end of the project.	

Table 32 Scope management implementation guide step 7

STEP 6 CONTROL SCOPE – CLIENT & CONTRACTOR		
Actor responsible	Client & Contractor	
Explanation	Project managers from both the client's and the contractor's side tend to keep the scope within the boundaries by monitoring the scope. As presented in the flow chart, it is checked by both the client and the contractor whether the project activities are still within the defined scope after step 3, 4, 5 and 6. If not, this leads to a scope change and the formal procedure is started.	
	It is advised to apply proactive management in projects which means that possible bottlenecks and scope changes are predicted, and anticipated on. This implies that the lessons learned from previous projects need to be captured. For example this focuses on when most changes can be expected of specific bottlenecks experienced in one scope management step every time. It is found in this research that the interpretation of the system breakdown structure is sometimes misunderstood, which is noticed when the work packages are created by the contractor. In the beginning of step 3, the project team members of the client must be warned for this, which decreases the negative impact this misinterpretation brings. Also, when project team members do not understand the importance of using a tool to track the scope, it is very difficult to monitor the scope in a later stage. Therefore, it needs to be stipulated that the scope state needs to be up-to-date and available to everyone in the project team. All the lessons learned from similar, previous projects need to be linked to the scope management steps. In case it is not possible to continue executing the activities within the defined scope, a scope change needs to be processed. Both actors identify and announce changes, and they both have a role in processing them. The client is responsible for the budget decisions, and the contractor is responsible to ensure the activities are adjusted to the new scope. A scope change follows the formal scope change procedure as described in the UAV-GC. When a scope change is handled, the scope definition is reviewed, as presented in the flowchart. Project team members must be aware of the long lead time of the formal scope change procedure. In case of crisis situations it is possible to speed up the process by using verbal agreements with the aim to reach fast consensus. However, it is highly important that in the end, the verbal agreements are documented to make them enforceable.	
Tools & Techniques	Relatics or Vise.	
Output	- An overview with the project experiences at the end of the project. - In case of a scope change, a renewed version of the scope state.	

Conclusion scope management implementation guide

The scope management implementation guide presents the lessons learned retrieved from the integration of theory and practice. The guide describes the seven steps, instead of the 5 presented by PMBOK, so two steps are added to this theory.

From the flow chart it is concluded that proactive management is essential. Without proactive management, proper monitoring of the scope is impossible.

The guide is a tool to execute the scope management process in a more organized way. Therefore, using this guide provides a mean to overcome the bottlenecks leading to an improved scope management process.

7.

Discussion, conclusion and recommendations

This research was performed with the aim to improve scope management by identifying the bottlenecks hampering this process. In this section, the results of the performed research are discussed and the limitations are summed up. It is concluded how to improve the scope management process and last, the recommendations for the company PACER and implications for future research are presented.

7.1. Discussion

Several findings of this research are discussed here, followed by the limitations of this research.

i. Reactive scope change management

According to the reviewed literature a reactive management style is defined by fast-decision making in case of crisis situations. When looking at the practical findings, it is indicated that this is indeed true. For example if the safety of the tunnel users is at stake, the formal procedure is skipped partly or accelerated by using verbal agreements.

However, using verbal agreements brings up an interesting discussion, because verbal agreements itself can be a bottleneck. Unclear communication already is a bottleneck that causes information loss between process steps. Verbal agreements are difficult to enforce in case of discussions and when different project teams are working on the project, verbal agreements certainly do not reduce the chance to lose information. Consequently, these agreements are considered as a threat to clear communication.

To conclude, verbal agreements can be used if they are used within a set of boundary conditions. It is possible to use them in crisis situations where a fast decision-making process is required. The agreements must always be translated in a written version to ensure the agreements are enforceable and clear communication is achieved. Using verbal agreements hereby increase the speed of the scope change process in crisis situation and, at the same time, not result in the bottlenecks 'loss of information' or 'unclear communication'. Applying the scope management implementation guide contributes to reducing these bottlenecks.

ii. Proactive management

This research stipulates the desire for proactive management. Not only to predict patterns and reduce scope change, but also to lower the amount of occurring bottlenecks. However, for this proactive management style no means are provided in practice yet. It is advised to use a tool to document lessons learned in projects. These documented lessons are input for predicting patterns which improves future projects. By linking scope change to risks and identifying them at an early stage, using the experiences gained from previous projects**,** proactive scope change management can be applied. In the reviewed literature it is already described that control systems must be used to learn from changes. Hence, using the current existing literature would already improve proactive management.

iii. Demarcation of the research

As described in section 1, this research focused on Dutch infrastructure projects using the UAV-GC contract. The results therefore hold for this type of projects. However, the implementation guide is applicable to construction projects as well, where the UAV-GC is used since 2006 and mainly the same project phases are present. Since the implementation guide is based on PMBOK, which is an international project management approach, most likely the guide is also useful for projects executed in other countries, not using the UAV-GC contract form. The following elements need then be taken into account;

- The responsible actor of each process step might be different if a less integrated contract form is used.
- The scope change procedure described in UAV-GC is lengthy, which was the basis for the advice to proactively manage scope change. This is not immediately the case for projects in other countries.

So, in order to use the implementation guide for projects in countries not using the UAV-GC contract form, the first six steps are described adequately. However, the responsible actor of each step, and the scope change procedure applied in step 7 of the implementation guide must be researched first.

Limitations of this research

- Throughout the whole research the focus has been laid on projects with two actors; one contractor and the client. It is not taken into account what happens if several sub-contractors work together to produce the outcome of the project. The responsibility structure could be different if more than two actors are involved in the research.

- Due to the time constraint of the research, two projects are studied from the contractor's point of view, and one from the client's point of view. No projects are studied interviewing both the client and the contractor.

- It is not researched whether applying this guide would contribute to the projects progress or keeping projects within budget. Therefore, it is advised to use this guide, but the added value can only be argued by qualitative findings, not quantitative results.

- It was not examined for what reason existing scope management literature is not incorporated in scope management practices. PMBOK describes the process partly, but is not used by professionals directly. Also other literature such as the advice to link scope change management to risk management is not applied in practice. The reviewed literature is used as a basis to identify the difference in practice and set up the implementation guide. However, research into what is needed to ensure project team members use this implementation guide is lacking.

7.2. Main conclusion: answers to the research questions

The objective of this research was to improve the scope management process by identifying the bottlenecks that hamper this process and providing solutions for these bottlenecks. Following from this objective, the main research question was formulated;

How can the execution of the scope management process in Dutch infrastructure projects be improved?

In this section, first the answers to the sub research questions are provided. Finally, based on the research results and answers to the sub research question, the answer to the main research question is presented.

1. What are the steps in the scope management process based on literature?

Given the reviewed literature, the PMBOK guide was argued to be an adequate guideline to describe scope management process steps. Based on this guideline, five steps are defined:

1. Collect requirements
2. Define scope
3. Create Work Breakdown Structure (WBS)
4. Verify scope
5. Control scope

2. How are the scope management process steps executed in practice?

In practice seven scope management steps are performed when managing scope:

1. Collect requirements
2. Define scope
3. Create System Breakdown Structure (SBS)
4. Create Work Breakdown Structure (WBS)
5. Verify scope
6. Validate scope
7. Control scope

In comparison with the PMBOK guide steps 3 and 6 form an addition. Create SBS means that the system is decomposed in subsystems. Elements within the subsystems are defined, which serve as input for the WBS. In practice this step is explicitly mentioned since the responsible actor for SBS is different from the WBS.

Since different actors are performing verification and validation, these steps in practice are separated. During verification, the contractor is responsible for executing the activities as agreed upon with the client. During validation, the client is responsible for checking whether the end result of the project meets the requirements as set in the beginning.

3. What are the experienced bottlenecks in the scope management process steps in practice?

Based on the exploratory interviews and the case studies several bottlenecks are identified classified in two categories;

i. Roles & responsibilities
- Lacking clarity about the responsible actor for each step in the scope management process
- No common understanding of the roles since they are not defined
- The roles within the project team are not linked to the WBS
- The contractor is responsible for creating the design on paper, but in real life the client still designs what must be constructed
- The role of a contract manager is missing in projects
- In larger projects in terms of the scope, a general scope manager is missing

ii. Reactive scope change management
- The lead time of the formal scope change procedure is too long
- Expectations concerning scope change are not identified and managed correctly
- There is a lot of discussion about the budget and schedule concerning scope change
- There is no system for keeping track of changes to seek for patterns in these changes

Besides these two categories, other bottlenecks were identified as shown in Table 33. Some of the bottlenecks are project specific, but two bottlenecks are identified in every researched project, which are presented in bold in Table 33.

