Utilizing Virtual Reality in a dynamic stakeholder process

Exploring the added value of using Virtual Reality in the stakeholder process of complex infrastructure projects.

R.A. Oudshoorn, 16 July 2018

This Master Thesis of R.A. Oudshoorn was written as part of the graduation assignment of the Master Construction Management and Engineering at the Delft University of Technology. The graduation assignment was conducted at Witteveen+Bos, a company based in the Netherlands, providing consultancy and engineering services worldwide in the fields of infrastructure, water, the environment, spatial development and construction.

The topic of this thesis explores the added value of using Virtual Reality in the stakeholder process of complex infrastructure projects and the potential future implications.

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PREFACE

You are about to read the research that has held my attention for the past nine months. With this report, I conclude my time as a student of the master Construction Management and Engineering. My interest in this topic was triggered by a conversation with Otto Schepers at the Witteveen+Bos business course.

Some words to express my gratitude are in order. First of all, my thesis committee. I was glad to capture a dream team of supervisors, without their support this thesis would not have been possible. Wim van der Woerdt helped me getting to know Witteveen+Bos, gave me great support during the project and further enhanced my knowledge of Systems Engineering. Marian Bosch-Rekveldt helped me structuring my report and keeping me on track with weakly meetings at the start of the project. Stephan Lukosch helped me understand what Virtual Reality is. Marcel Hertogh supported this research with his good mood, wisdom and by being the chair of this committee

Furthermore, I would like to thank my family and friends for supporting me through my whole study time and listening to my never-ending stories over my graduation topic last year. Special thanks to my brother and father for reviewing my thesis. Thanks for my lovely girlfriend Lauren Ebbers for the beautiful cover she made for this thesis. Lastly, I would like to thank some of my study buddies, Robbert van Staveren for being my fellow warrior for the past nine months. I would like to wish Gigi Zacheo good luck with his VR company contributing to the future of VR in the infrastructure sector and would like to thank him for introducing me to Jidde Koekoek who send his thesis to me all the way from Nepal.

Enjoy reading,

Remco Oudshoorn, July 2018

SUMMARY

Virtual Reality (VR) is a hot topic; some argue that VR causes a computing revolution as impactful as the smartphone. The infrastructure industry recently adopted VR as a tool in the stakeholder process. This thesis defines Virtual Reality as a three-dimensional virtual environment in which one can interact. VR is applied in several projects which indicates that the contracting authority is willing to pay for the use of VR. However, it is still unknown what the benefits of applying VR in the stakeholder process are.

This thesis contains exploratory research into the added value of using VR in the dynamic stakeholder process. The goal of this thesis is to give insight into how VR is applied in the stakeholder process of complex infrastructure projects and to explore the added value resulting from this application. The main research question therefore is:

WHAT IS THE ADDED VALUE OF VIRTUAL REALITY IN THE STAKEHOLDER PROCESS OF COMPLEX INFRASTRUCTURE PROJECTS?

This thesis focusses on complex infrastructure projects for which dynamic management is required. The stakeholder process when using dynamic management is defined as a dynamic stakeholder process. The dynamic stakeholder process consists of the Systems engineering (SE) stakeholder process and the interactive stakeholder management process. The foreseen goal of the dynamic stakeholder process was to satisfy the stakeholders and to improve the design. With the interactive stakeholder management, stakeholders are involved during the entire project. Although the involvement of stakeholders is desirable, it is not always successful. The stakeholder process is often inefficient and does not satisfy these goals of the stakeholder process. Nine risks were identified from the literature that can cause the stakeholder process to be unsuccessful.

VR is used as a tool to contribute to the dynamic stakeholder process. The use of VR is seen as successful when it contributes to the foreseen goals, the efficiency of the stakeholder process or helps cope with the threats. Three concepts are discussed by means of a literature study, SE stakeholder management, Interactive stakeholder management and VR. This study identified nine key elements for the dynamic stakeholder process.

The dynamic stakeholder process starts with analysing the project. Resulting in the process plan and a strategy for the process. By satisfying the key elements of interactive management the stakeholder process is made appealing to join and is available for all the relevant stakeholders. These stakeholders can deliver valuable input on items which they find important. The input delivered by the stakeholders is processed by using SE. The input is translated into problems, objectives and needs. All the relevant needs are transcribed to SMART customer requirements and can be implemented to improve the design. Different types of VR are applied as tools in the dynamic stakeholder process for different purposes.

Case studies were used to find out how VR is applied in the dynamic stakeholder process. VR has only been used in a few complex projects so far which makes this research more of explorative nature. Three complex infrastructure projects in which VR was used in the stakeholder process were selected. Interviews were held with important stakeholders and the key people in the project team who are the project managers from Witteveen+Bos and the contracting authority. In this way, the project and process success and the added value of VR are assessed from different views.

A cross-case analysis was done to compare the different cases and construct more general conclusions about the aspects influenced by the use of VR. After which a decision-making framework is made to evaluate the use of VR in the dynamic stakeholder process.

The case study research shows that the use of VR in the dynamic stakeholder process can improve the stakeholder satisfaction due to a better understanding of the project. The use of VR in the dynamic stakeholder process can improve the efficiency regarding time. When using an online VR, the

stakeholders will give desires earlier and when using a high immersive VR clarifying the project takes less time. The efficiency regarding costs is still unknown. The use of VR in the dynamic stakeholder process can reduce the risks of wrong problem framing, communicational difficulties and late changes in requirements. When using a VR on an online platform, the risk of bad representation of stakeholders can also be reduced.

General success factors for the stakeholder process were identified. A decision-making framework is constructed which includes these success factors and the threats of stakeholder involvement. With this framework, the use of a tool in the dynamic stakeholder process can be evaluated.

Four success factors were determined, create project understanding, create a feeling of being heard, satisfy boundary conditions and improvement of the design which together lead to more satisfaction over the process and project. The dynamic stakeholder process has an impact on these success factors (See Figure 1).

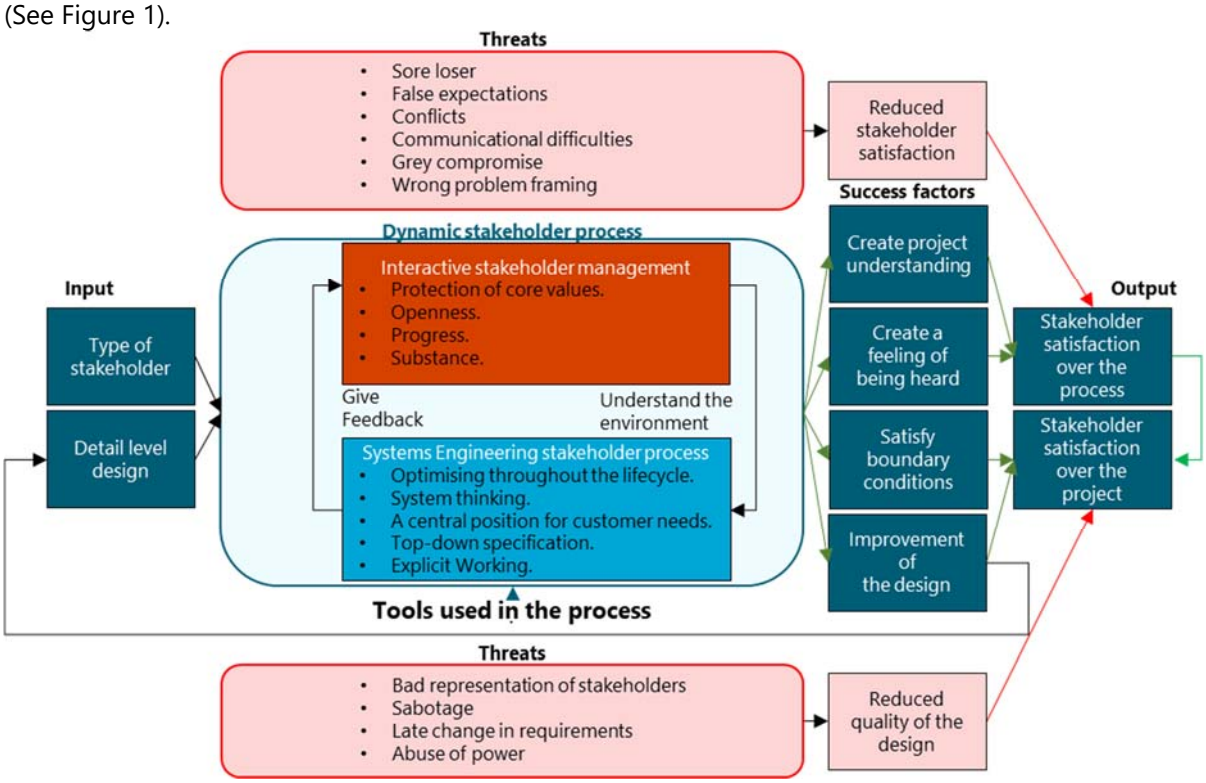

Figure 1 Decision framework for a tool in the stakeholder process.

The decision to use VR must be based on the risk of the project and the purpose for using VR. A high immersive VR on stakeholder information meetings can be used to contribute to the *substance*. A low immersive VR on an online platform can be used to contribute to the *openness*, *progress*, and *substance*. The use of both types of VR leads to a better understanding of the project. When VR is used to improve the *openness* and *progress*, the project design can be improved by having more input from stakeholders. However, processing this input requires thorough attention to create customer requirements that can be used to improve the design. When VR is used to improve the *top-down specification* by verifying and validating the customer requirements, the project design can be improved by having higher quality customer requirements. Further explanation of the added value of VR and opportunities for using Virtual Reality in the future are given in this thesis.

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LIST OF ABBRECIATIONS

CRS	Customer Requirement Specification
RWS	Rijkswaterstaat
SMART	Specific Measurable, Acceptable, Realistic and Time-bound
SRS	System Requirement Specification
SE	Systems engineering
VR	Virtual Reality
3D	three-dimensional

1 INTRODUCTION

Virtual Reality (VR) has been used in the stakeholder process of several infrastructure projects. Infrastructure projects are all projects concerning roads, rail lines, tunnels, bridges, channels, harbours and airports. According to Baker, Fisher & Murphy (1983), infrastructure projects are considered successful when the project mission is fulfilled, and there is a high level of satisfaction among the stakeholders. Everyone who is affected by these projects or has an impact on these projects are considered stakeholders (Bryson, 2004). The use of VR in the stakeholder process indicates that the client is willing to pay for the use of VR. However, it is still unclear what VR can contribute to the outcome of the stakeholder process (Koekoek, 2017).

In the last decade, the focus of the government changed towards more involvement of stakeholders in infrastructure projects. Desires of these stakeholders for something in the project are called customer needs. Nowadays customer needs have a central position in civil engineering projects (Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen, 2013). Infrastructure projects cannot be executed anymore without thorough attention for the stakeholders. A stakeholder process with more involvement is required because people are more abundant nowadays (Raats, van Gelder, Post, Koppenjan, Houben & Weusting, 2010). Insufficient or late participation of stakeholders will result in objections and time delays for the project (Steenbakkers, 2018). Implementation of a new environmental code in 2021 will further develop the involvement of stakeholders. Government organisations are then required to take different interests of stakeholders into account in the decision-making process (Steenbakkers, 2018).

Complexity is often claimed as a reason for large infrastructure projects to be unsuccessful (Kaming, Olomolaiye, Holt & Harris, 1997). Dynamic management is used to deal with this complexity (Hertogh & Westerveld, 2010). Dynamic management combines systems engineering (SE) with interactive management. With SE the project is split up into more manageable parts, and with Interactive management, stakeholders are engaged during the entire project (see Figure 2).

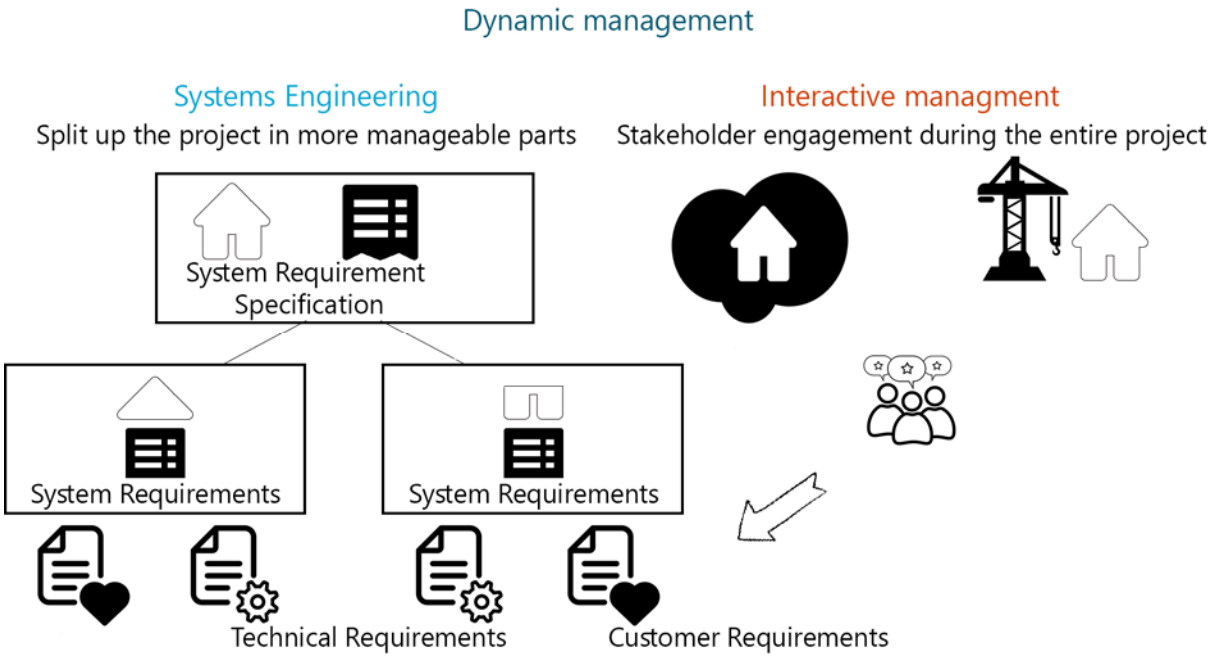

Figure 2, simplified representation of dynamic management.

The stakeholder process when using dynamic management consists of the SE stakeholder process and the interactive stakeholder management process. This stakeholder process is defined as dynamic stakeholder process. With interactive stakeholder management, all the interactions with the stakeholders are managed. The SE stakeholder process is used to process all the needs of stakeholders for the project. This thesis defines two goals for the dynamic stakeholder process 1) satisfying the stakeholders and 2)

improving the design. Stakeholders can have valuable information to improve the project which can be obtained by involving them (Rydin, 2007). Co-creation with the stakeholders results in better outcomes at lower cost (Bason, 2010).

The goal of this thesis is to elaborate on the use of VR as a tool in this dynamic stakeholder process and to discover if the use of VR can contribute to the success of the stakeholder process of complex infrastructure projects.

1.1 Problem description

In the dynamic stakeholder process, the stakeholders are involved during the entire project. Although the involvement is desirable, it still does not always lead to the desired results (Koekoek, 2017). The stakeholder process is often inefficient and does not satisfy the goals of the stakeholder process.