Table 33 Identified bottlenecks during this research

Identified bottlenecks
Information is lost between the process steps
Decision-making within the steps takes too much time
There is a lack of information due to different composition of the team in project phases
Knowledge shared among project team members of different project teams is not correctly documented
Stakeholder involvement is not done thoroughly in the beginning of the project
The stakeholders are not involved throughout the complete process
Team members do not see the importance of a tool to track scope state
There is no overview of possible risks that can result in scope change
Not everyone in the project team agrees with the process approach

4. Which lessons can be learned in each of the scope management process steps?

Comparing empirical and literature findings led to the following lessons learned:

1. Collect requirements

Thorough stakeholder identification and involvement is required to ensure all necessary requirements are gathered. In this first step the scope management steps and roles associated with it must be defined. This is highly important to create the basis for the scope management process. In case of large projects, it is required to decide whether assigning a functionary responsible for scope management is beneficial.

2. *Define scope*

The scope state provides the basis for monitoring the scope throughout the project. Therefore, the scope state needs to be well documented and accessible to everyone in the project team. When the project management plan is created, the scope management steps as identified in the first step must be defined and documented. If possible, it is advised to ask the contractor for input to provide a realistic set of scope management steps in the project management plan.

3. *Create SBS*

While decomposing the main system in subsystems, it is key that the client realizes this is the input for the WBS made by the contractor. The SBS must therefore be self-explaining. However, the potential information loss needs to be taken into account since different actors are creating it.

4. *Create WBS*

Before project start-up it is advised to organize joint meetings with the client and the contractor to prevent misinterpretation of the SBS. At the contractor's side, the roles within the scope management steps must be defined. An important role is the role of a contract manager. These roles need to be linked to the work packages created in this step.

Aside from the meetings concerning the transfer of the SBS, meetings must be organized concerning the verification of activities throughout the project. The contractor needs to link the activities resulting from the work packages to a set of verification plans. This plan is discussed with the client to prevent misunderstanding. Last, it is recommended to identify elements part of the WBS which are likely to change and have a large risk during the project.

5. *Verify scope*

The verification plan created alongside the WBS is executed. When verifying whether the execution lives up to the agreements between the client and the contractor, it is recommended to the contractor to communicate regularly with the client to discuss the verification reports. The results of these discussions are input for the verification reports made during the continuance of the project.

6. *Validate scope*

The verified activities from the contractors side serve as input for the client to check whether the end result of the deliverables are in accordance with the initial goal and the stakeholders wishes. Organizing regular meetings with the stakeholders is advised to ensure that the requirements are up to date and to keep the stakeholders satisfied.

7. *Control scope*

This step hovers over the project in almost each phase of the project. It is two-sided; monitoring the scope with the aim to prevent scope change from happening and handling scope change in case it does happen. Monitoring the scope is based on the scope state as created in step 2. It is advised to apply a proactive management style to prevent bottlenecks and scope change from happening, by predicting patterns in previous projects. In case scope change does happen, the formal procedure is followed, which is subject to a long lead time. In case of crisis situations, verbal agreements can be used to speed up the process. Nonetheless, a written version of the agreement is always required in the end.

In case scope change is expected or happens, the capacity of employees needs to be checked along with the risk the scope change brings. The scope changes must be documented, including their cause and impact in order to serve as input for seeking patterns or future projects to make proactive management possible.

Based on the results of this research and the answers to the sub research questions, the main research question is now answered:

How can the execution of the scope management process in Dutch infrastructure projects be improved?

The scope management process is improved by executing 7 scope management steps and by assigning the responsible actor for each of these steps. In addition, the process is improved by being aware of the bottlenecks hampering the scope management process and by applying proactive management. Finally, scope management is improved by using the scope management implementation guide, which is the mean to overcome the bottlenecks hampering the scope management process.

1. *Scope management steps*

The defined scope management steps in literature are not fully adequate to describe the situation in practice. In practice, seven scope management steps are executed instead of the 5 steps defined in literature. Two steps are missing in PMBOK; "create System Breakdown Structure (SBS)" and "validate scope". The client is responsible for executing these two steps:

i. By creating the SBS, the system is decomposed into subsystems with the aim to gain insight in large amount of information. It is hereby important to consider how the systems are designed, what the systems do and how critical interfaces of the system must be managed.

ii. Regular checks are important to track whether the requirements are in accordance with the project output. It is at the end validated whether the result of the project is as promised to the stakeholders and fulfills the required functions.

2. *Actors responsible for the scope management steps*

The client and the contractor are both partly responsible for the scope management process. The responsible actor of each scope management step is provided in Table 34.

Table 34 Responsibility charting scope management steps

Scope management steps	Responsible actor defined in practice
Collect requirements	Client
Define scope	Client
Create SBS	Client
Create WBS	Contractor
Verify scope	Client
Validate scope	Contractor
Control scope	Client & Contractor

3. *Bottlenecks hampering the scope management process*

Bottlenecks are frustrating the proper execution of the 7 steps of scope management. Awareness of these bottlenecks is needed in order to overcome them.

- Many roles and responsibilities are needed to execute the scope management steps but are not defined or documented. By using a way of responsibility charting such as the RACI chart, this is improved.

- Scope change is managed reactively which in combination with the lengthy scope change procedure described in the UAV-GC is time consuming. By applying proactive management, scope changes and bottlenecks are predicted, which partly prevents them from happening. This way, scope is monitored more adequate and this speeds up the scope change process.

- Other bottlenecks are present of which the following two are perceived as highly important and are present in the three studied cases:

    a. The stakeholders are not involved throughout the complete project. They must be included in the RACI chart. During regular meetings with the stakeholders, the client can assure that the requirements are up-to-date.

    b. Information is lost between the process steps due to bad communication and different project teams working on different steps of scope management. By regular meetings between the client and the contractor and a documentation of those meetings, means are provided to decrease the amount of lost information.

4. Applying proactive management

It is advised to apply a proactive management style to prevent bottlenecks and scope change from happening. Proactive management means that experiences from projects are documented, with the aim to improve future projects. Not only when managing scope change, but especially in monitoring scope, this is necessary. In each of the process steps these lessons serve the aim to predict patterns in possible bottlenecks and scope changes. By creating an overview of these past experiences and applying those in current projects, scope is managed proactively.

5. Applying the scope management implementation guide

The scope management implementation guide is developed to provide the practical mean to improve scope management. It is not argued that the PMBOK is totally inapplicable. Therefore, the tools and basis of PMBOK are useful, but an addition is needed to overcome the bottlenecks. This addition is provided in the scope management implementation guide. This guide gives an overview of the steps that need to be executed, the roles linked to it and the deliverable of each step. Aside from this visualization, an explanation of each scope management step is provided, which helps overcoming the bottlenecks currently present in projects. This visualization integrates theory and practice, and provides the information missing in the PMBOK guide. By using the implementation guide in Dutch infrastructure projects, scope management is improved.

7.3. Recommendations

The conclusion and discussion of the performed research led to recommendations for the professionals from PACER and recommendations for future research.

Recommendations for professionals from PACER

Professionals from PACER are working in different disciplines and fulfill different roles. Scope management plays an important role in almost all of those roles, which makes the result of this research valuable to nearly all experts from PACER.

- Systems engineers contribute to scope management by managing the requirements during the project. These requirements flow through the scope management steps from collecting the requirements to validation.
- It is examined in this research that contract managers are essential when managing scope. The contract managers must use the implementation guide to ensure the steps are defined in the contract and the roles and responsibilities are linked to the steps.
- Since thorough stakeholder involvement is lacking in the current scope management steps, stakeholder managers are important actors in executing this task.
- Risk management is connected to managing scope change. In addition, risk management is essential in the steps 'collecting requirements' and 'definition scope'. Hence, the proposed implementation guide is valuable to risk managers because it gives insight in these steps.

During the quick scan interviews it was experienced that experts from PACER have substantial knowledge concerning the bottlenecks within the different steps of scope management. However, there is no documented overview presenting all these insights. The existing knowledge is now brought together in this implementation guide. In addition, this implementation guide is a new way of looking at scope management which provides PACER with new insights in scope management. Using this guide increases the added value of PACERs.

Professionals from PACER work independently for either the client or the contractor. The objective view these experts have, provides the perfect position to keep the overview of scope management and the performed steps. Using the implementation guide helps to keep this overview.

It is advised to emphasize on the need for regular communication and meetings with the other actors in the process: the client, the contractor or the stakeholders. This improves the communication and thereby prevents information loss between the process steps.

PACER professionals need to be aware that the implementation guide is not a perfect fit to every project. Generally, the roles and responsibility division between the client and the contractor is in accordance with the implementation guide and the sequence of the steps are as presented. However, there can be exceptions due to the fact that each project is specific, especially complex infrastructure projects, so the roles and responsibility division could differ. It is also possible in very short projects that some steps are skipped or merged. In such cases, the need for a good documentation of roles and responsibilities is even higher.

The list of bottlenecks and lessons learned must be extended using more projects. It is recommended to create an overview of lessons learned when performing scope management tasks, to extend the implementation guide with extra knowledge.

Recommendations for future research

i. Several interviewed experts emphasized on the need to assign a scope manager. A research into this manager, or the possibility to assign another combination of functionaries such as contract- and risk manager is recommended.

ii. During the validation of the implementation guide it is brought up that a separate implementation guide for the client and the contractor must be designed. Since this guide is mainly developed for professionals from PACER that work for both the client and the contractor, the aim is to create mutual understanding of the responsibilities and steps performed by both actors. The implementation guide could however be extended with a guide for the client and for the contractor, with more in-depth information of the steps.

iii. The implementation guide is developed for Dutch infrastructure projects. However, it was argued that this guide is applicable for the construction industry as well. This is not tested yet. A research into the applicability in this, and other industries is interesting in order to conclude which aspects are industry specific and which aspects are widely applicable.

iv. This research is of qualitative nature. If subsequent research only includes finished projects as cases for the case studies, it is possible to quantify the results. It could be researched whether the use of the implementation guide influences the projects result in terms of schedule or costs.

v. It is examined during the literature study that a control board must manage scope change. It is interesting to research who must be asked to join this control board. A first assumption is that an independent actor such as an advisor from PACER is a part of this board. A future research into this is beneficial for the possible introduction of control boards within projects.

8.

Personal reflection

When the search for a graduation topic started I was interested in researching success factors: why are projects successful? The funny thing is that eventually I researched the opposite: the bottlenecks hampering project success instead of helping them. However, when looking at it positively, overcoming bottlenecks is a success factor in a certain way, so somehow I still achieved my first goal.

Reflecting on the process of my graduation thesis it can only be said that the road was bumpy. The many ups and downs I experienced taught me a lot valuable lessons.

I had high expectations of the timeline of my thesis and I was disappointed when I needed to adapt this planning after the first green light meeting. In addition, it was difficult to wait for the approval of the case study interviews. Since three colleagues from PACER managed to schedule all the interviews before the end of December, this all worked out in the end. A lesson learned is to lower the expectations in future projects a little, and be aware of possible 'bottlenecks' in my own planning.

Writing this report was harder than I expected. Since writing a thesis has an iterative nature, I had to revise my own work several times. After the 10th time, it was hard to be critical. Also, I experienced the difference between writing papers for my master courses and this thesis as very difficult. A different way of concluding and linking findings to each other was not easy for me. And last, even though I am normally a 'good feedback receiver' I realized that when it concerns a project you work on fulltime for 7 months, sometimes it is difficult to 'kill your baby'. In the beginning of the thesis one of the committee members offered to help with the writing style of the thesis, but I didn't accept the help. If I could start over, I would definitely accept it in an earlier stage.

Performing the literature study was a difficult part for me. Not only because reading scientific articles all day for several weeks was not really my thing, also because the scope of my own project changed a lot. I started off with a totally different idea of the thesis than what it is now. This is the reason that in the end, a large part of the literature I studied was not useful for the research. Deleting a large part felt like a disappointment.

Last, working individually for 7 months was not easy for me. I realized during this project that I am best functioning in a team. Even though a lot of people helped me in the process, it was still mainly a lonely experience. I could have asked for more brainstorm session with my supervisors or colleagues, but most of the time I chose to work on the thesis alone. Asking for specific feedback earlier in the process could have helped me in my writing, so this is a lesson I learned.

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Appendices

A. Company overview of PACER

The practical part of this research is executed at PACER B.V, a consulting firm specialized in technical projects and processes within the field of infrastructure. The firm is Dutch and located in both Utrecht and Rotterdam. Around 46 people are working at PACER. PACER is specialized in three management areas; project management, risk management and contract management (PACER B.V., 2017).

Project management

Within project management PACER focuses on different aspects; environmental & stakeholder management, advising on work breakdown structures (WBS), scope management, probabilistic planning and technical project management. The last form is executed by using systems engineering. PACER applies their knowledge to the used project management style of the project and advises mostly on complex project management issues.

Risk management

PACER is experienced in the following disciplines concerning risk management;

- The RISMAN method
- Monte Carlo Simulation
- Reliability Availability Maintainability & Safety analyses
- Fault Trees
- Failure Mode Effect and Criticality Analysis
- Security and Health

Using these methods it is possible to set up a project specific risk management procedure and to manage this procedure, rejuvenate, actualize, test and manage a risk dossier. It is possible to organize and lead a risk session. And last giving workshops within above mentioned disciplines of risk management.

Contract management

PACER participates strongly in contracting processes conducted by public, governmental parties. Aside from preparing contracts, PACER also contributes to the completion and compliance of contracts. This is done for both national as well as international companies on a daily basis. The following tasks lie within this discipline;

- Risk based contract management
- Cost estimation and control
- Coordination of the market approach
- Verification and validation of contract management
- Contract scans, reviews and second opinions

Experts from PACER are working within one of those disciplines. The roles they fulfill vary from advisor project management, risk manager, systems engineer, contract manager and advisor environmental & stakeholder management. The experts from PACER work at both executing as commissioning side of projects. Experts from PACER use the procedures from the client they work for in the execution of their projects.

B. Interview coding method

A trustworthy analysis is required to process the interviews to derive credible and valuable conclusions. The interviews are recorded in order to make transcripts, that will be send to the interviewees for approval. The transcripts will be analyzed in two coding steps, first cycle coding and second cycle coding which will help organizing and evaluating the data *(Clifford, French, & Valentine, 2010).*

First Cycle Coding

Reoccurring patterns are detected in this first process by coding passages from the transcripts. This will be done in two or three steps, depending on the amount of data.

1. First, open coding is used; an interview transcript is scanned and parts are selected that might be important for this research. Keywords from this phrase are written done to summarize it and will be collected in the *open coding column.*
2. During the second step, key categories are created by *axial coding*. This allows the researcher to follow these categories and test the relevance (Evans, 2013). During this step, similarities between different transcripts are identified and used to rewrite the keywords into coherent categories.
3. The last step is called *selective coding*, this is a systematic approach with the goal to define final core categories (Evans, 2013).

There are three elemental methods distinguished to do this; descriptive, in vivo and process coding.
*Descriptive coding assigns labels to summarize in a word what was mentioned in a passage.
*In vivo coding uses words that were mentioned by the interviewee literally.
*Process coding uses verbs to describe a passage. It is also possible to use other sorts of coding such as affective coding (emotions or beliefs), attribute coding, causation coding and so on.

First cycle coding is done using Excel, and is performed for each case separate.

Second Cycle Coding

To summarize segments of data, codes from the last step in the first cycle coding are clustered into smaller numbers of categories, constructs or themes. These *pattern codes* usually look like one of those four – often also interrelated – summarizers;

i. Categories or themes
ii. Causes/explanations
iii. Relationships among people
iv. Theoretical constructs (Miles, Huberman, & Saldana, 2014)

The result of the two coding steps is an overview presented in Excel, in which the data is summarized and ready to be analyzed.