1.1.1 Efficiency

It is a challenge to have an efficient stakeholder process regarding cost and time (Hordijk, Sara, Sutherland & Scott, 2015). Inefficiency is partly caused by the two-fold purpose of the stakeholder process. On the one hand an increase of requirements can lead to more public support but on the other hand, too many needs can hamper the design and can result in an inefficient process.

The efficiency of a stakeholder management process depends on the social relationships between the stakeholders, their communication skills and the methods used to support the communication between stakeholders (Voinov & Bousquet, 2010). An inefficient process results in less budget and time available to realise the project.

1.1.2 Threats to the dynamic stakeholder process

Several threats were identified from literature which can cause the stakeholder process to be unsuccessful. Threats are uncertain, future events that can have a negative impact on the goals of the stakeholder process.

False expectations

Integration of stakeholders can lead to false expectations (Bakker, Hertogh & Bosch-Rekveldt, 2017). Not everyone can visualise the impact of a project. When stakeholders misinterpret the design or the impact of the design on their situation, it could lead to false expectations of the project. The involvement of the stakeholders can lead to dissatisfaction of the stakeholders when stakeholders build false expectations (Mayer, Edelenbos & Monnikhof, 2005).

Late formulated or changed requirements

At the start of the project, the possibility for stakeholders to influence the design is higher than when project realisation starts but paradoxically stakeholders often only become active after the realisation started (Gemeente Rotterdam, 2014). Stakeholders might only realise what they want in the project after they see a concept design and the impact becomes clear to them. It can also occur that stakeholders just become active late in the decision-making process to seize an opportunity to influence the project (De Bruijn & Ten Heuvelhof, 2008). According to Bjarnason, Wnuk and Regnell (2012), continuous requirement inflow can occur due to late formulated or changed requirements. When the needs of stakeholders require changes late in the project, it will lead to a large amount of rework (Bosch-Rekveldt, Smith, Mooi, Bakker & Verbraeck, 2011).

Conflicts

Integration of stakeholders can lead to lots of discussions and no decisions (Bakker, Hertogh & Bosch-Rekveldt, 2017). Stakeholders have different needs and expectations which are often contradictory (McManus, 2002). This can lead to conflicts between stakeholders, for example, a stakeholder might

actively try to hinder another stakeholder followed by the revenge of the other stakeholder (De Bruijn & Ten Heuvelhof, 2008). These conflicts can lead to dissatisfied stakeholders.

Sabotage

It is not possible to satisfy all stakeholders for complex projects. The majority of people that participate in the stakeholder process are doing this with the sole purpose of defending their interests (Hartman, 2000). People who hold a more neutral view towards the project are less interested in participating in the stakeholder process. Some stakeholders might engage in the project with the purpose of sabotaging the project. By participating in the stakeholder process, stakeholders obtain knowledge which they can use to make objections (Raats, van Gelder, Post, Koppenjan, Houben & Weusting, 2010).

Bad representation of all stakeholders

Possibilities to participate in the stakeholder process are divided unequally (Hartman, 2000). Knowledge, skills and social contacts are required to have an impact during the stakeholder process. The stakeholders participating in the stakeholder process are often a bad representation of all stakeholder. According to Hartman (2000), especially higher educated, native, outspoken, working or retired males are interested in participation when involving inhabitants. This group will have a disproportionate influence on the project compared to other groups. Some group of stakeholders do not have the time to go to information meetings, for example, starters and young parents, or do not have the mobility to go. Consulting the wrong stakeholders or forgetting to consult an important one can result in a faulty design and discontent stakeholders. It might occur that projects that "successfully" went through the stakeholder process end up being hindered or even stopped by a discontent stakeholder who did not participate in the process (Märker & Pipek, 2000).

Abuse of power

The stakeholder process can be seen as undemocratic since some stakeholders can have more power than others. Powerful stakeholders might be interested in realising something in the project that is not part of the scope. These stakeholders might abuse their power to force certain decisions that do not improve the design (Hordijk, Sara, Sutherland & Scott, 2015). A stakeholder can also be influential, irrational group behaviour or formation of protest groups can also be seen as an abuse of power.

Communicational difficulties

Stakeholders may have a different cultural background. When people do not know how to deal with these cultural differences, it can lead to communicational difficulties. Lower educated people often have problems with participation (Hartman, 2000). Lower educated stakeholders do not always understand the professional language of experts, and therefore it can be challenging to communicate with them (Hordijk, Sara, Sutherland & Scott, 2015). These communicational difficulties can make it difficult to satisfy the needs of these stakeholders which can lead to dissatisfied stakeholders.

Grey compromise

When involving many stakeholders, there may be a lot of different opinions about the project. The stakeholders should come to a compromise together. The compromise can be a decision about which none of the stakeholders is enthusiastic (De Bruijn & Ten Heuvelhof, 2008).

Wrong problem framing

The problem of the project can be formulated together with the stakeholders that are willing to participate early in the project to make the stakeholder process attractive to join. Early participants might frame the problem in such a way that it becomes impossible for other parties to get involved in the project (Bruijn, ten Heuvelhof & in 't Veld, 2008). As a result, the excluded stakeholders can be dissatisfied.

1.2 Thesis outline

This thesis consists of a literature study and case studies. The design of this research is explained in chapter 2. With the literature study three concepts are elaborated on 1) Systems engineering stakeholder process, 2) Interactive stakeholder management process and 3) Virtual Reality. These three concepts form the context of this research (See Figure 3). The colours indicate in which chapter the topics are covered.

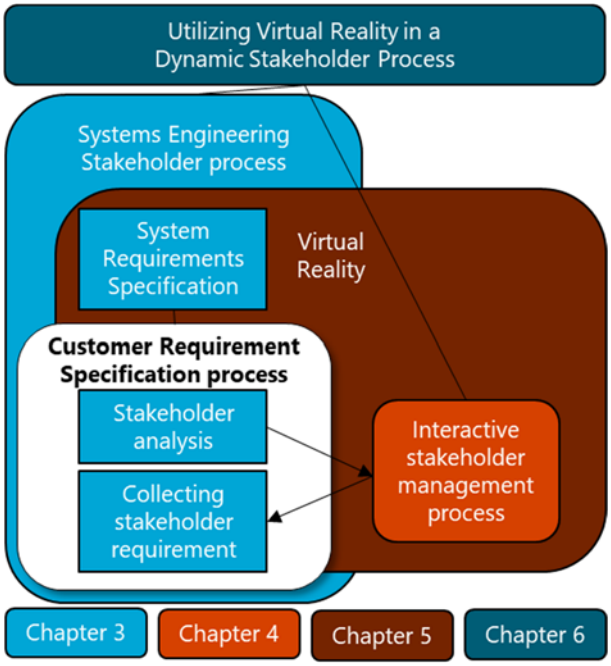

Figure 3, the concepts covered in this thesis.

SE includes analysing all the stakeholders of the project. Interactive stakeholder management process contains all the interactions with the stakeholders. Part of SE is documenting all the needs of stakeholders in the CRS process. VR is used as a tool in the stakeholder process and therefore effects the CRS. The contracting authority decides which requirements in the CRS are included in the system requirement specification (SRS). The SRS contains all the requirements of the system and can be used as the input for making the VR.

Chapter 3 elaborates on the first concept. SE is defined after which the application of the key principles in the stakeholder process is elaborated on. Chapter 4 elaborates on the second concept. Interactive management is defined after which the application of the key principles are elaborated on. Chapter 5 elaborates on the third concept, VR is defined after which different types of VR are explained, and the state of art application of VR in the stakeholder process is given. Chapter 6 gives the conclusion of the literature study and provides the framework used in the case studies.

Several case studies in combination with interviews and data analysis will then provide insight in how VR is used as a tool in the dynamic stakeholder process and explores what the added value of VR to the stakeholder process is. In total three projects are studied which are elaborated on in chapters 7,8 and 9. Chapter 10 consists of the cross-case analysis. After this thesis gives conclusions and recommendations in chapter 11.

2 RESEARCH DESIGN

2.1 Research objective

This thesis will give the reader insight into how VR is applied in the stakeholder process of complex infrastructure projects. The goal of this thesis is to explore the added value of using VR in the stakeholder process for complex infrastructure projects.

2.2 Research questions

What is the added value of Virtual Reality in the stakeholder process of complex infrastructure projects?

Sub-questions

1. How is Virtual Reality applied in the stakeholder process for complex infrastructure projects?
2. Does the use of VR in the stakeholder process improve the project design?
3. Does the use of VR in the stakeholder process lead to more stakeholder satisfaction?
4. Does the use of VR in the stakeholder process improve the efficiency?
5. Does the use of VR in the stakeholder process help to cope with the identified threats?

2.3 Research Relevance

This thesis has both scientific and societal relevance.

Scientific relevance

This thesis contributes to the field of dynamic management of infrastructure. It elaborates on the dynamic stakeholder process and provides the reader with the key principles of SE in the stakeholder management process and the key principles of interactive stakeholder management. VR is currently applied as a tool in the dynamic stakeholder process, but the benefits are unclear. This thesis will solve the knowledge gap that is now present and provides the reader with the added value of the use of VR in the dynamic stakeholder process.

Societal relevance

A successful stakeholder process improves the design and leads to a more supported design for civil projects. Furthermore, a lot of infrastructure projects are commissioned by the Dutch government.
According to Eelco de Groot, a lecturer at the TU Delft in the field of public acceptation and risk management among other things, the Netherlands can save hundreds of millions of euros of tax money if residents are earlier and better involved in projects that have an impact in their neighbourhood (Van der Ploeg, 2018). The society benefits directly and indirectly of improvements of the stakeholder process.

2.4 Scope

Infrastructure projects are often managed with an integrated approach with five disciplines. These disciplines are project management, contract management, technical management, risk management and process management. This thesis focusses on process management of complex infrastructure projects. Process management includes managing the decision making during the project while consulting stakeholders and negotiate with them (de Bruijn & ten Heuvelhof, 2008). For the stakeholder process of complex infrastructure projects to be successful a dynamic stakeholder process is required. This process consists of a SE stakeholder process and interactive stakeholder management. The contribution of VR to this process is elaborated on.

Application of VR in the other domains is out of the scope of this thesis. In the technical domain, one can think of methods of VR used to identify technical requirements. For example, the use of VR by constructors to determine how the project can be executed. In the project management domain, VR could, for instance, play a role in improving the project planning or improving the distribution of material by using a VR of the construction site (for example see Wang, Zhang, Chau, & Anson, 2004).

Figure 4 shows a broad classification of shared spaces among the dimensions artificiality and transportation. Shared space is any place where people have a common spatial frame of reference (Benford, Greenhalgh, Reynard, Brown & Koleva, 1998). This research focusses on VR since it deals with stakeholder management for new infrastructure projects which therefore involves a not yet existing environment and requires high artificiality and transportation. High artificiality entails that the shared space is developed from computer data instead of from the real word (Benford, Greenhalgh, Reynard, Brown & Koleva, 1998). A project design is made with a computer which makes augmented or virtual reality two options for the shared spaces. The difference between VR and Augmented Reality is the level of transportation. With VR people leave the physical world behind while Augmented Reality compliments on the real world. When there is a built environment present, using augmented reality might be complicated. Due to this and due to VR being further developed, VR is already applied in the stakeholder process; this thesis will only discuss VR.

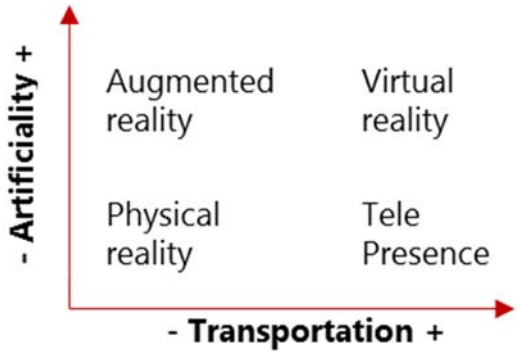

Figure 4, broad classification of shared spaces based on (Benford, Greenhalgh, Reynard, Brown & Koleva, 1998). Artificiality is high when the shared space is generated from computer data and low when it is made from the real world. Transportation is high when people leave the physical world behind.

2.5 Methodology

A pragmatic research approach was used since the different research questions ask for different research methods (Howitt & Cramer, 2011).

2.5.1 Part 1 Literature study

In this thesis was focussed on applying VR as a tool in the stakeholder process of complex infrastructure projects. For complex infrastructure projects, the stakeholder process consists of the CRS process which manages all the customer requirements and an interactive stakeholder management process.

A literature study was performed which elaborated on three concepts, 1) SE stakeholder process, 2) Interactive stakeholder management process and 3) Virtual Reality. In the literature study, the research topics were first broadly explored to see how these topics relate. The literature study provides insight into the key elements of dynamic stakeholder management and how VR can be applied in this process. Literature recommended by the supervisors, other students and master theses with similar research topics were the basis of this. Additional keywords relevant to this thesis were found by using Scopus and limited to the subject area's appropriate for this thesis. Keywords were used to find more articles about the research topic by making use of google scholar focussing on the most cited articles. Keywords relevant to this thesis are shown in Appendix A.

2.5.2 Part 2 Case studies

Case studies are helpful when trying to understand complex socials phenomena (Yin, 2017). Case studies are descriptive and exploratory with the aim to establish a link between the causes and the effects (Howitt & Cramer, 2011). The purpose was to find out what happened and discovering factors of process success that were influenced by the use of VR in the stakeholder process. Many different variables can cause the process to be successful which cannot be held constant. This makes it hard to use quantitative methods to infer causality that using VR leads to a successful stakeholder process. Besides that, VR has only been used in a few complex projects which makes this research more of explorative nature. Qualitative research is, therefore, a suitable approach for this thesis to discover the factors which cause VR to have added value for the stakeholder process or not. The cases are studies by means of document analysis and interviews.

Selection criteria

This thesis was focussed on complex infrastructure projects. Three complex infrastructure projects in which Witteveen+Bos applied VR in the stakeholder process were selected. Convenience sampling was used to select the interviewees. Interviews were held with important stakeholders and the key people in the project team which were the project managers from Witteveen+Bos and the contracting authority. In this way, the project and process success and the added value of VR are assessed from three different perspectives.

Interviewees

Interviewees A9 project

CA-A9	Process manager Contracting Authority: RWS.
PM-A9	Process manager Witteveen+Bos.
IS-A9	Important stakeholder Gemeente Amstelveen.

Interviewees Vestdijk project

CA-Ve	Project manager Contracting Authority: Municipality Eindhoven.
PM1-VE	Project manager: Witteveen+Bos.
PM2-VE	Project manager: Witteveen+Bos.
IS1-VE	Important stakeholder: Fietsersbond.
IS2-VE	Important stakeholder: Pullman hotel.

Interviewees Zaanenstraat project

PM-Za	Project manager: Witteveen+Bos.
CA-Za	Process manager Contracting Authority: Gemeente Haarlem.
CA-Za	Process manager Contracting Authority: Gemeente Haarlem.
CA-Za	Communication advisor Contracting Authority: Gemeente Haarlem.
IS-Za	Important stakeholder: Vrije school Kennemerland.

Interview method

A semi-structured interview was used. Semi-structured interviews have the advantage that one can explain complex definitions and let the interviewee elaborate more on a particular topic when this seems essential. By doing so, the lack of structure creates "richer" data (Howitt & Cramer, 2011). Face-to-face interviews were used since this improves the control over the data-collection (Howitt & Cramer, 2011). The result of the interviews must lead to a rich description of the case.