C. Scope management processes PMBOK

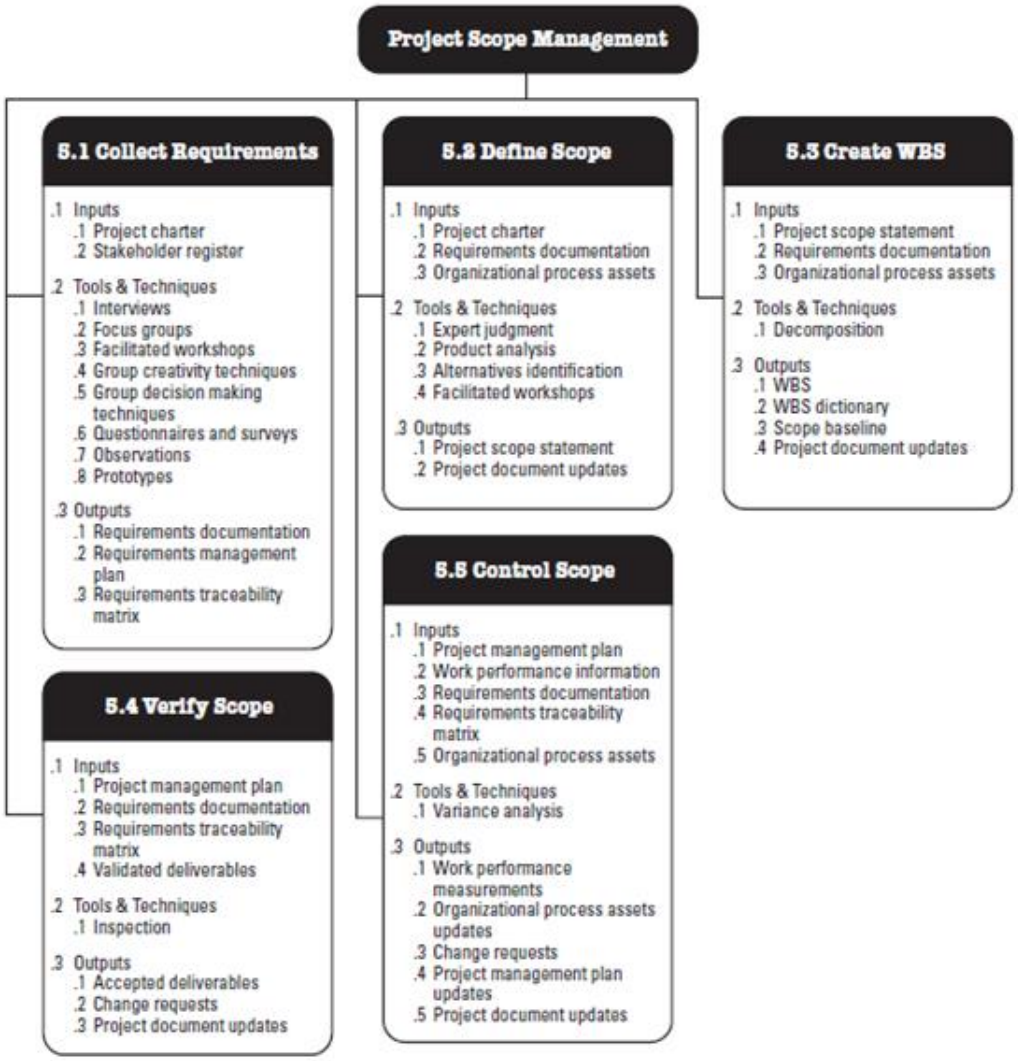

Figure 10 Overview scope management according to PMBOK guide (Project Management Institute, 2013)

D. Literature study: causes of scope change

Research points out that scope change are among others is caused by poor definition of the requirements and the scope of the project in the initial stage *(Dumont, Gibson, & Fish, 1997; Kumari & Pillai, 2014*). Other causes are found; technological uncertainty and a change in environment in which the project is conducted – for example a new law or new policy that changes standards *(Meredith & Mantel, 2009)*. A very recent research was conducted by Sharma *(2016*) focusing on causes for scope change in the field of large infrastructure projects. He stated that poor communication between key partners, poor interdisciplinary communication and task assigned to the wrong people are in the top 18 causes for scope change (*Sharma, 2016)*.

Causes can be categorized by nature – external or internal – which is dependent on the point of view. Researchers identified the following internal causes; change in management, lack of timely and effective communication and lack of integration, errors in the design and lack of common understanding between actors of the contract *(Hwang & Low, 2012; Ndihokubwayo & Haupt, 2009; Elshahat, Dawood, Alaryan, & Emadelbeltagi, 2014)*. When looking at external causes we can distinguish; inclement weather, uncertain inflation and governmental intervention, lack of experience at the contractor's side, the contractor's desire to improve his financial conditions and unavailability of equipment. *(Hwang & Low, 2012; Elshahat, Dawood, Alaryan, & Emadelbeltagi, 2014; Gokulkarthi*

& Gowrishankar, 2015). Sunday (*2010*) researched causes of variation in projects and distinguished consultant, owner and contractor related causes, see Figure 11.

Table 6: Consultant Related Causes of Variation

Causes of Variation	Importance Index (%)	Rank
Inadequate working drawing details	86.67%	1
Design discrepancies	76.00%	2
Conflicts between contract documents	74.67%	3
Inadequate scope of work for contractor	74.67%	4
Errors and omissions in design	68.57%	5
Consultant's lack of required data	68.57%	6
Lack of coordination	67.14%	7
Consultant's lack of judgment and experience	62.96%	8
Lack of consultant's knowledge of available materials and equipment	62.67%	9

Table 7: Owner Related Causes of Variations

Causes of Variation	Importance Index (%)	Rank
Change of plans or scope by owner	85.33%	1
Impediment in prompt decision making process	82.67%	2
Inadequate project objectives	76.00%	3
Replacement of materials or procedures	70.67%	4
Change in specifications by owner.	69.33%	5
Change of schedule by owner	56.00%	6
Owner's financial problems	52.73%	7

Table 8: Contractor Related Causes of Variations

Causes of Variation	Importance Index (%)	Rank
Differing site conditions	84.00%	1
Shortage of skilled manpower	80.00%	2
Contractor's desired profitability	77.33%	3
Contractor's financial difficulties	76.00%	4
Contractor's lack of required data	66.67%	5
Lack of communication	66.67%	6
Contractor's lack of judgment and experience	65.71%	7
Defective workmanship	52.00%	8

Figure 11 Actor specific causes of scope change (Sunday, 2010)

Table 35 presents an overview of the most mentioned causes of scope change found during the literature study (*Sharma, 2016; Dumont, Gibson, & Fish, 1997; Ndihokubwayo & Haupt, 2009; Hwang & Low, 2012; Meredith & Mantel, 2009; Gokulkarthi & Gowrishankar, 2015).*

Table 35 Overview causes of scope change (Dumont, Gibson, & Fish, 1997; Sharma, 2016; Ndihokubwayo & Haupt, 2009; Meredith & Mantel, 2009; Hwang & Low, 2012)

Internal causes	External causes
Poor definition of requirements in scope description	A change in law or standards set by environment
Technological uncertainty	Governmental interventions
Users or team members learning new things about the project or environment	Uncertain weather conditions
Lack of coordination	Unavailability of equipment
Lack of integration of project parts	Uncertain inflation
Disputes between team members	Lack of experience of the contractor
Errors and omissions in design	The contractors' desire to improve his financial conditions
Poor interdisciplinary communication	
Tasks assigned to wrong person within project team	

E. Change procedures as described in the UAV-GC

Procedure when change is initiated by the client

Figure 12 presents the procedure starting from the client that assigns a change in the work of the contractor. At the bottom of Figure 12 it can be seen that a request to change from the client can end with the advice from the board of experts. However, it is not stated in this procedure how this should continue. The stated deadlines are deadlines that differ per project, agreed by the client and the contractor *(Centrum voor aansprakelijkheidsrecht, 2005)*.