Interview protocol

The interview questions were elaborated on by the thesis supervisors, and a pilot interview was held to validate the items used in the interview (See Appendix B). After the test interview, the questions were adjusted resulting in the interview protocol shown in Appendix C. This protocol was used as a guideline for the interview. The interviews were however responsive; the interview questions differ per interviewee since the questions depend on the answers of the interviewee. During the interview, a checklist was used to see if all the subjects were covered during the interview.

Procedure interview

The interviewee first signed an informed consent form (See Appendix H). Informed consent is the principle that people give consent to take part in the research (Howitt & Cramer, 2011). After signing the informed consent, the interviewee was explained that they are questioned about a specific project. The first part of the interview was used to elaborate on the context of the project. The context of the project consisted of the elaboration on the project, elaboration on the process and elaboration on the use of VR. This part was important to underpin the project and process success, discover the purpose of using VR in the project and discover the criteria for a tool to be successful.

The second part of the interview was used to elaborate on the aspects of added value that are defined in chapter 6.2 as important values for a successful stakeholder process. The interviewee is asked if the use of VR in the stakeholder process contributed to an improvement of the design, stakeholder satisfaction and the efficiency of the process.

In the third part of the interview, the cope with threats was evaluated by the interviewee. The interviewee was first asked to identify the risks of involving stakeholders in an infrastructure project. A bowtie diagram with the risks of stakeholder involvement identified from literature is showed to the interviewee (See appendix). Since a risk will not always fire and there are only three cases studied, the approach of elaborating on the cope with threats is made in general instead of specific to the case. The cope with threat is evaluated to validate the framework of risks identified from the literature. The goal of this is to discuss what the impact of using VR is on these risks. Additional risks that are not covered in the introduction are discussed in the cross-case analysis.

Analysing the qualitative data

A low detailed Jefferson transcription was used to transcribe the interview data. Using Jefferson transcription gives more information about what happened in the conversation, helps to get familiar with the data and makes the text easy to refer to during the analysis (Howitt & Cramer, 2011). After transcribing the data, the data was coded using the programme Atlas.ti. The codes represented the essence of what the interviewee said and made the data more manageable. The codes were combined into a theme. The following themes were used based on the literature study and the test interview (See Appendix B):

1. Background: Project goal
2. Background: VR purpose
3. Background: Complexity
4. Background: Elaboration project
5. Background: Elaboration project
6. Background: Elaboration success stakeholder process
7. Pros of using VR in the stakeholder process.
8. Cons of using VR in the stakeholder process.
9. Stakeholder satisfaction.
10. Improvement of the design.
11. Efficient process.
12. Risks: risks of involving stakeholders.
13. Risks: measures to avoid.
14. Risks: measures to reduce.
15. Risks: a negative influence on risk event.

By doing the thematic analysis, factors that are important for VR adding value to the stakeholder process per case are identified.

Document review

Additional documents are used to understand the project and to make the case description. The CRS is used to validate the allegations of the interviewees and to evaluate the improvement of the design and the efficiency. The efficiency of the process itself is assessed by identifying waste in the stakeholder process (see chapter 6.2.4.).

Validation case study

With the project managers, a validation session is held. The case study is discussed with the project manager to review the case study, the conclusions, the recommendations and the pros and cons that they gave during the interview.

2.5.3 Cross-case analysis

A cross-case analysis was done to see both the similarities and differences between the cases in order to give a more general conclusion. A cross-case comparison is made by looking at the predefined aspects of added value. General conclusions are given on these aspects of added value. Furthermore, a decision-making framework is created to evaluate the use of a tool in the stakeholder process. In the case study research, the interviewees are asked about the goal of the stakeholder process. This is done to check if the goal for the stakeholder process that is assumed to be improve the design and stakeholder satisfaction is in line with the goal of the stakeholder process mentioned by the interviewees. The success factors for the stakeholder process mentioned by the interviewees are combined into general success factors for the stakeholder process. The use of VR is evaluated by using this framework. First, the intended use is discussed after which the actual result is discussed, and finally, the future possibilities are discussed.

Part 1 Literature Review

3 SYSTEMS ENGINEERING STAKEHOLDER PROCESS

This chapter describes the stakeholder process when using SE. SE is defined, and the key principles of SE and their relation with the stakeholder process is explained. The different steps of the CRS are elaborated on. This chapter gives practical advice to apply SE in the stakeholder process successfully.

3.1 Defining systems engineering

According to Wasson (2006): "Systems engineering is a multidisciplinary application of analytical, mathematical, and scientific principles to formulate, select and develop a solution that has acceptable risks, satisfies the user operational need(s) and minimises the development and life-cycle costs."

Just under a decade ago SE was introduced in the civil industry to deal with the increased complexity of its projects (Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen, 2013). System engineering is used to deal with detail complexity (Hertogh & Westerveld, 2010). Detail complexity is the type of complexity that is caused by the interrelated parts of which the project consists and can cause rework and higher costs when interfaces between the interrelated parts are not well managed (Hertogh & Westerveld, 2010). SE is an effective way to split up the project into more manageable components and effectively communicate information about the interrelated parts (Bakker, Hertogh & Bosch-Rekveldt, 2013).

Figure 5 shows the process of how an infrastructure project is conducted with a SE approach. An infrastructure project starts with an initiative from an institution such as Rijkswaterstaat (RWS), a municipality or a private initiator. This initiating party is called the contracting authority. RWS is the executing governmental organisation for the ministry of infrastructure. RWS is the largest infrastructure contracting authority in the Netherlands and requires the use of SE from its contractors. Due to that, many companies in the infrastructure industry use SE to manage their projects. Consultancy firms can support the contracting authority, the contractor or both.

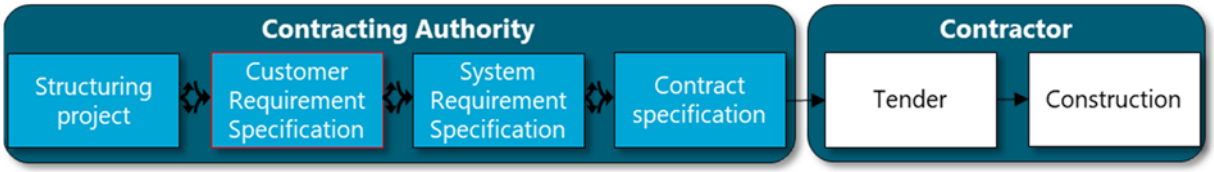

Figure 5, process description of infrastructure projects when using systems engineering.

3.2 Key principles of systems engineering

With SE customer needs have a central position. In this chapter, the key principles of SE and their relation with the stakeholder process are discussed. The key elements of the SE school of thought are *optimisation throughout the life cycle*, *system thinking*, *a central position for customer needs*, *top-down specification* and *explicit working* (Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen, 2013). The key principles are written in *italic*, to make clear when there is referred to these key principles.

3.2.1 Optimisation throughout the lifecycle

With SE the design for the project must be the optimal solution for taking the entire lifecycle of the project into account. According to Wasson (2006), every system completes five phases during its life cycles,

1. Definition
2. Procurement
3. Development
4. Operation & Support
5. Disposal

The definition phase for a civil project includes structuring the project and defines the CRS and the SRS. The procurement consists of the contract specification and the tender. The development phase consists of all the activities that are required to meet the deliverables of the contract, with the objective to create a system that satisfies the SRS. The operation and support phase include the time that the system is in use after which the system is disposed of.

Optimisation throughout the lifecycle can reduce short-term benefits that are not favourable in the long term (Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen, 2013). The interest and role of the stakeholders can be different per phase of the project. Involving stakeholders that are important in a later stage already in the definition phase can resolve issues later on (Nicholas & Steyn, 2012). *Optimisation throughout the lifecycle* does involve an awareness that the environment can continuously change during the lifecycle (Van Son, 2013).

3.2.2 System thinking

System thinking requires people to realise that the project is part of a more extensive system which has interfaces with the project. The project has to take this larger system into account when a design is made. With SE a project is defined as a system that consists of elements that have a mutual relationship and accomplish a defined objective (Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen, 2013). All the functions that the system needs to fulfil are documented in the SRS. The SRS is a combination of technical requirements, interface requirements, aspect requirements and customer requirements,

When executing a project, the system that is designed is called the System of interest. Every system has relations with other systems and is a subsystem for a larger whole, for example, a bridge system is part of the transport system. With *system thinking* this larger whole is taken into account together with all including parties involved.

A tube model can be made for the system of interest to give an overview how the system of interest fits in the larger whole which helps to identify the systems influenced by the project and the stakeholders belonging to these systems (see Figure 6).

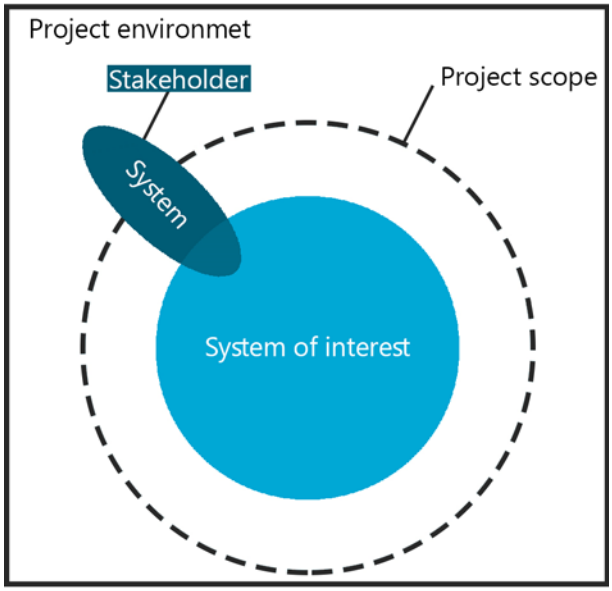

Figure 6, tube model.

3.2.3 A central position for customer needs

The solution space is all the solutions that fulfil the system requirements limited by physical boundaries, guidelines, standards, time and budget (Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen, 2013). In other words, the solution space consists of all the different execution options of the project that fulfil the requirement. With SE customer needs have a central position and form the basis for the solution space for the project. The needs of the customer must be used as a guiding star to the designers (Baarends, 2015). The solution space for the project can be different for every stakeholder. Figure 7 shows a visual representation of a solution space based on the needs of three stakeholders. Every stakeholder interested in the project sees the problem from another perspective and has another preferred solution (de Bruijn & ten Heuvelhof, 2008). In this example SP A represents the solutions that satisfy the needs of stakeholder A, which is called the solution space of A. The magenta and white square are the only solutions to the project that meet the needs of both A and B. Adding a third stakeholder to this example, result in only the white square of possible solutions to the project. The white square represents all possible solutions for the project which satisfy the customer needs and is called the solution space to the project. This example only shows the solution space with regards to stakeholders. The real solution space of the project contains all variables and will, therefore, be smaller. In other words, not all the solutions accepted by the stakeholders are realistic for the project. When the project matures, decisions are made which narrows down the solution space.

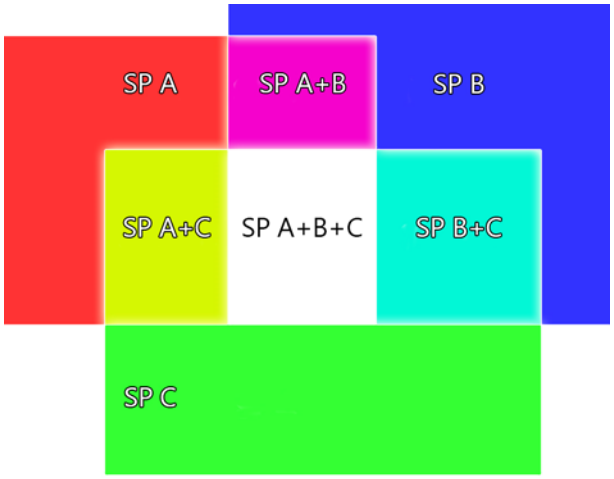

Figure 7, a visual representation of the solution space.

3.2.4 Top-down specification

With SE requirements are used to make a design. *Top-down specification* starts with the mission, vision and ambition and ends with a specific solution. The left side of the model shows the requirements, the right side of the model shows the design (see Figure 8).

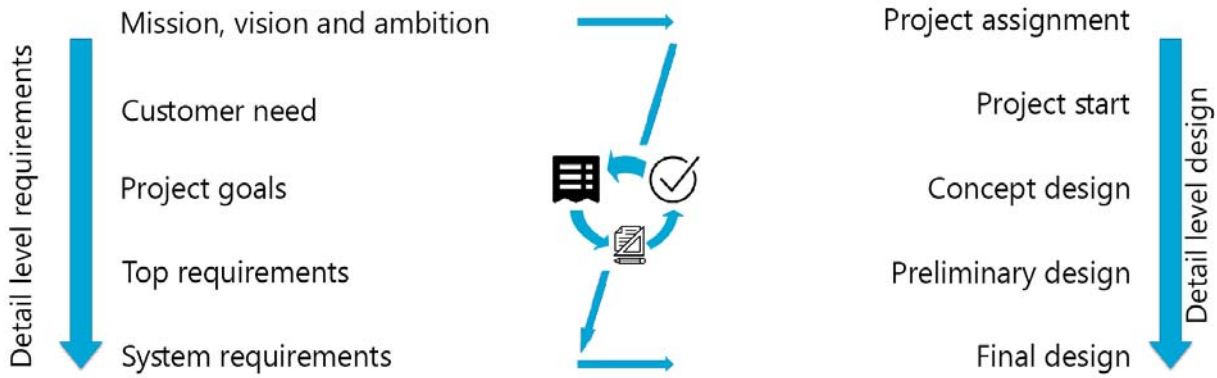

Figure 8, top-down specification.

A civil project starts with a client that has a mission, vision and ambition. The client defines the need for the civil project. From these need the project goals are set. The project goals are used to start with the concept design. Via *top-down specification*, the project requirements will be specified in more detail which results in all the system requirements that the system needs to fulfil. The right side indicates the integration into a system that meets the requirements (Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen, 2013). At the start of the project, requirements do not have to be Specific, Measurable, Acceptable, Realistic and Time-bound (SMART) since this will lead to a lot of detailed requirements (Baarends, 2015). The level of SMARTness should depend on the phase of the project and should be determined by the process and project manager together.

The requirements are verified in the design, and the client validates the design. According to Wasson (2006), verification covers if the system meets the need and validation checks whether the right system was chosen to fulfil this need. With regards to the customer requirements verification covers if the solution satisfies customer need. For verification, it is essential that the requirement has the right level of detail (Wasson, 2006). For every requirement, a verification method must be selected. There are different verification methods possible for example inspection, analysis, demonstration, test, certification, similarity, simulation, validation of records or verification via child requirement (Wasson, 2006). Defining the verification method is a way to assure a legitimate basis of the requirement. When it is not possible to identify a test plan the requirement must be rewritten. Validation checks whether the customer needs are right. The validation is done by the contracting authority, who checks whether the project delivers the promised performance. For validation, it is essential that the requirement fits in the objective of the system (Wasson, 2006).

By means of verification, specification and design the project evolve from a mission, vision and demand in the top left corner to a final design in the down left corner.

3.2.5 Explicit working

Explicit information handling is necessary between different parties and during different phases. It must be possible to communicate project information transparently, systems such as Relatics can be used to manage all project information. A customer requirement specification (CRS) document is made that entails the collection and managing of all the customer requirements. This document includes all the decisions on customer requirements. The stakeholders that gave a customer requirements must be notified what happened with his customer requirement.

3.3 Customer requirement specification process

The CRS process starts after the project is structured (see Figure 9). In the structuring phase, the client defined the mission, vision, ambition and the need for the project. The Project Management Plan is the result of structuring the project.

Figure 9 shows the seven steps of the customer requirement process; there are no straight arrows between the different process steps but arrows that diverge and then arrows that converge. This represents that there is no single outcome of each process step instead every step in the process is broadly explored after which decisions are made to narrow it down, and the next step of the process starts (van Oosterhout, 2010).

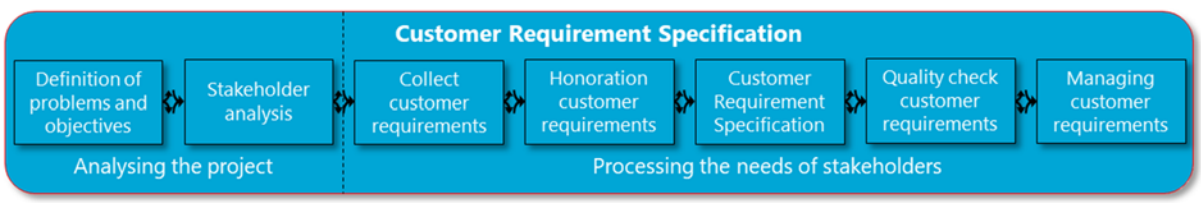

Figure 9, customer Requirement Specification process translated from Kramer (2017).

The customer requirement specification starts with analysing the project. First, the problems and objectives are defined, and a stakeholder analysis is done. After analysing the project, the stakeholders are involved, and the needs of the stakeholders are processed. The seven different steps of the stakeholder process are further elaborated below.

3.3.1 Definition of problems and objectives

The first step of the process is defining the problems and objectives (see Figure 10). The goal of this step is to discover the problems of the project and the objectives of the project (Kramer, 2017).

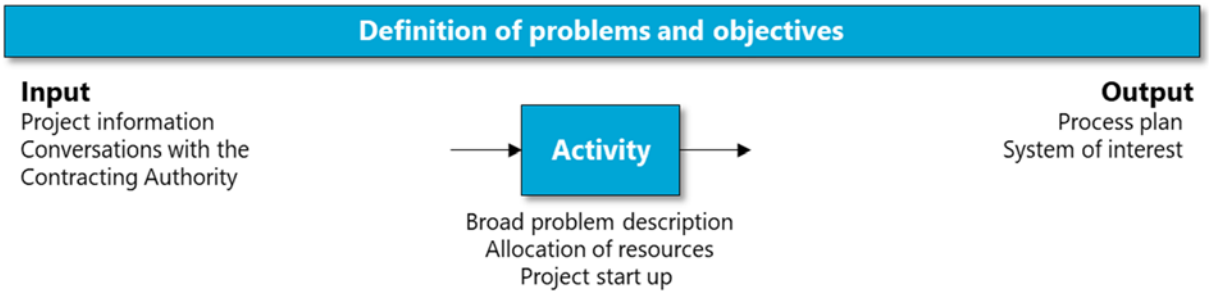

Figure 10, process description definition of problems and objectives.

Different stakeholders have a different perception of the problem. Raising complexity by a broad problem description can result in an easier decision-making process since this gives room for negotiation. However, too vague and unclear definition of the problems might result in stakeholders doubting the use of cooperation. The sources indicating the problems must be documented to improve the traceability.

The project manager must incorporate sufficient resources for the process of collecting requirements and the project design and estimates the time required for the process and adds this to the project planning. Incorporating sufficient resources at the start is difficult since it is not clear which information is needed to come to a decision and how long the process will take (De Bruijn & Ten Heuvelhof, 2008). Room for slack time must be incorporated in the plan since tight planning will limit the room for negotiation. Plans, deadlines and milestones can weaken the negotiation between stakeholders.

A project start-up can be done to form a committed team and to create a common view of the project plan, decision making and the honoration of requirements (Baarends, 2015). This project start-up can give more clarity about the responsibility's and improves the communication which can reduce delays. The project start-up can also function as a check to see if the team is appropriate for the project. The team must be interdisciplinary enough to deal with multiple domains of the project such as the technical, social and cultural domain. When the project team is only focussed on one domain, it will lead to an incomplete set of requirements.

A process plan must be incorporated into the Project Management plan which specifies the problems, objectives, roles, tasks, positions, information distribution, decision making and planning. The process plan needs to be communicated transparently to the stakeholders (Baarends, 2015).

3.3.2 Stakeholder analysis

The second step of the process is the stakeholder analysis (see Figure 11). The goal of this step is to discover what the stakeholders of the project and their interest and power (Kramer, 2017). This is required to make a strategy for the interactive stakeholder management process.

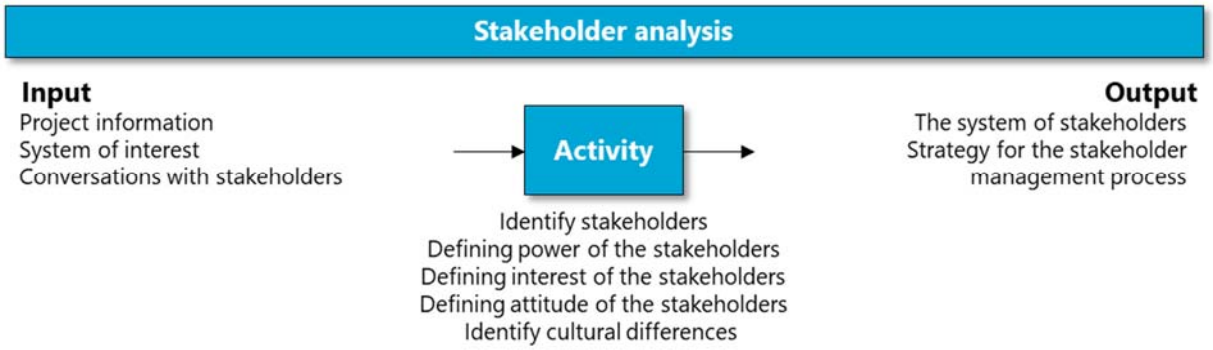

Figure 11, process description stakeholder analysis.

In the stakeholder process many different types of stakeholders can exist, for example, the contractor, the contracting authority, government organisations, the owner, the operator, the users, organisations, businesses etc. It is important to identify for every stakeholder, the relationships with other stakeholders, core values, power, attitude, interest and culture. This classification is required to make a strategy for managing the stakeholder process which is discussed in chapter 4.3.

According to Baxter and Sommerville (2011), the identification of the system of stakeholders often goes wrong. There are different methods to categorise stakeholders. One way is categorizing stakeholders based on Murray-Webster & Simon (2006). According to Murray-Webster & Simon (2006) power, interest and attitude are the three most important dimensions when considering stakeholders for a project. Power is having the resources or having a position to influence the project. Two types of power can be distinguished (De Bruijn & Ten Heuvelhof, 2008), production power and blocking power. Production power means that a stakeholder will make funds available when desires are satisfied. Blocking power means that a stakeholder can halt the decision making. Interest is how active the stakeholder tries to influence the project. Attitude is whether a stakeholder supports or resist the project. Figure 12 shows the dimensions and a categorisation among these dimensions. This categorisation can make communication easier and can be used to make a strategy for the interactive stakeholder management process.

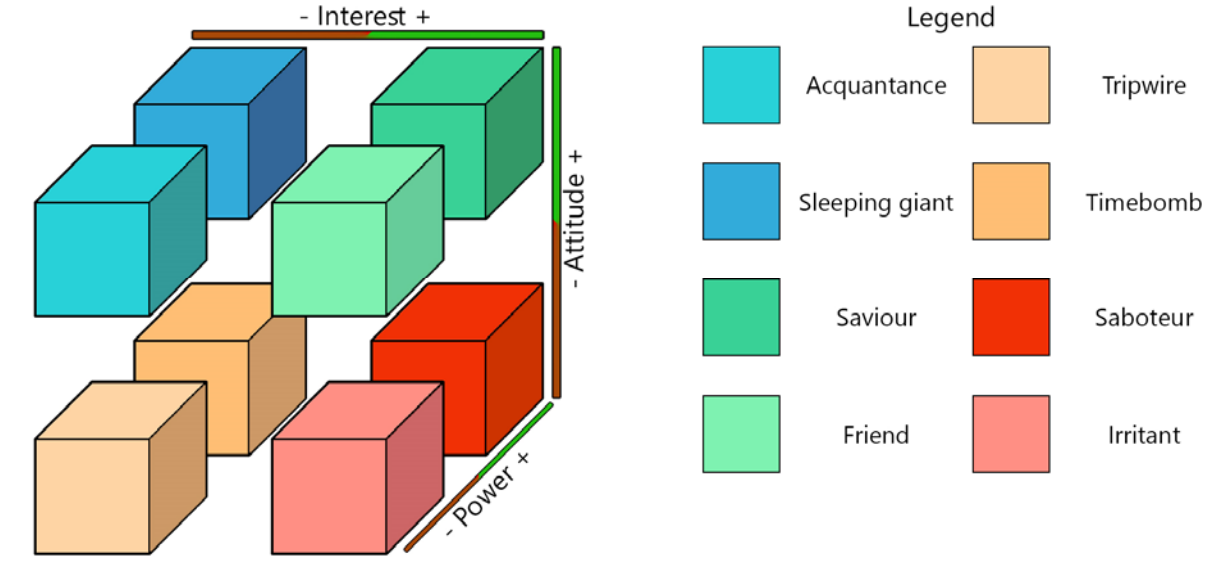

Figure 12, visualization of stakeholder categories based on Murray-Webster & Simon (2006).

Hofstede, Hofstede & Minkov (2010) identified five cultural dimensions, power distance, collectivism, masculinity, uncertainty avoidance and long/short-term orientation. These Cultural differences can be identified by using these dimensions (See Table 1).

Table 1, different cultural ideals based on Hofstede, Hofstede & Minkov (2010)

Dimension	Explanation	Level	Example ideals
Power distance	The extent to which less powerful people accept and expect unequal power distribution.	High	Inequalities between people are desirable.
		Low	Inequalities between people must be minimized.
Collectivism	Importance of a group versus the importance of the individual.	High	In-group members get better treatment than people outside the group.
		Low	Individualistic, people should get the same treatment.
Masculinity	The extent to which gender roles are distinct.	High	Support the strong.
		Low	Feminine, help the needy.
Uncertainty avoidance	the extent to which the members of a culture feel threatened by ambiguous or unknown situations.	High	A strong belief in experts and technical solutions.
		Low	A strong belief in common sense and generalists.
Long/short-term orientation	Respectively fosters virtues that are oriented toward future rewards and are oriented to the past and present.	Long-term	Importance of future benefits.
		Short term	Importance of this year benefits.

The stakeholder analysis must repeatedly be performed. It can occur that during the interviews with the stakeholders one discovers that important stakeholders are missing in the stakeholder analyses which need to be included or that the attitude of a stakeholder has changed.

3.3.3 Collect customer requirements

The third step of the process is collecting customer requirements (see Figure 13). The goal of this step is to collect and document all customer desires (Kramer, 2017).

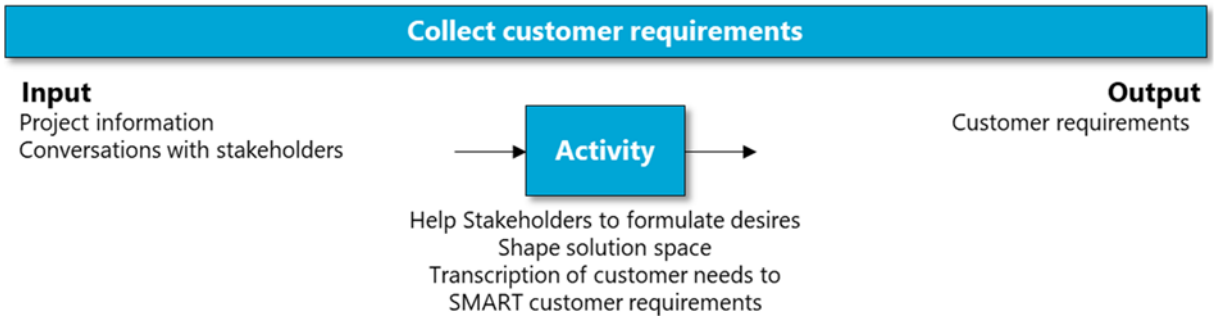

Figure 13, process description collect customer requirements.

The process manager helps stakeholders to formulate desires and gives the stakeholders insight into the consequences of their desires. The task of the process manager is to shape the solution space given by the stakeholders. The process manager must be aware that these stakeholders might use the CRS-process to accomplish goals outside the scope of the project (Baarends, 2015). In order to create requirements that a designer can use, unstructured ideas of stakeholders must be translated into problems, objectives and needs (Nicholas & Steyn, 2012). These needs of the stakeholders form the basis of the customer requirement (Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen, 2013). The customer requirements must be unique. Each requirement has a specific objective and serves to specify

the system to be developed (Wasson, 2006). Needs that are identical are combined into one customer requirement. The skills of the process manager are essential to collect as little irrelevant requirements to the project as possible. These needs have to be transcribed to SMART customer requirements to be useful for the designers. For the level of SMARTness of the requirements, there is a tension between the contracting authority and the contractor. The contracting authority wants vague requirements since this gives him room for negotiation to explore other options where the contractor wants the requirements to be as specific as possible (Baarends, 2015).

3.3.4 Honoration of customer requirements

The fourth step of the process is honouring customer requirements (see Figure 14). The goal of this step is to select all customer requirements that will be used in the design (Kramer, 2017).

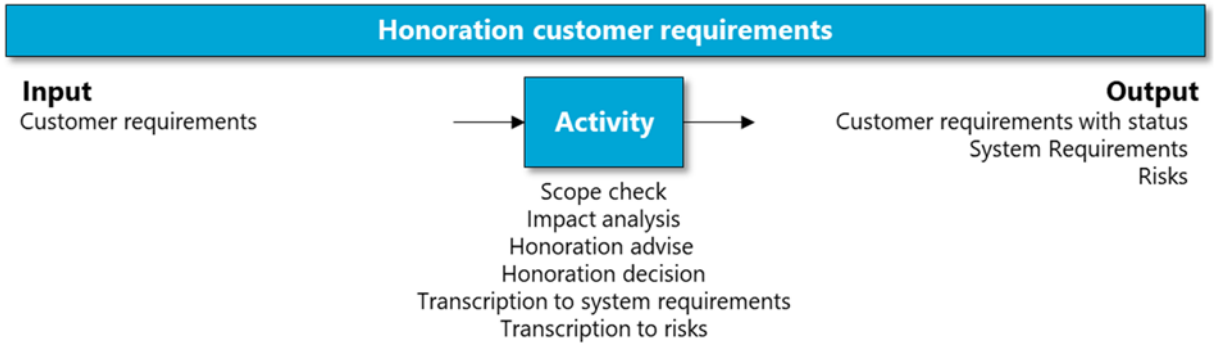

Figure 14, process description honoration customer requirements.