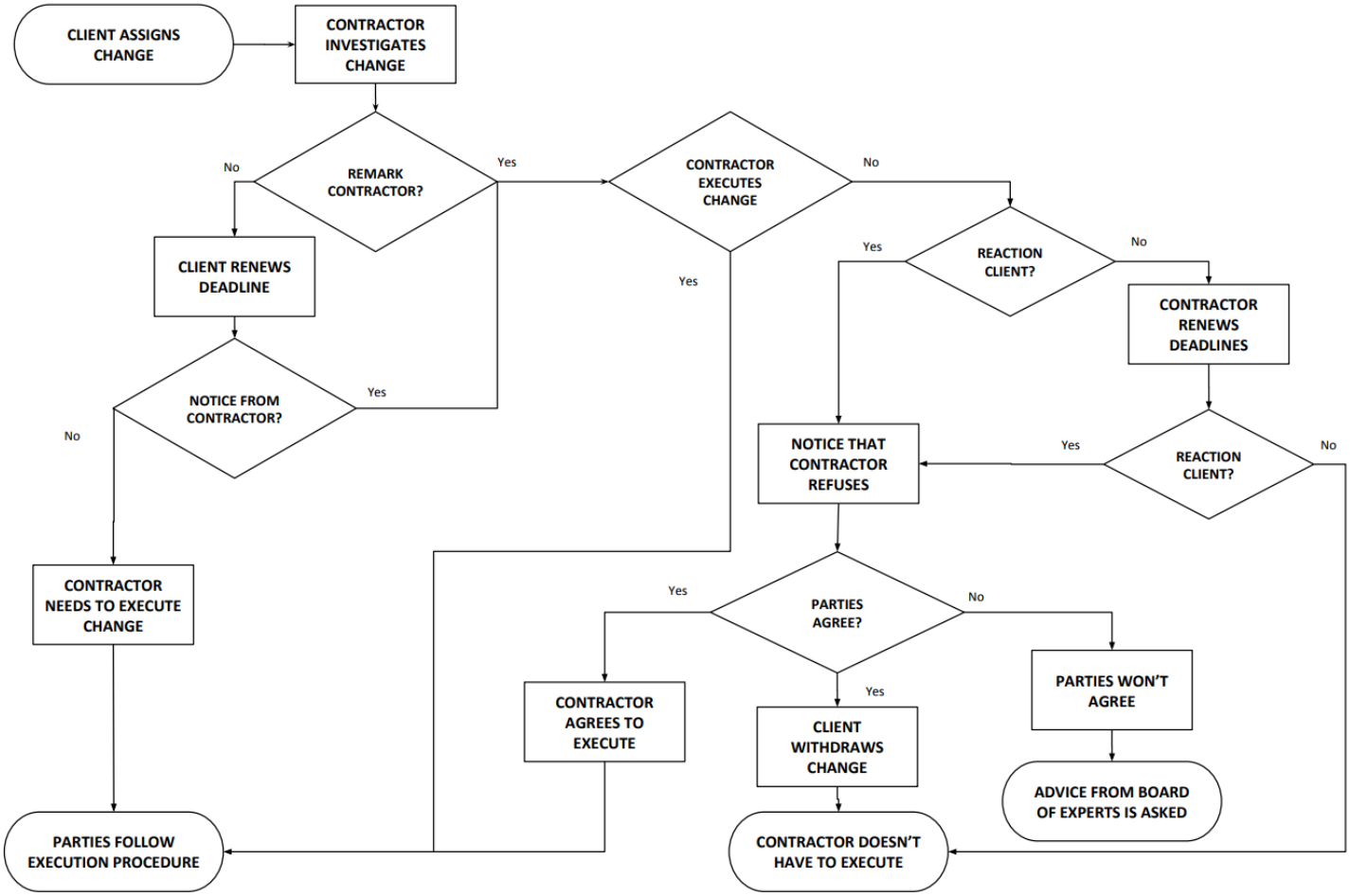

Figure 12 Change initiated by the client (translated version) (Centrum voor aansprakelijkheidsrecht, 2005)

Procedure when change is initiated by the contractor
In case the contractor submits a change, this can follow three processes.

1. A risk or fault that lies within the responsibility of the contractor. In this case the contractor notifies the client, which then should decide how to solve the problem. For example changes as a result of no timely licensing, problems with the soil quality, damages to the works or environmental pollution.

2. A change that can be submitted without the participation of the client. It can be for example the case that it was indicated in the contract that the contractor should come up during the planning phase with a design for a specific part of the construction. If there are changes in this design during the planning period, these changes can be accepted without acceptance of the client.

3. A change for which acceptance of the client is needed. In this case, the acceptance procedure should be followed.

Figure 13 presents the procedure as described in UAV-GC in case the contractor submits a formal request for acceptance. The goal of this procedure is to prevent situations to have an open end. In practice, the end of this procedure should either be a renewed request for acceptance, or an accepted request by the client, as can be seen in Figure 13.

There are a few guidelines important for the application of this procedure. It is stated that a client cannot persist on extra work at every moment of the project. The acceptance authority is limited to the agreed terms within the acceptance plan, which is part of the contract between the client and the contractor. There is a little flexibility in the procedure when it comes to this point; the deadlines for acceptance can be agreed on by the participating actors, and can therefore differ per project.

Last, aside from the contractor, the client is also obliged to adhere to the stated acceptance rules and deadlines. If there is an exceedance to the stated deadlines from the client's side, this gives the contractor the right to cost compensation. If the procedure itself results in costly delay, the contractor can be entitled to cost compensation as well *(Centrum voor aansprakelijkheidsrecht, 2005)*.

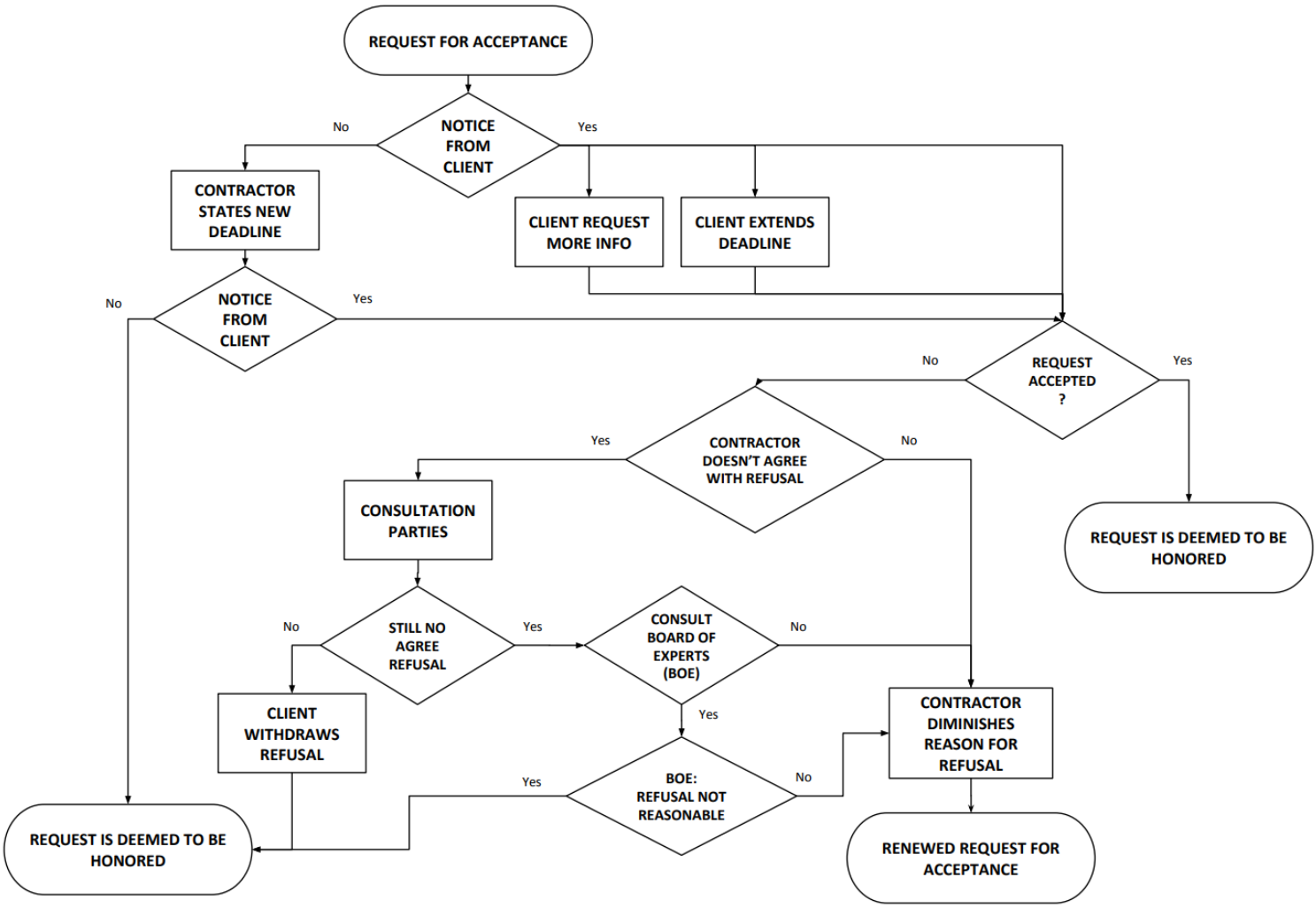

Figure 13 Change initiated by the contractor (translated version) (Centrum voor aansprakelijkheidsrecht, 2005)

F. Quick scan

This appendix consist of the profiles of experts from PACER interviewed in the quick scan and the interview questions that were asked. Last, it presents the score card that contributed to defining the research direction for the case studies.