All the customer requirements will get one of the five statuses: Not processed, honoured, conditionally honoured, rejected, and secured. The status secured means that the requirement is already met, for example, due to legislation or due to another requirement. The requirements that are not relevant for the current design cycle have the status not processed so that they can be evaluated later. With the honoration process, each customer requirement will be reviewed based on a scope check and an impact analysis (Kramer, 2017). Requirements that are not within the scope need to be considered during a scoping study (Baarends, 2015). For the impact analysis, variables need to be determined beforehand on which the honoration decision will be made, for example, time and costs.

Customer requirements that can lead to risks for the project are documented in the risk register (Kramer, 2017). The honoured customer requirements are transcribed to system requirements which are included in the SRS. The stakeholders must validate the system requirements.

Consultancy firms can help the contracting authority with the honoration of customer requirements. These consultancy firms can make the honoration decision for requirements that are within the assignment or give an honoration advice to the client based on the scope check and impact analysis.

3.3.5 Customer requirement specification

The fifth step of the process is making the CRS document (see Figure 15). The goal of this step is to document all customer requirements that will be used in the design (Kramer, 2017).

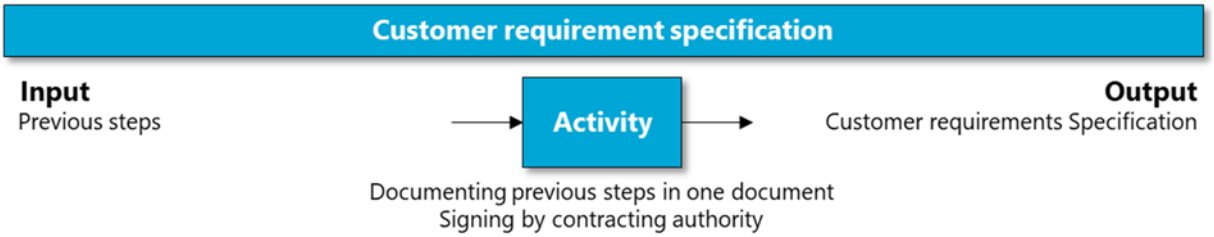

Figure 15, process description customer requirement specification.

The CRS document entails all the information of the previous steps in one document which include the objectives, problems, stakeholder analysis, methods of stakeholder involvement used and all the customer requirements. Table 2 shows a standard format of the information that is provided in the CRS document per customer requirement. Every customer requirement gets a code. When a customer requirement is (partly) honoured it will become part of the system requirements. A system requirement is written for these requirements.

Table 2, format customer requirement in the customer requirement specification.

Code	Title	Defined in System Requirement	Stakeholder
CR-XXXX	Title requirement.	SR-XXXX	Name of the stakeholder.
Explanation	An explanation of what the requirement entails		
Status	status of the requirement.	Date	application date requirement.
Explanation	An explanation of why the requirement is honoured/ partially honoured/ rejected or secured.		
Validation	Which validation method that is used: inspection/ analysis/ test/ demonstration/ analogy/ simulation/ sampling/ through child requirements.		
Source	The reference document		

3.3.6 Quality check

The sixth step of the process is checking the quality of the CRS document (see Figure 16). The goal of this step is to check the quality of the customer requirements specification.

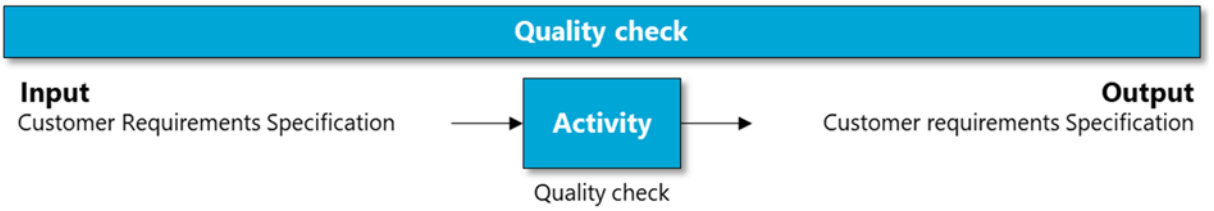

Figure 16, process description quality check.

Reviewing the customer requirements must be done carefully to prevent irrelevant requirements in the CRS (Hooks, 1994). During the project, customer requirements can change due to changing interests and is therefore not a static document. The requirements are audited and updated by different people in the organisation. Common mistakes in defining the customer requirement specification are duplicated, missing or misplaced, and conflicting requirements (Wasson, 2006).

3.3.7 Managing customer requirement specification

The seventh step of the process is managing the CRS document (see Figure 17). The goal of this step is managing all changes in the customer requirements specification.

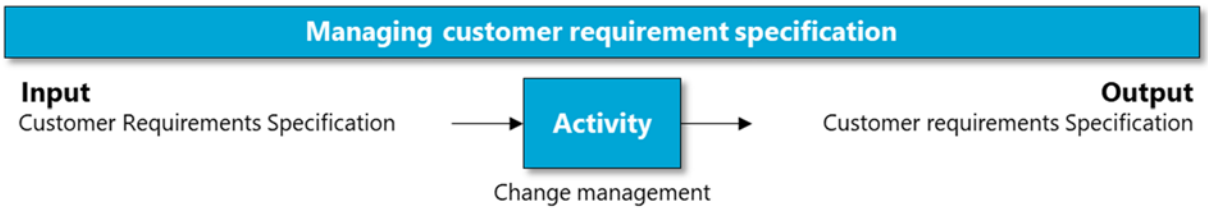

Figure 17, process description managing customer requirement specification.

Defining the CRS is a continuous process (Kramer, 2017). In every process phase, when discovering new stakeholders or needs, the CRS must be revised. Change management is necessary to track and implement changes in the document immediately and notify all the stakeholders if changes occur (Wasson, 2006). The version number of the document needs to be adjusted accordingly. For example, changing the document version from v1.0 to v1.1 when changes within requirements occur and changing the version v1.0 to v2.0 when adding new customer requirements. The changes regarding the previous version must be documented in the customer requirement specification.

3.4 State of the art application of Systems engineering in the dynamic stakeholder process

Five key elements of systems engineering are described. The dynamic stakeholder process starts with analysing the project these are the first two steps of the CRS process and result in a process plan, the system of interest, the system of stakeholders and a strategy for the stakeholder management process. With the dynamic management process, the interactive stakeholder management is used which will be elaborated on in the next chapter. The input of the stakeholders is processed by using systems engineering. All the relevant needs are transcribed to SMART customer requirements and can be implemented to improve the design.

4 INTERACTIVE STAKEHOLDER MANAGEMENT PROCESS

This chapter defines interactive stakeholder management and describes the key principles of an interactive stakeholder management process and elaborates which strategy to use. This chapter gives practical advice to apply an interactive stakeholder management process successfully.

4.1 Defining interactive stakeholder management

Interactive management is defined as a stakeholder management process with a high level of stakeholder involvement during the entire project. Interactive stakeholder management is necessary to deal with dynamic complexity. Dynamic complexity is characterized by limited understanding, limited predictability and the tendency of the project to change over time (Hertogh & Westerveld, 2010). Dynamic complexity can cause late scope changes, discussions about need and necessity and sometimes even termination of the project (Hertogh & Westerveld, 2010). Due to this complexity, there is no consensus about the problem at hand and no unambiguous substantive solution to the project (Bruijn, ten Heuvelhof & in 't Veld, 2008).

Using an interactive stakeholder management process results in negotiated knowledge about the purpose of the project, the weighing criteria and the data that must be used to make decisions (de Bruijn & ten Heuvelhof, 2008). Involving a diverse group of stakeholders that represent all interests can lead to synergy, better decisions and contributes to public acceptance which can make the project realisation easier (Raats, van Gelder, Post, Koppenjan, Houben & Weusting, 2010; Voinov & Bousquet, 2010).

It is not always possible to have a successful process since there is also a luck factor present, it takes only a few important stakeholders with an obstructionist position to damage the process (Voinov & Bousquet, 2010). Stakeholders will behave strategically and will try to maximise their interest in every issue. Different forms of strategic behaviour can be noticed during the process, for example, lying, holding back information, priming, threatening and coalition building. By using strategic behaviour, stakeholders can influence the decision making by changing the gain or loss perspective of other stakeholders. The strategic behaviour is however allowed and is even necessary for stakeholders to have a good process (De Bruijn & Ten Heuvelhof, 2008).

Stakeholders will face each other on different issues and can therefore not behave all the time strategically. They should act proportionately to remain their relation with the other stakeholders. The advantage of involving multiple stakeholders is that by creating multiple issues, deadlocks in the decision-making process can be prevented (De Bruijn & Ten Heuvelhof, 2008). If there is only one issue, stakeholders can have a different opinion about the issue which makes it hard to make a decision. Because the stakeholder process contains multiple issues and is repetitive, it creates the opportunity to exchange issues and make package deals with each other. The stakeholder management process can be frozen to make a decision after which the process continues. Formal decision making is only confirming the decisions made during the process.

4.2 Key principles of stakeholder process management

According to De Bruijn & Ten Heuvelhof (2008), stakeholders must respect the process and respect the other stakeholders. Respect for other stakeholders entails that stakeholders must not affect the core values of other stakeholders and use power in a reserved way. Interactive processes are not "self-executive" at least one person, the process manager, is needed to manage the process (Edelenbos & Klijn,2005). Respect the process entails that the process manager cannot change the procedure during the process and cannot negotiate on the same issue with multiple stakeholders at the same time without being transparent about this. The skills of the process manager are the boundary conditions for a successful process.

There is no such thing as the optimal process design since every process design will cease to be effective at some stage (de Bruijn, ten Heuvelhof & in 't Veld, 2008). Besides the skills of the process manager de Bruijn, ten Heuvelhof & in 't Veld (2008) defined four key elements for a good process *protection of core values*, *openness*, *progress* and *substance*. The key principles are written in *italic*, to make clear when there is referred to these key principles.

4.2.1 Protection of core values

The outcome of the process is uncertain due to the dynamics of the problems and therefore participating in the process can be risky. To make the process appealing for the stakeholders, their core values must be protected, and rules about the ability to leave the process must be present (de Bruijn, ten Heuvelhof & in 't Veld, 2008). Because different stakeholders have different problem perceptions, problems must be framed as dilemmas by the process manager. This helps stakeholders to put their view and core values into perspective. An important aspect of protecting core values is that stakeholders cannot be expected to commit to the outcome of the process beforehand. The outcome must be explained as a result of negotiation and therefore contain benefits and loses for stakeholders.

4.2.2 Openness

Openness means that the initiator offers the stakeholders the opportunity to steer the decision making and address issues that they find important (de Bruijn, ten Heuvelhof & in 't Veld, 2008). The process must be available for relevant stakeholders and the process. Stakeholders must be included on specific topics they find important. It is important that the stakeholders understand, the process organisation, the scope and subjects, the entry and exit rules, the decision making and how their core values are protected.

4.2.3 Progress

When stakeholders can benefit from the participation than the process will be attractive to join (de Bruijn, ten Heuvelhof & in 't Veld, 2008). The stakeholders must be able to identify opportunities and serve their interest. Early participation can be stimulated by letting early participants define the problems. The benefits for the stakeholders should however not be paid out too soon since this might reduce the incentive to cooperate.

Different problems will ask for attention at the same time, to resolve problems a sense of urgency among stakeholders is necessary. They should have a feeling that there is an issue that needs to be resolved by cooperating. An adequate authorisation of the process manager is required to make certain decisions and keep momentum.

4.2.4 Substance

Substance includes all the information used in the process and the project. Procedures must be set to create *substance* and discuss information (de Bruijn, ten Heuvelhof & in 't Veld, 2008). Experts can have a role to inform stakeholders. Knowledge and experience of users can also be valuable sources of knowledge for the project (Rydin, 2007). Users can be experts regarding their direct environment. The stakeholders make a selection of the information that is important for the project together.

4.3 Strategy for Managing stakeholders

The strategy for managing the stakeholders is based on the stakeholder analysis discussed in chapter 3.3.2. Table 3 shows how the different categories of stakeholders must be approached in the project according to the power, attitude and interest based on Murray-Webster & Simon (2006). All stakeholders with high power are seen as important stakeholders.

Table 3, stakeholder categories based on Murray-Webster & Simon (2006).

Category	Power	Interest	Attitude	Approach
Acquaintance	Low	Low	Positive	Inform them about the project.
Sleeping giant	High	Low	Positive	Engage them in the project.
Friend	Low	High	Positive	Use them for input on the project.
Saviour	High	High	Positive	Satisfy their needs.
Tripwire	Low	Low	Negative	Do not harm their core values.
Timebomb	High	Low	Negative	Satisfy their needs because these needs will keep their interest in the project low.
Irritant	Low	High	Negative	Do not harm their core values.
Saboteur	High	High	Negative	Try to change their attitude by engaging them in the project.

Relations with other actors can influence the attitude of a stakeholder. Stakeholders might have a negative attitude towards an issue because they do not want to hurt their relationship with another stakeholder (De Bruijn & Ten Heuvelhof, 2008). Changing the interdependencies can create favourable conditions for the decision making.

Cultural aspects can also influence the behaviour of stakeholders. Culture embodies the unwritten rules of social behaviour (Hofstede, Hofstede & Minkov, 2010). Cultural differences can lead to different expectations about the process, for example, there can be a difference in how business is discussed. It is essential to identify cultural differences when present in the project and adequately respond to this, for example by involving someone in the project that is familiar with this culture.

4.4 State of the art application of interactive management in the dynamic stakeholder process

By satisfying the key elements of interactive management the stakeholder process is made appealing to join and is available for all the relevant stakeholders. These stakeholders can deliver valuable input on items which they find important. Virtual Reality can be used in the stakeholder management process and will be elaborated on in the next chapter.

5 VIRTUAL REALITY

This chapter defines the VR together with the history and the development. The different types of VR are elaborated on. The state of art application of VR in the stakeholder process of complex infrastructure projects is described.

5.1 History and development virtual reality

The first appearance of the word virtual reality was a translation of the French phrase “la réalité virtuelle” used by Antonin Artaud in 1938 to describe the illusion of theatre (Artaud, 1958). Theatre combined “pure arts” such as painting that use only one sense into a “combined art” which uses multiple senses because people desired to transmit the full richness of experience (Heilig, 1955). Although one can argue that watching a play is not the same as experiencing something in real life, people do empathise with the characters in the play, and by doing so, one engages in the virtual reality of the play.

The development of machines changed the theatre since it became possible to fixate a creation by recording it with a camera and made it possible to watch the completely the same play again (Heilig, 1955). Improvements have been made ever since to reproduce peoples vision as closely as possible, first the addition of colour later the addition of widescreen and the first 3D films were already developed in 1900 (Heilig, 1955). Sound was added to movies to capture more consciousness. The information received by the eyes, ears, nose, mouth and skin can be perceived consciously although not all are perceived consciously at the same time (see Figure 18).