F.1. Profiles interviewees

Due to anonymity the interviewees are presented in Table 36 by abbreviations instead of their names.

Table 36 Profiles of quick scan interviewees

Respondent	Role in current project	Abbreviation	Years of experience in this role
1	Advisor contract management	CM 1	3
2	Advisor risk management	RM	1
3	Process coordinator	PC	2
4	Advisor change management	CHM 1	3
5	Systems engineer	SE 1	4
6	Systems engineer	SE 2	2
7	Advisor change management	CHM 2	3
8	Advisor change management	CHM 3	1
9	Advisor contract management	CM 2	2

F.2. Interview protocol

The exploratory interviews were semi structured which means a standardized list of interview questions was used. The following questions are asked to every experts;

Table 37 Interview questions exploratory interviews

Interview questions exploratory interviews
What is your role within the project you execute for PACER?
How many years of experience do you have?
I'm researching bottlenecks within the process of scope management. It starts with a focus on scope change, in which I define scope change as a change in prescribed activities that lead to the end goal of a project. What are you experiences with scope change and the causes of them?
What process is used when handling scope change?
In your projects, who is involved in the scope change process?
Can you mention any other bottlenecks in the scope management process?

F.3. Score card quick scan results

The quick scan serves as a basis for the case studies. Selective codes are used to determine which aspects are most important to research in-depth. There were seven key aspects selected after the first two coding steps;

- Involvement of many roles and disciplines
- During initiating and planning phase scope was changed a lot
- Time pressure
- Unclear documentation
- Procedure was not followed
- Communication
- Reactive scope change management

Because of the time limit of this research it was chosen not to research all 7 of these aspects but only the most mentioned ones. Therefore a score card was made in which it was counted how many experts mention a specific aspect. Note that if one expert mentioned several things about the same aspect, this still counts as one. So the maximum amount of points per aspect comes to 12. Table 38 shows this score card in which it can be seen that involvement of many roles and disciplines has the highest score, followed by reactive change management and communication. These three topics require the most attention when researching scope management more in-depth.

Table 38 Ranking elements mentioned during quick scan

Selective code	Score code
Involvement many roles and disciplines	9
During initiating and planning phase scope was changed a lot	2
Time pressure	4
Unclear documentation	3
Procedure was not followed	4
Communication	5

G. Example coded interview quick scan

This is a part of the Excel file in which the quick scan interviews are coded. The table is in Dutch because all the transcripts are in Dutch, but the last column contains a translation in English.

Question	Explanation	Role of respondent	Open coding	Axial coding	Selective coding	Translation
Can you mention bottlenecks in the scope change management process?	*Het kan voor de projectmanager lastig zijn om te snappen hoe kostenoverzichten worden opgesteld. Dit ligt aan de ervaring van de contractadviseurs in hoeverre dit goed gaat. Zij kijken of het realistisch is, in samenwerking met de technisch adviseurs.*	*PC*	Samenwerking projectmanager, contractadviseur en technisch adviseur van belang	Samenwerken verschillende rollen en disciplines nodig	Verschillende rollen en disciplines betrokken	**Involvement many roles and disciplines**
	Hoe een wijziging wordt opgepakt is afhankelijk van het contract en de manier van samenwerken.	*RM*	Contract en samenwerking beïnvloeden oppakken wijziging	Samenwerken verschillende rollen en disciplines nodig	Verschillende rollen en disciplines betrokken	**Involvement many roles and disciplines**
	Geïsoleerd ontdekken welke wijzigingen zijn voorgekomen, waarom en door wie is een grotere zoektocht dan in een geïntegreerd proces.	*CHM1*	Geïsoleerd wijzigingproces lastig	Samenwerken verschillende rollen en disciplines nodig	Verschillende rollen en disciplines betrokken	**Involvement many roles and disciplines**
	Als afwijkingen hangen aan de kwaliteit zorgt dit voor discussie. Niet over noodzakelijkheid maar wel over de kosten ervan.	*CHM1*	Discussies over kosten afwijkingen	Discussies zorgen voor vertraging	Communicate	**Communication**
	De procedures worden niet altijd gevolgd, dat kan knelpunten opleveren.	*SE1*	Knelpunt; procedure niet volgen	Procedure niet volgen	Procedure niet volgen	**Procedure was not followed**
	In principe worden de procedures gebruikt die in de UAV-GC beschreven staan. Soms gaat dit ook wel iets informeler, dan wordt er gebeld met informatie over de afwijking.	*CHM2*	Procedures UAV-GC soms informeler	Belangrijk om mondeling overeenkomen te voorkomen	Procedure niet volgen	**Procedure was not followed**
	In principe worden afwijkingen geaccepteerd door de contractmanager maar die moet ook input hebben van de technisch manager om te zien of alles technisch gezien in orde is. Je bent dus wel afhankelijk van de disciplines om je heen.	*CM1*	Afhankelijkheid disciplines groot	Verschillende rollen en disciplines belangrijk	Verschillende rollen en disciplines betrokken	**Involvement many roles and disciplines**
	De opdrachtgever vertrouwt in principe op de expertise van de opdrachtnemer als het gaat om wijzigingen.	*SE2*	Expertise opdrachtnemer belangrijk	Kennis projectteam		
	Ik ben zelf voorstander van alles op papier, en niet teveel mondelingen overeenkomsten. Ik merk nu bij de Haringvlietbrug dat als verschillende mensen er met een verschillend idee in zitten, is mondeling niet handig	*SE3*	Papier beter dan mondeling	Belangrijk om mondeling overeenkomen te voorkomen	Procedure niet volgen	**Procedure was not followed**
	Bij afwijkingen en wijzigingen kijken we vooral naar de aspecten planning (tijd), kosten of de scope van het project. In de voorbereiding wordt deze scope regelmatig, in samenspraak met de interne opdrachtgever, aangepast, als dit past binnen budget en capaciteit.	*CM2*	Scope in voorbereiding veel aangepast	Scope in voorbereiding veel aangepast	Scope in voorbereiding veel aangepast	**During initiating and planning phase scope was changed a lot**

Figure 14 Example coding interviews quick scan in Excel

H. Interview questions case studies

The interview questions are standardized and based on the variables derived from the researched literature presented in section 2 and 3 and the quick scan: scope definition, the scope management steps, roles and responsibilities, and reactive versus proactive management of scope change. These five variables are operationalized, which means a definition is presented, along with an indicator that can be measured during the interviews. These definitions and indicators are set up also using researched literature from section 2 and 3.

Table 39 presents this operationalization of the variables. The indicators are used as a basis for the interview questions, to ensure all required information is derived from the case study interviews. The interview questions are presented in Table 40.

Table 39 Operationalized variables

Variable	Definition	Indicator
Scope management process steps	Development and management of scope from design till end of the project follows formal process. Consists of five steps; collecting requirements, defining scope, create WBS, verifying scope, controlling scope (AWE Services, 2006; Project Management Institute, 2013).	- Procedure is set up and well known - Process steps are followed - Definition of 'good scope management process' available
Many roles and responsibilities in scope management process	Many individual team members execute tasks concerned with scope management, this means they can be responsible or accountable for a (part of a) step in the process	- Several managers execute scope management tasks - Clearness responsibility scope management tasks
Reactive management of scope change	A manager takes action when changes appear. This concerns mostly a crisis situation and a fast decision is required. Characterized by creative, innovative and new ways of creating solutions (Reh, 2017). There is a fear for change and managers try to avoid changes instead of predicting them (Lee & Ryu, 2013).	- Changes are seen as a bottleneck in scope management process - Action occurs after change - Procedure not always followed; creative solutions brought up
Proactive management of scope change	Preventing future problems by analyzing previous ones. Requires analytical characteristics and thinking in patterns. It needs to be researched *why* something happens instead of *what* can be done to solve it. This requires evaluation of changes (Reh, 2017). External threats need to be predicted and initiative is needed to change things in a certain way to improve current situation (Lee & Ryu, 2013).	- Previous changes are analyzed to search for patterns - Initiative to change current situation - Changes are seen as an opportunity

Variable	Definition	Indicator
Scope management process steps	Development and management of scope from design till end of the project follows formal process. Consists of five steps; collecting requirements, defining scope, create WBS, verifying scope, controlling scope (AWE Services, 2006; Project Management Institute, 2013).	- Procedure is set up and well known - Process steps are followed - Definition of 'good scope management process' available

The questions are stated in Dutch because all the interviewees are Dutch.

Table 40 Standardized interview questions case studies

Topic	Interviewvragen
Rol geïnterviewde	*Uw functie is …* kunt u in een paar zinnen beschrijven wat dat voor dit project inhoudt? Wat is uw achtergrond qua opleiding? Hoelang bekleedt u deze functie in dit project? Heeft u ervaring in deze rol in eerdere projecten?
Het begrip scope	Wat is de scope van het project waar u aan werkt? Hoe is deze scope in uw project vastgelegd? Hebt u het idee dat iedereen in het project van de scope op de hoogte is? Hoe is deze scope naar u gecommuniceerd?
Scope management (het proces)	In hoeverre bent u bekend met de theorie omtrent scope management? *Laat overzicht van process stappen PMBOK zien – zie* Figure 10. - Als bekend: kent u deze process stappen? - Als niet bekent: deze stappen zijn er, herkent u ze terug in uw project, eventueel met een andere naam? Wat zou kunnen verbeteren aan dit proces? Welke stappen? Wanneer zou u scope management als goed beoordelen?
Scope management (rollen)	Wie is er verantwoordelijk voor scope management in uw project? Welke rollen kunt u nog meer onderscheiden die betrokken zijn bij scope management? Hoe beoordeelt u deze rollen, vindt u één verantwoordelijke belangrijk of bent u voorstander van verschillende verantwoordelijken?
Scope change	Is de scope tijdens de werkzaamheden in uw project gewijzigd? Wijzigt uw werk op het moment dat de scope wijzigt? Hoe wordt er over de status van scope gecommuniceerd? *Uit de literatuur blijkt dat scope change een knelpunt is in scope management, ik ben benieuwd naar uw ervaringen hiermee.* Ziet u wijzigingen in de scope als een knelpunt?
Scope change (reactief management)	Hoe wordt er gereageerd op scope change door de leden van het projectteam? Worden er procedures gevolgd nadat scope change voorvalt? Komt het voor dat in plaats van het volgen van het proces een andere creatieve oplossing wordt gehanteerd? Zou uw deze manier van reageren als reactief bestempelen?

I. Example coded interview case studies

This is a part of the Excel file in which the interviews of case 1 are coded. The table is in Dutch because all the transcripts are in Dutch, but the last column contains a translation in English.

Table 41 Example coded interview

TOPIC	QUESTION	EXPLANATION	ROLE	OPEN CODING	SUMMARY CODE	TRANSLATION
Scope change en status scope	**Zie je die wijzigingen als een knelpunt in het proces van scope management?**	Nee niet echt. Je stelt een contract op en kan niet alles voorspellen.	PC 1	Wijziging geen knelpunt	Soms, proces vastleggen lastig	**Sometimes, proces of documenting difficult**
		Het is een verstorende factor ja. Helaas horen ze er wel echt bij.	MPQ 1	Wijziging verstorende factor	Soms, proces vastleggen lastig	
		Ja, maar dat is een knelpunt omdat we nog niet goed weten hoe we dat moeten inrichten in de processen.	PM 1	Wijziging knelput in procesvorm	Soms, proces vastleggen lastig	
		Eigenlijk niet, behalve dan dat het lastig is wanneer je ze moet meenemen.	TC 1	Wijziging niet echt een knelpunt	Soms, proces vastleggen lastig	
	Hoe wordt er gecommuniceerd over een verandering van de status van de scope?	Het wordt bijgehouden in Relatics, die wijzigingen worden niet perse medegedeeld aan het team.	PC 1	Relatics houdt nieuwe scope bij	Scope status in Relatics	**Relatics keeps track of new scope**
		Uiteindelijk als we een nieuwe scope overeen zijn gekomen dan komt er een beschrijving van de van – naar situatie. Die naar situatie wordt geïntegreerd in de eisen met behulp van Relatics, de eisen management tool. In het projectteam overleggen wordt hier dan over gecommuniceerd. Hier ga je er dus ook vanuit dat een wijziging goed wordt verwerkt in de scope, en een nieuwe scope status is dan het geval.	MPQ 1	New situation in Relatics	Scope status in Relatics	
		Een officiële wijziging, vaak gaat het via het officieuze kanaal, dan wordt er gesproken van 'hee er zit iets aan te komen'. Vaak wordt er nog een mailtje achteraan gestuurd door de teamleden van de opdrachtgever zodat je weet wat er komt.	PM 1	Mailtje naar teamleaden		
		Er wordt niet door iedereen constant Relatics gecheckt. De project manager, de site manager en de technisch manager zouden overal van op de hoogte moeten zijn. Het bijhouden van alle informatiestromen voor de andere teamleden wil niet altijd lukken.	TC 1	Relatics houdt alles bij	Scope status in Relatics	

J. Validation of implementation guide

The integration of theory and practice led to the insights as presented in section 5. As a result of these findings a first version of the implementation guide for scope management was designed, see Figure 15.