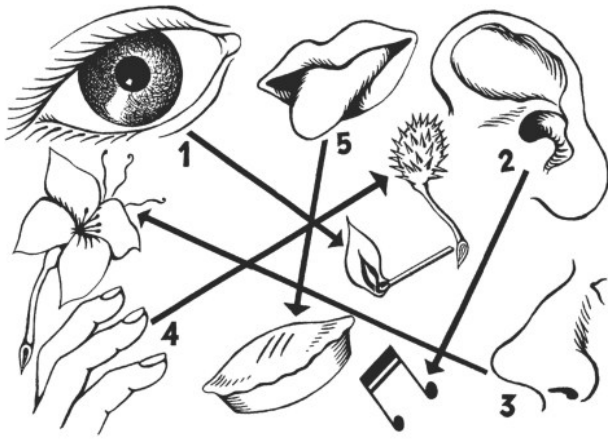

Figure 18, the order in which senses ask for attention is approximately 70% sight, 20% sound, 5% smell, 4% touch and 1% taste retrieved from Heilig. (1955).

Heilig (1955) saw the future cinema as a place where people can sense the world fully by 3D coloured vision, sounds, smell and feel of texture, temperature and pressure. Morton Heilig (1955): “We will feel physically and mentally transported into a new world.” Figure 19 shows the “Stereoscopic-television apparatus for individual use” that should give the user a complete sensation of reality that was patented by Morton Heilig in 1957 (United States of America Patentnr. US2955156A, 1957). Although it looks familiar to the current VR headsets, it was not a commercial success by that time.

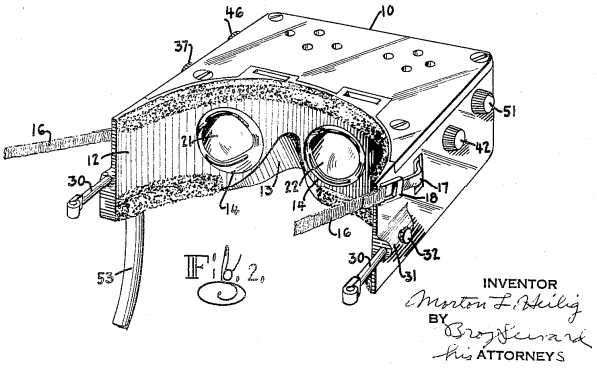

Figure 19, stereoscopic-television apparatus for individual use which creates an actual 3D image. It is formed by placing a small television tube before each eye which can show a film recorded by a different camera. One earpiece for each ear to experience stereophonic sound. One air duct before each nostril to provide sent, breeze and different temperatures.
retrieved from (United States of America Patentnr. US2955156A, 1957).

The first successful application of VR was decades later to create a safe way to educate pilots. Figure 20 shows the Link trainer patented in 1931. It was applied by almost every nation that fought in the second world war to train over 500000 air force pilots (Angelo, 2000).

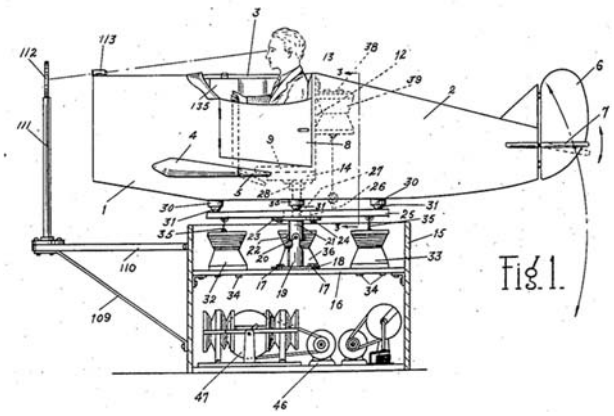

Figure 20, combination training device for student aviators and entertainment apparatus retrieved from (United States of America Patentnr. US1825462A, 1931)

VR gave new possibilities such as to train dangerous tasks without the risks otherwise present (for example, it is a common form of training, for example, tank crews and police officers (Krueger, 1991)). VR makes it possible to do experiments that are not ethically responsible in real life (for example, experiments on pedestrians crossing behaviour). VR also makes experiments possible that are impossible or costly in the real world (for example, when the judgement in the experiment is affected by time, see Atmosphere and light perception in different contexts by Oudshoorn (2014)).

In the 1990's the first consumer VR headsets were launched ("History Of Virtual Reality", n.d.). These devices were however not a success by that time partly due to technical difficulties. Now 20 years later, VR is hyped. AR and VR are causing a computing revolution that is as impactful as the smartphone (Fink, 2018). In an interview, Mark Zuckerberg CEO and founder of Facebook mentioned VR among the next big things in tech: "When everyone is using mobile phones, I believe the next platform will be virtual reality." (Zuckerberg, 2014). In March 2014 Facebook bought Oculus a company, that develops 3D goggles, for $2.3 billion (Munster, Jakel, Clinton & Murphy, 2015).

Different commercial VR headsets were launched in 2017 by companies such as Sony and HTC. Table 4 shows the VR headsets that were sold the most.

Table 4, most sold headsets per type in 2017 (Statista, 2018).

Type of VR	VR headset	Units sold
Mobile VR	Samsung Gear VR	3.650.000
	Google Daydream View	2.250.000
High-end VR	Oculus Rift	850.000
	HTC Vive	950.000
	Sony PlayStation VR	2.550.000

Some VR companies are pioneering with offering a VR of live sports, music and theatrical events which might drive consumers to pick up VR headsets. Eventually, this can result in consumers creating VR environments of their events, for example making a VR of your ski trip or your wedding (Munster, Jakel, Clinton & Murphy, 2015). Munster, Jakel, Clinton & Murphy (2015) believe in mainstream adoption of VR headsets in the next ten years because of the diverse application possibilities for VR and the rapid development of the technology. They expect prices for a highly immersive VR set (headset + computer) to drop from $1000+ in 2016 to $500+ in 2025. This will further increase the adoption, from 2020 they expect a further growth due to compelling content that comes available (see Figure 21).

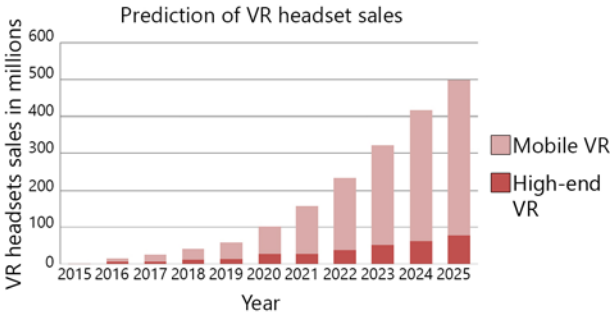

Figure 21, adoption prediction of VR goggles adjusted from Munster, Jakel, Clinton, & Murphy (2015).

5.2 Defining virtual reality

"What is Virtual Reality?" is almost a philosophical question since to answer it one should define when something is real. According to Wann & Mon-Williams (1996), the term virtual reality is an oxymoron since reality implicitly presumes that the natural setting is perfectly mimicked which is not the case with the current systems classified as VR and might not be possible at all. Although it would be most effective to abandon the term VR, it is stuck in academic as well as popular use (Steuer, 1992).

At the moment there is no clear consensus on how VR should be defined. Various articles are written with propositions for the definition of VR. According to Krueger (1991), the term Virtual Reality is typically defined in terms of technology. In 1989 the term virtual reality was used to bring all virtual projects under a single rubric, and since then VR usually refers to three-dimensional (3D) realities implemented with stereo viewing goggles and reality gloves. The VR headsets are output devices for the VR, and the VR gloves are input devices for the VR (See Figure 22).

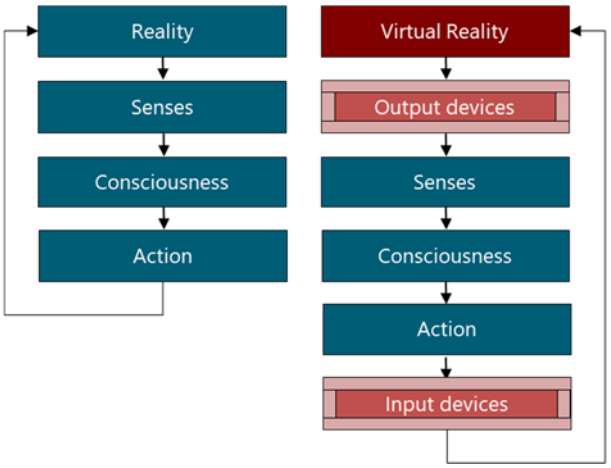

Figure 22, comparison Reality and Virtual Reality adjusted from (Billinghurst & Thomas, 2016).

According to Steuer, (1992) VR can be defined in terms of experiencing "a real or simulated environment in which a perceiver experiences telepresence". Pimentel & Teixeira (1995) define VR in term of user experience "Virtual reality is the place where humans and computers make contact".

In this thesis, a definition of VR is used without prescribing it in terms of hardware use. Describing VR in terms of technology leads to problems when the hardware changes and makes it hard to compare VR with non-VR since the dimension on which VR varies are unclear (Krueger, 1991). This thesis defines VR as a three-dimensional virtual environment in which one can interact.

5.3 Different types of VR

It is reckoned that there is a clear difference in perceiving a VR that is a 3D model on a 2D display and observing a 3D virtual environment with VR goggles. The difference can be described in terms of immersion. Immersion is the feeling of being closed off from the real world (Slater & Wilbur, 1997). Figure 23 shows an example of current technologies that can deliver high to low immersion. According to Slater & Wilbur (1997), the level of immersion can be measured with the extent that a VR delivers an inclusive (shut off physical reality), extensive (use of multiple senses), surrounding (panoramic view) and vivid (quality of the representation) representation.

High immersion low

Figure 23, current technologies for high and low immersion.

1. An example of highly immersive VR, perceiving a 3D model with stereoscopic goggles and headset.
2. An example of a somewhat less immersive as with goggles, perceiving a 3D model with a Google Cardboard.
3. An example of a medium immersive VR is a Cave Automatic Virtual Environment; this is a room on which walls multiple synchronised views are projected (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992). Retrieved from Disney. (2015). (http://www.leisureopportunities.co.uk/images/HIGH651449_531920.jpg)
4. An example of a low immersive VR, perceiving a 3D model on a 2D display.

5.3.1 Inclusive representation

To deliver a high inclusive experience, the movements in the real world must match the movements in the virtual world. A mismatch in movement, for example, a jump in the real world with nothing happening in VR will lead to dissatisfaction (Krueger, 1991). Different methods can be used to move in the virtual environment (Koekoek, 2017). When using VR goggles, one can walk in the real world and move in the virtual world. The size of the virtual environment is then limited to the movability in the real world. A disadvantage is that it is not possible to explore the large virtual environment. Another option is using a controller that represents the steering wheel in the virtual worlds. In this way, one can fly or drive true the virtual world while having a match with the physical environment. Another option is teleportation, several points are set in the VR, by clicking arrows the user will teleport to the next point, but this lowers the amount of immersion.

A mismatch in representation, for example, not being able to see hand will lead to dissatisfaction (Krueger, 1991). The representation is more inclusive when people are able to see the virtual representation of the body parts that they would see in the real world. When using a VR headset people typically first try to look at their hands, because hands are important for non-verbal communication (Munster, Jakel, Clinton & Murphy, 2015). When people are able to see their own body when looking down in VR this improve the level of immersion (Krueger, 1991).

5.3.2 Extensive representation

To deliver a high extensive experience, the VR must make use of multiple senses. According to Dubois, Guastavino & Raimbault (2006) and Alcántara-Alcover, Artacho-Ramírez, Zamora-Álvarez, & Martinez (2014), it is essential to have a holistic approach when creating a VR. This holistic approach means that there should be attention for more than just the visual aspect of the VR since sight is only one of the five senses with whom people judge an environment. Adding sound to the VR is feasible and makes the VR more immersive. Other senses such as smell are more challenging to add to the VR.

5.3.3 Surrounding representation

To deliver a high surrounding experience, the VR must cover the entire view even when people move their head. Images arrive on the human eyes in two dimensions (Grodin, 2016). The brain creates a 3D image out of the two 2D images perceived by both eyes. When using goggles, stereoscopic cues for depth perception can be used, by showing slightly different pictures for each eye. This makes it is easier to estimate distances and heights.

Using VR goggles, a mismatch between the focal distance and the vergence distance occurs. When using VR, the focal distance is the distance from the eyes to the screen, and the vergence distance is the distance from the eyes to the object looked at in VR. In real life, the vergence distance and the focal distance are the same (see Figure 24). This mismatch can cause visual discomfort, visual fatigue, nausea, diplopia, eyestrain or dizziness (Krueger, 1991; Hoffman, Girshick, Akeley, & Banks, 2008).

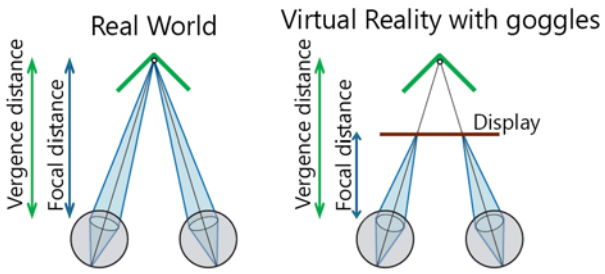

Figure 24, difference viewing object in the real world and in VR adjusted from Hoffman, Girshick, Akeley, & Banks (2008).

5.3.4 Vivid representation

To deliver a high vivid experience, the quality of the VR must be high. The quality of VR depends on the device used. The VR can look different regarding colour and detail when using various devices. Besides the quality due to the device used, the quality of the virtual environment itself can differ. This includes the level of interaction with the VR as well. A VR can be static, dynamic or interactive. In a static VR, objects in the VR do not move. In a dynamic VR, the objects in the VR are in motion, for example driving cars and flying birds. In an interactive VR, objects in the VR are in motion and react on the behaviour of the one using the VR. The more interactive the VR is, the more complicated the model is, and the more computing power is necessary to run it.

5.4 State of the art application of VR in the stakeholder process

The methods used in the stakeholder process depend on the purpose of the level of involvement, the budget and the time available (Voinov & Bousquet, 2010). Different types of VR are currently applied in the stakeholder process of complex infrastructure projects. VR can be used in a tool in the stakeholder process in combination with other methods, for example using a low-immersive VR on an online to collect customer requirements together with a stakeholder information meeting to collect customer requirements.

5.4.1 Stakeholder information meetings with high immersive Virtual Reality

With a high immersive VR, the visual perception can be the same as the real environment (Luigi, Massimilianoa, Anielloa, Gennarob, Virginia, 2015). People can perceive depth which might be of importance when evaluating a project.

With a higher level of immersion, people can experience a sense of presence (Lombard, Turner, Ratan, von der Pütten, McArthur, Biocca & Ijsselsteijn, 2017). Presence is defined as having a sense of being in the virtual environment. It let people overlook the role of the technology that the person uses to experience that virtual environment. When people feel present in the virtual environment, it is likely that people will behave in the same way as in the real world. When using a high immersive VR, it is possible to let people experience the future project.

According to Koekoek (2017), the use of high immersive VR can result in better-informed plans or decision because it improves on seven values that are important for the stakeholder process.

1. Learning about the project due to a better sense of proportions and experiencing the environment.
2. Motivation and engagement.
3. Enthusiasm.
4. The credibility of the design.
5. Collaboration.
6. Collaborative learning.
7. Communication due to shared knowledge.

A disadvantage of using VR for the collaboration is that when using immersive VR, people can be amazed by the technology which distracts them from the task of commenting on the environment (Koekoek, 2017).

There are two downsides recognised for using a high immersive VR in the stakeholder process 1) Availability and 2) Usability. In September 2016 approximately 10% of the people in the Netherlands had the availably of VR goggles (CBS, 2016). Currently, people will still have to come to the stakeholder meeting to have the availability of the high immersive VR. With the current technology to experience high immersive VR people can have usability issues that can cause visual discomfort, visual fatigue, nausea, diplopia, eyestrain or dizziness (Krueger, 1991; Hoffman, Girshick, Akeley, & Banks, 2008).

5.4.2 Online platform with low immersive Virtual Reality

With the use of a low immersive VR on an online platform, stakeholders have more flexibility than with a high immersive VR on a stakeholder meeting. They can view the project from their home. Only 8% of the inhabitants of the Netherlands does not have access to the internet (CBS, 2016). The level of immersion of the VR experienced at home depends on the device used to visit the VR. Using goggles or a Google Cardboards that includes your smartphone can make the VR more immersive. It is possible to allow people to give desires via this online platform which gives more people access to participation. The process manager can process the input given on this platform. Downsides of this are that the desires do not have the full enrichment of verbal communication and that there is less control for the process manager. The process manager does not know who is looking at the VR and what the quality of the VR encountered is.

5.4.3 Risks of using Virtual Reality

Two additional risks for the stakeholder process when using VR were identified.

1. Level of detail of the VR.
2. Errors made in the VR design.

The level of detail required for the VR depends on the task for which the VR is used (Al-Kodmany, 2002). The level of detail necessary for using VR in the stakeholder process is unknown. When the quality of the virtual environment is too high, it can confuse the user and can make the VR misleading (Al-Kodmany, 2002). The VR can be better looking than the project will in the real situation. Another problem can be that the VR looks so realistic that people might assume that it is the final design (Koekoek, 2017). When the quality of the virtual environment is too low, it can limit the experience of a user (Al-Kodmany, 2002). According to Koekoek (2017), people are very critical about these errors.

6 USING VIRTUAL REALITY IN A DYNAMIC STAKEHOLDER PROCESS

This chapter summarises the results of the literature study and provides a framework which is used to evaluate the added value of using VR.

6.1 Conclusion literature study

This thesis focusses on the use of VR in the stakeholder process of complex infrastructure projects. Dynamic management is required to successfully manage these complex projects (Hertogh & Westerveld, 2010). Dynamic management combines the use of SE with interactive management. The stakeholder process when using dynamic management consists of the SE stakeholder process and the interactive stakeholder management process. In this thesis, this stakeholder process is called a dynamic stakeholder process.

Interactive stakeholder management is necessary to deal with dynamic complexity. Using an interactive stakeholder process results in negotiated knowledge about the purpose of the project, the weighing criteria and the data that must be used to make decisions (de Bruijn & ten Heuvelhof, 2008). Having an interactive stakeholder management process can lead to synergy, better decisions and contributes to public acceptance which can make the project realisation easier (Raats, van Gelder, Post, Koppenjan, Houben & Weusting, 2010; Voinov & Bousquet, 2010). Four key elements defined by De Bruijn, ten Heuvelhof & in 't Veld (2008) need to be satisfied to have a good interactive stakeholder process.

1. *Protection of core values.*
2. *Openness.*
3. *Progress.*
4. *Substance.*

Besides these key elements, the skills of the process manager are essential. Satisfying these key principles will result in a stakeholder process that is appealing to join and is available for all the relevant stakeholders. These stakeholders can deliver valuable input on items which they find important.

SE is used to deal with detail complexity (Hertogh & Westerveld, 2010). SE is an effective way to split up the project into more manageable components and effectively communicate information about the interrelated parts (Bakker, Hertogh & Bosch-Rekveldt, 2013). Five key elements defined by Buck, Dronkers, Nijpels, Siertsema, van der Linde & Verhagen (2013) need to be satisfied to have a SE stakeholder process.

1. *Optimising throughout the lifecycle.*
2. *System thinking.*
3. *A central position for customer needs.*
4. *Top-down specification.*
5. *Explicit Working.*

Satisfying these key elements will result in specific customer requirements with which the design of the project can be improved. SE helps to identify all relevant stakeholders for the project and helps to translate their input into problems, objectives and needs. All the relevant needs are transcribed to SMART customer requirements and can be implemented to improve the design.

There is no such thing as the optimal process design for the dynamic stakeholder process. Every process design will cease to be effective at some stage (de Bruijn, ten Heuvelhof & in 't Veld, 2008). VR can be applied in as a tool in the dynamic stakeholder process for different purposes. This thesis defines Virtual Reality as a three-dimensional virtual environment in which one can interact. Different types of VR can be distinguished in terms of immersion. These different types of VR have pros and cons regarding depth perception, availability, usability, communication and behaviour. Two additional risks were identified in literature when using VR as a tool in the stakeholder process. First, wrong quality of the VR design. When the quality of the VR is too high, it can be misleading. The VR can be better looking than the real situation, and people might assume that it is the final design (Al-Kodmany, 2002; Koekoek, 2017). When the quality

of the virtual environment is too low, it can limit the experience of a user (Al-Kodmany, 2002). Second, Errors can be made in the content of the VR which dissatisfy the user.

6.2 Framework to evaluate the added value of Virtual Reality in a dynamic stakeholder process

The tools used in the stakeholder process depend on the purpose of the tool, the level of involvement, the budget and the time available (Voinov & Bousquet, 2010). To evaluate the success of using VR in the dynamic stakeholder process, the success of the total stakeholder process needs to be evaluated. This thesis focusses on complex infrastructure projects. As described in previous chapters a dynamic stakeholder process is used for the stakeholder process of these complex projects. The dynamic stakeholder process consists of a SE stakeholder process and interactive stakeholder management process. The goal of the dynamic stakeholder process is twofold, satisfying the stakeholders and improving the design.

As mentioned in chapter 1.1.2 several threats were identified from the literature that can have a negative influence on these goals. Besides the threats, it is a challenge to have an efficient stakeholder process regarding cost and time (Hordijk, Sara, Sutherland & Scott, 2015). Improving the efficiency of the process can contribute to the goals of the dynamic stakeholder process.

According to Wasson (2006), a new system is successful when it can perform the mission and cope with threats. Applying this definition makes VR a successful tool in the dynamic stakeholder process when it contributes to improving the design, satisfying the stakeholders and coping with threats concerning these goals. The efficiency of the stakeholder process partly depends on the tools used in the stakeholder process (Voinov & Bousquet, 2010). The effect of using VR on the efficiency of the stakeholder process is, therefore, an important aspect as well. From literature, these are the identified aspects on which the added value of VR to the process can be judged (See Figure 25).

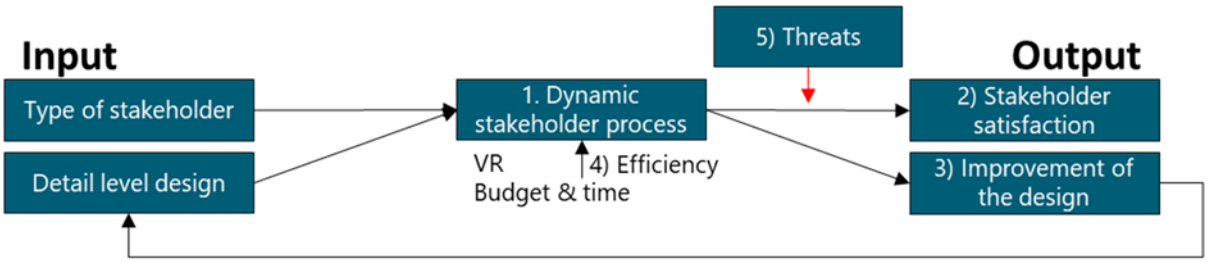

Figure 25, structure to evaluate the added value of VR in the stakeholder process of complex infrastructure projects.

This structure is used in the case study research, the chapters in the case study research correspond with the numbers in the framework. The appreciation of the different aspects is given below.

6.2.1 Dynamic stakeholder process

The use of dynamic management in the stakeholder process is evaluated by discussing the use of VR, SE and interactive stakeholder management in the stakeholder process. The use of VR is described, and an indication of the level of immersion is provided. The application of an interactive stakeholder management process is evaluated by discussing if the stakeholders were able to give desires. The application of a SE stakeholder process is assessed by discussing if the desires of stakeholders were transcribed to specific needs. Furthermore, indications that key principles of SE and interactive management are not met or that errors are made in the CRS process will be discussed. The pros and cons of using VR in the process that do not relate to stakeholder satisfaction, improvement of the design, efficiency or coping with threats are evaluated.

6.2.2 Stakeholder satisfaction

The improvement of satisfaction among stakeholders is evaluated by asking the interviewees about the direct contribution of VR to stakeholder satisfaction. The stakeholder satisfaction consists of stakeholder satisfaction over the process and stakeholder satisfaction over the project. Furthermore, the interviewees are asked about the success factors of the stakeholder process. The indirect contribution of VR to success factors of the stakeholder process is taken into account by relating the pros of VR to these factors.

6.2.3 Improvement of the design

The improvement of the design is evaluated by analysing the amount and quality of the honoured customer requirements (see Figure 26). The interviewees are asked to assess if the use of VR improved the design.

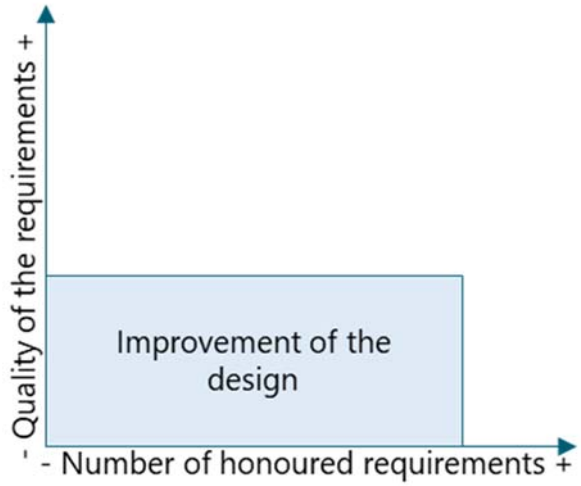

Figure 26, improvement of the design

The allegations by the interviewees are validated by evaluating the system requirements that were the results of honoured customer requirements. These requirements are added to the design and are therefore an indication for improvement of the design. There is an improvement of the design due to VR when the use of VR results in more honoured customer requirements. It is assumed that requirements that do not contribute to the design are not honoured. However, another possibility to improve the design is without having more honoured requirements. When the quality of the requirements is higher, the implementation of the honoured requirements contributes more to the design.

6.2.4 Efficiency

The efficiency is evaluated by asking the interviewees about the direct contribution of VR to efficiency and assessing the amount of waste present in the CRS process. The interviewees were asked whether the process is efficient regarding costs and time. The efficiency of the stakeholder process itself can be evaluated by looking at the CRS document. Different types of waste can be present in the stakeholder process. Table 5 indicates the types of waste that can be present in the stakeholder process, where this type of waste can be present and what the possible causes can be.

Table 5, eight types of waste were identified from literature (Ohno, (1998), Liker & Morgan (2006), Oppenheim (2011) and Womack & Jones (1996)) added are examples of possible causes in a particular process step.

Type of waste Description.	**Possible CRS process step**	**Possible cause**
Defects Inspections and repair of problems.	All steps	Monitoring the system and checks if it is functioning.
Inventory Storing information that is not used.	All steps	Different versions of the CRS.
Motion The time it takes to get to a location where the task needs to be performed.	Collection of requirements	Stakeholder meeting on distant location.
Over-processing Doing an unnecessary task or doing a task too extensive.	Problems and objectives definition	Ambiguity about the objectives
	Collection of requirements	Irrelevant requirements transcribed and incorporated into the CRS.
	Stakeholder analysis	Time spent on stakeholders that are not important to the project.
Overproduction Producing more than necessary for the next step**.**	Collection of requirements	Too many requirements given by stakeholders
	Collection of requirements	Making a VR with too much detail
	Collection of requirements	Comments with too much detail
Talent Underutilization of people's talents, skills and knowledge.	Collection of requirements	Stakeholders are not involved
Transportation Excessive information distribution.	Honoration customer requirements	Reading customer requirements on which one is not entitled to make the decision
	All steps	Transferring irrelevant requirements
Waiting Waiting for information or information waiting to be used.	Collection of requirements	Unknown when the needs of stakeholders are complete
	Honoration customer requirements	Postponed decision to have room for negotiation
	All steps	Delayed previous step

The presence of waste of overproduction, transportation and over-processing can be evaluated by the number of irrelevant requirements in the CRS document. Irrelevant requirements can be measured by the number of requirements that are not within the scope of the project (Baarends, 2015). Baarends (2015) assumes 5% of total requirements reasonable for a stakeholder process. Waste of inventory is disregarded as types of waste for the CRS process.

6.2.5 Coping with threats

Coping with threats is evaluated by discussing a framework with all the threats with the interviewees (see Figure 27). This framework contains the general risks of stakeholder involvement. The interviewees indicate whether the use of VR in the stakeholder process can be a measure to avoid/ reduce the risk or that VR causes additional risks or increases the risks. Since the risks are not explicitly evaluated per project coping with threats is assessed in the cross-case analysis. Additional Risks mentioned by the interviewees will be added to the framework.