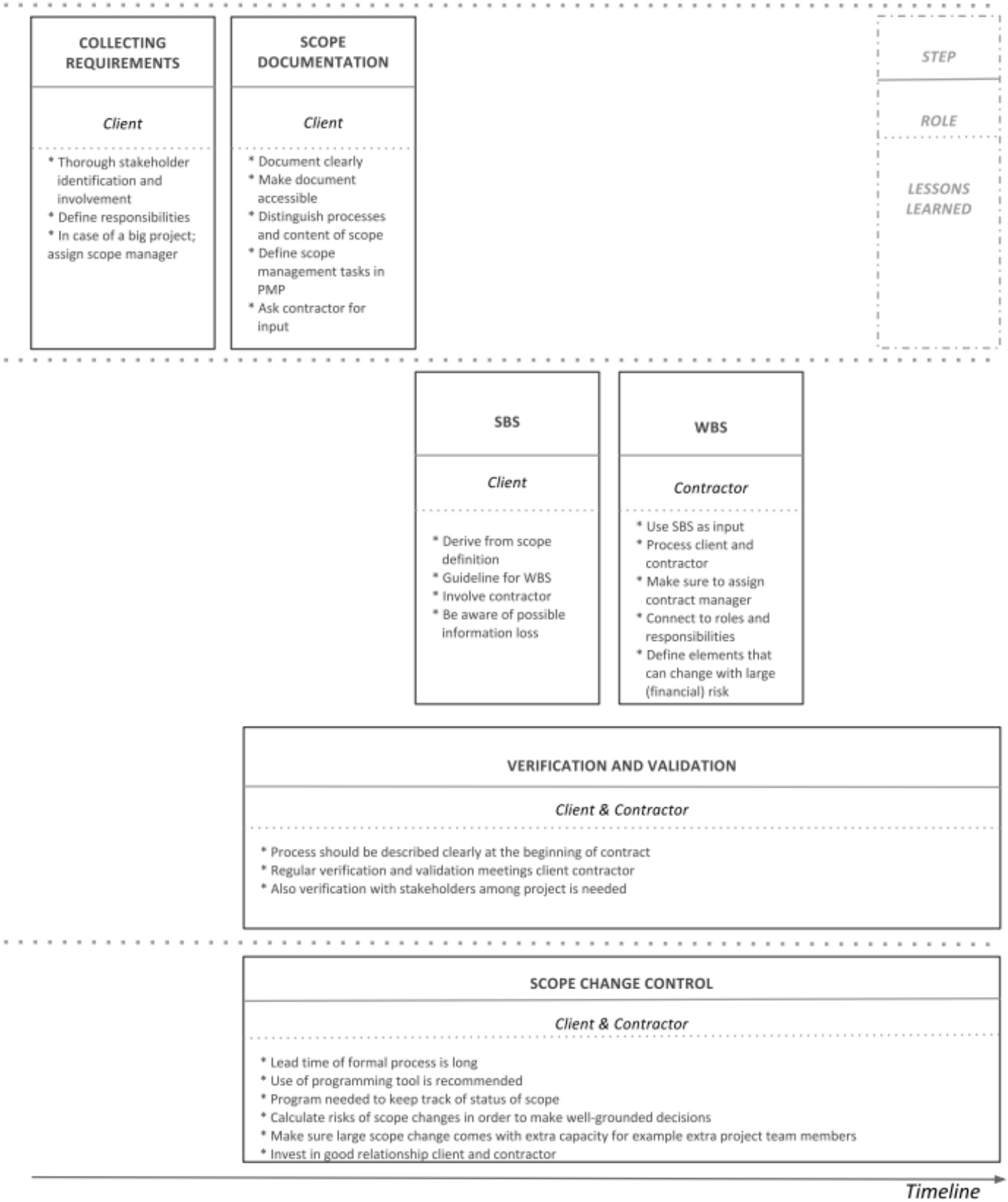

Figure 15 First design implementation guide

This implementation guide is validated by two professionals from PACER, with the aim to check whether the proposed guide is correct or not. Also, the validation is used to find out whether it is applicable in projects. This section describes the method and results of the validation.

Validation method

The experts both have more than 10 years of experience within the field of scope management in projects. Each expert is interviewed separately which reduces the chance that their answers are influenced by one another. The validation is done following these steps:

1. The general context of the research is presented for about 5 minutes. This includes a summary of the research direction based on the theoretical background, goal of the research and the research questions.
2. First the PMBOK guide (2013) is shown to present the baseline for the developed guide presented in along with an explanation.
3. Each expert is asked to rank the topics by filling in Table 42. This ranking is based on a scale ranging from 1 to 3, in which 1 = totally agree, 2 = neutral and 3 = totally disagree. Besides, the explanation for giving this score was asked. This ranking is used to determine which aspects need the most improvement.
4. The experts are asked if the guide is applicable in their projects.

Table 42 Validation topics

Topic
Guide describes process in a comprehensive way
Timeline of steps is logical
Feedback loop should be present between the layers
Identified roles match process steps
Lessons are comprehensible described
Goal of the guide is clear
Clear which lessons are important for which actor

Validation results

Results validation expert 1

The result of the validation by expert 1 is presented in this section. First the ranking table is shown followed by the opinion of the expert concerning applicability of the guide in practice.

Table 43 Validation expert 1

Topic	Ranking (1-3)	Motivation for score
Guide describes process in a comprehensive way	1	Clear. The process could be more clearly described, which recommendations are for the contractor and which recommendations for the client. SBS is a good addition to the PMBOK guide.
Timeline of steps is logical	3	Could be more clear that vertical means the phases and horizontal means time.
Feedback loop should be present between the layers	3	I do not think that all the process steps should be completed again when the scope changes, only WBS needs to be redesigned but not step 1 and 2.
Identified roles match process steps	1	Yes very clear. Just ensure to look at verification and validation. Distinguish which one is responsibility of the client and which one is responsibility of the contractor, I think you could make a distinction there. There is a difference and it should be explained.
Lessons are comprehensible described	2	Few additions. Very important that the client and the contractor meet to discuss the interpretation of the requirements, between step SBS and WBS. Also, between this steps the responsibility shifts from the client to the contractor, at this moment the contract is signed. Maybe this can be added. Not clear what is meant with programming tool in the last step.
Goal of the guide is clear	2	Together with explanation of researcher clear. I think you should change lessons learned to recommendations to make this more clear. Furthermore, this guide seems to be the proposed implementation of the PMBOK guide, so the actions from PMBOK can still be used but the recommendations from this research are needed, an explanation about this in writing is needed in my opinion.
Clear which lessons are important for which actor	2	Yes clear, could be improved in verification and validation step. Also, in step 2 it is mentioned that the contractor should be asked for input, but this is not always possible during the tender phase.

Applicability in project according to expert 1

This guide is important, especially in large projects. At this moment, this is not used properly in projects in my opinion. The projects I currently work on are not that big, but I still see the importance. It is needed to create awareness that this should be treated as an important project management area. A different process should be defined in the contracts and project management plan as well. If a separate process for scope management is set up, I think a functionary should be assigned to be responsible for this process. Other than the roles already defined.

Results validation expert 2

The result of the validation by expert 2 is presented in this section. First the ranking tables is showed, and second a summary with the proposed adaptions to the guide. Last, the opinion of the expert concerning applicability of the guide is presented.

Table 44 Validation expert 2

Topic	Ranking (1-3)	Motivation for score
Guide describes process in a comprehensive way	2	The guide describes the process clearly. However, I'm curious if this guide replaces the PMBOK guide or if it is a tool to better implement the PMBOK guide.
Timeline of steps is logical	1	Timeline is very logical; first preparation, then scope definition followed by SBS/WBS. V&V and scope change are present from scope definition, which is clear.
Feedback loop should be present between the layers	2	SBS and WBS – as part of scope management are possible after scope is defined, so this is a clear relation. However, scope change is in my opinion an essential part of scope management so this should be incorporated in the guide.
Identified roles match process steps	2	The contractor seems not to play an active role in every step, but when it comes to the overlapping steps V&V and scope change control, the contractor does play a role. If you split up the guide; one guide for the client and one guide for the contractor, would the overlap be the same? In other words, isn't there a scope definition phase for the contractor too? Besides, it seems that the contractor is known at the scope definition phase, this is not the case in every contract form so be aware of this. The contract is made later on, and then the contractor is assigned.
Lessons are comprehensible described	3	Not clear if it is about the results to be achieved or the actions that needs attention.
Goal of the guide is clear	2	Is it the purpose that the guide contains tips and tricks for different phases, or it is an action plan? I think it can help to get insight in the processes. Because of the term 'lessons learned' it seems to be an evaluation guide that needs to be filled in. Dependent on the goal of the guide, the term lessons learned might be confusing.
Clear which lessons are important for which actor	3	The guide presents clearly which actor plays a role in which step but it not clear to what extent. Maybe scope management is different for the client and the contractor? Should there be two guides then maybe?

Applicability in projects according to expert 2
The guide gives insight in the process of scope management and can therefore be used, however it is at this moment not clear enough to use it correctly. It needs to be clear what the goal is and how to use the guide. Explanation of the steps and intended use will help.

Conclusion validation

The remarks of the experts during validation are combined and led to adaptions to the guide. Aspects ranked with a 2 of 3 are both improved. The adaptions are presented in Table 45. As a result of the validation it was decided to stipulate the timeline of the process steps, and therefore a flow chart was developed. The final implementation guide including this flow chart can be seen in section 6, Figure 9.

Table 45 Implementation recommendations retrieved during validation

Recommendations to implement in the guide
Add of vertical axis presenting the layers.
Add following recommendation to SBS process step; discussion interpretation requirements between the client and the contractor.
Change WBS recommendation 'use SBS as input' to ´use contract including SBS as input'.
Change 'lessons learned' to recommendations, change 'role' to responsible role, and change 'step' to process step.
Verification and validation step is split up into two processes; one for the client, one for the contractor.
Change recommendation 'in case of a big project; assign scope manager' in step collecting requirements to 'discuss whether a functionary is assigned to manage this process'.
Assign validation to be responsibility of the client; to track the validity of the project amongst the desires of the stakeholders.
Assign verification of the executed activities to be responsibility of the contractor.
Add feedback loop between scope change and scope management layer in additional guide.