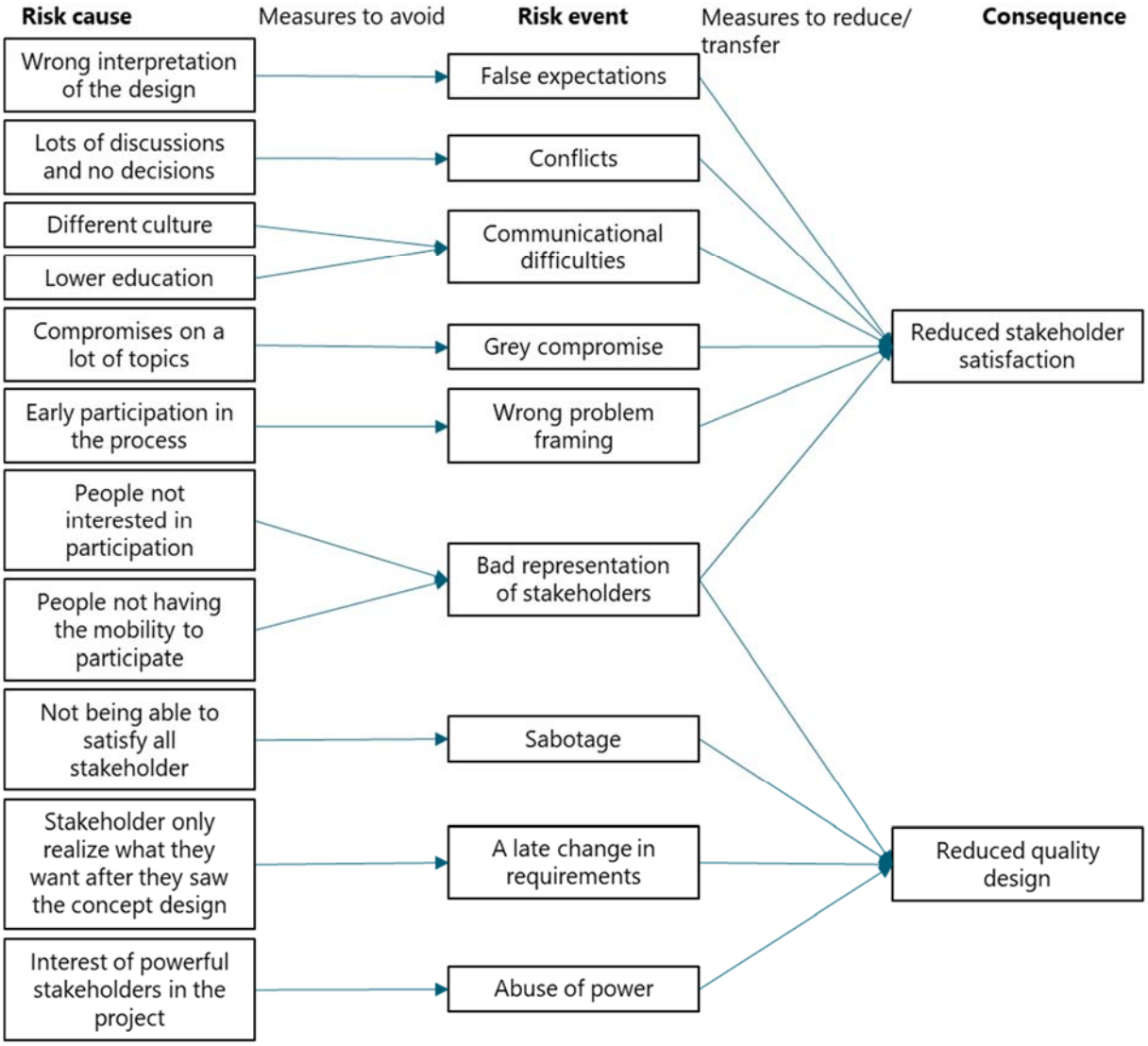

Figure 27, the risk causes are events present in the environment which give rise to uncertainty (Hillson & David, 2000). Risk events are uncertain events that might occur that influence the objectives of the stakeholder process. A consequence is an unplanned variation from the project objective due to the risk event happening.

Part 2 Case studies

[ThumbsUp!.(Unknown) Immerse Plus Virtual Reality Headset [Online picture] retrieved from http://www.immerseheadset.com/]

7 CASE STUDY A9 BADHOEVENDORP HOLENDRECHT

In this chapter, the added value of VR in a dynamic stakeholder process for the project A9 Badhoevendorp-Holendrecht was analysed using the framework discussed in chapter 6.2. First, a general case and process description is made. In the general case description, the objective of the project is described, and the complexity of the project is evaluated. The use of a dynamic stakeholder process is evaluated by discussing the application of VR, the use of SE and the use of interactive management in the stakeholder process. After the evaluation of the dynamic stakeholder process, the effect of using VR on the stakeholder satisfaction, improvement of the design and efficiency is evaluated.

Project description

The A9 Badhoevendorp-Holendrecht is an RWS project. The ministry had the vision to improve the traffic flow between Schiphol and Almere. At the moment there are many traffic jams in the project area, on average the A9 has four hours of traffic jam every day. The amount of traffic is expected to grow by 2% per year which will further increase this problem. The goal of the A9 Badhovendorp-Holendrecht was widening of the road to improve the mobility and accessibility of the Amsterdam area.

The A9 Badhovendorp-Holendrecht was part of the SAA (Schiphol-Amsterdam-Almere) program that was initiated in 2002 to improve the traffic flow. The SAA consist of 5 projects, two of the SAA projects are finished, one is completed except the technical installations, and one will be finished May 2019 which makes the A9 Badhoevendorp-Holendrecht the last project to complete. All five projects need to be finished to improve the traffic flow. Without upgrading the A9 the investments in the other projects are wasted since the A9 will then be the bottleneck causing the traffic jams on the other roads as well.

On 21 March 2011, a track decision was made, which included a tunnel of 1.8 km at the A9 near Amstelveen (Rijkswaterstaat, May 2011). The alderman signed a contract with RWS to contribute to the project, but at the time Amstelveen had to pay for the tunnel there was no money available. An alternative had to be found which will be a less satisfactory alternative than a tunnel but an improvement of the current situation. Expansion of the road without a tunnel would require a sound barrier with the height of 28 meters to pass the sound norm. The stakeholders would not have accepted this. Research on different alternatives was done which resulted in an underpass. The track decision was approved on 7 March 2017. At the moment, the final technical specifications are prepared to put the project to tender.

As mentioned in literature, detail complexity is caused by the interrelated parts of which the project consists, and dynamic complexity is characterised by limited understanding, limited predictability and the tendency of the project to change over time (Hertogh & Westerveld, 2010). Elements of both detail and dynamic complexity are present in the project. Several examples given by the interviewees indicated that both dynamic and detail complexity were present in the project.

Three examples are given by the contracting authority, and one example given by the process manager indicate that there is limited understanding and that the project changed over time, which are two characteristics of dynamic complexity.

1. Changing the design in a less satisfactory alternative, due to a lower budget available.
2. Making an alternative plan for the project.
3. The legislation on noise allowance changed during the project, and the project sound norm was based on the design of a tunnel.
4. Having many stakeholders in the area (mentioned by the process manager).

Two examples indicated that the project consisted of interrelated parts, which is a characteristic of detail complexity.

1. Intervening on a vital highway will result in more traffic on other roads (mentioned by the important stakeholder).
2. Existing building and technics in the area (Mentioned by the process manager).

Dynamic management is required to deal with the complexity of the project. A dynamic stakeholder process was used, the important stakeholders were allowed to give desires for the project design and two important stakeholders are permitted to validate the final design that is made by the contractor and a SE approach was used.

7.1 Dynamic stakeholder process

Figure 28 shows the stakeholder process of the A9, which is explained on the next page. As mentioned in 3.3 there is no single outcome of each process step instead every step in the process is broadly explored after which decisions are made to narrow it down, and the next step of the process starts (van Oosterhout, 2010). It is not a linear process the outcome of one step can influence the work in the previous step.

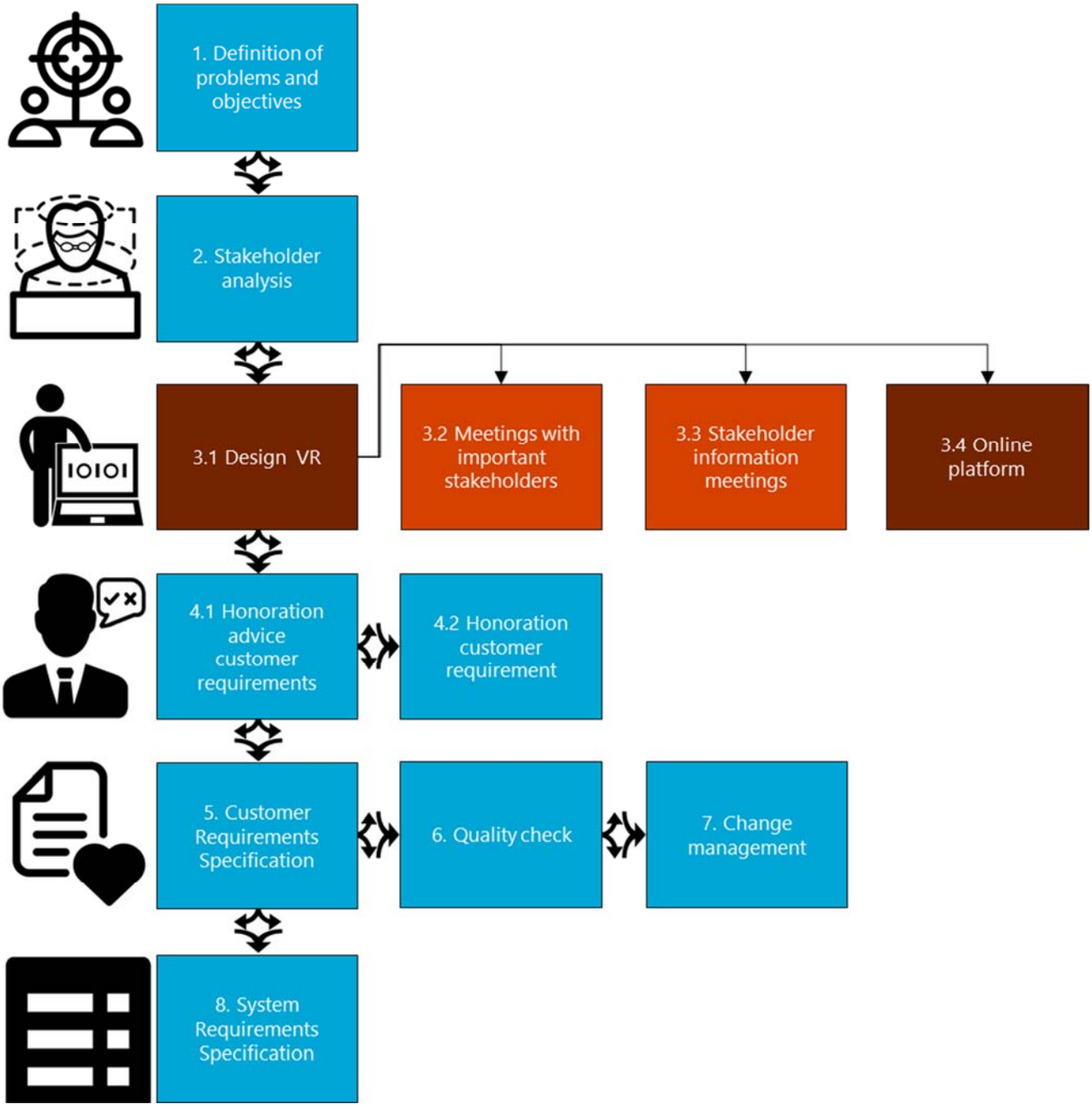

Figure 28 Stakeholder process A9

Since SE was used the six different steps of the CRS process discussed in chapter 3.3 are present in the stakeholder process (See Figure 28).

1. Definition of problems and objectives:
   The ministry makes the vision, RWS was in charge of executing the project. The driving simulator was used to show the project to the ministry.
2. Stakeholder analysis:
   A stakeholder analysis was done to see how to manage the stakeholders in the process. After the stakeholder analysis, a strategy to approach the stakeholders was made.
3. Collect customer requirements:
   Different stakeholders were reached in different ways based on their importance and preference.

3.1 Design VR:
A risk-driven design was made which started with the contours of the underpass and road design. The risk-driven design was transferred in a concept integral design. This design was used to study the effects of the project on subjects such as ecology, sound. The and was used to create a VR. A 3D model of the concept integral design was used to make the VR, the design of the VR was improved by using the technical and customer requirements collected with the VR.

3.2 Meetings with important stakeholders:
There was regular contact with the important stakeholders to explore their desires and involve them in the project. Three of these important stakeholders were municipalities. The VR or visualisation made with the VR were used in these meetings.

3.3 Stakeholder information meetings:
Inhabitants could give input for the project via the municipalities. Five information meetings were held in the municipalities of Ouder-Amstel and Amstelveen and in Badhoevendorp to give stakeholders the chance to provide input. The VR was used at these information meetings. During other meetings, the VR was used at important benchmarks and visualisations were used otherwise. In Amstelveen, a visitor centre was opened for inhabitants since there was the most resistance to the project.

3.4 Online platform:
The VR created by Witteveen+Bos was used by XKP to make an online platform. On the online platform, information is provided via movies, articles and visualisations. On the online platform, it was possible to switch between the current and future situation.

4. Honoration customer requirements:

4.1 Honoration advice customer requirements:
Witteveen+Bos manually put the desires given by the stakeholders into a database. Witteveen+Bos clustered all the needs into themes to give a honoration advice.

4.2 Honoration customer requirement:
The themes were discussed with the municipality who honoured the requirements.

5. Customer requirements specification:
   The CRS was made. The process then continues at step 3 until the moment that the stakeholder process is terminated.
6. Quality check.
7. Change management.
8. System requirements specification:
   All the honoured customer requirements were then transcribed to system requirements. The system requirements are processed and used to make the integral project design. The system specification for this integral project design and the track decision together were the basis for the contract that was put to tender.

7.1.1 Application of the Virtual Reality tool in the stakeholder process

Three purposes for using VR were mentioned by the contracting authority and the process manager (See Table 6).

Table 6, the purpose of using Virtual Reality in the A9 project.

Interviewee	The goal of using Virtual Reality
Contracting Authority	1. Creating support for the project by the government, surrounding and road users.
Process Manager	2. Making difficult information easy to understand.
	3. Showing the effects of the project from the perspective of the stakeholders.

Two purposes mentioned by the process manager relate to *substance* (see chapter 4.2.4). The VR was supposed to make difficult information easy to understand and shows the effects of the project from the perspective of the stakeholder. The purpose mentioned by the contracting authority to create support of the project is a higher goal of the stakeholder process. The application of VR was seen as successful by the interviewees.

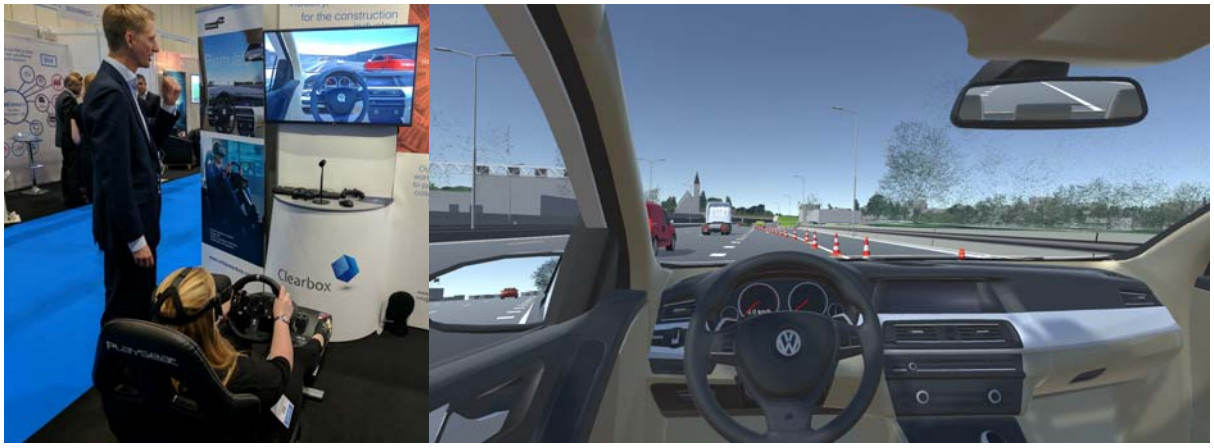

Figure 29 High immersive VR driving simulator setup used in for the A9 project. Left image retrieved from Witteveen+Bos VR. (2017). (https://pbs.twimg.com/media/DMbCWiaW4AEOkbc.jpg). Right image retrieved from Witteveen+Bos. (N.d.). (http://bim.Witteveen+Bos.com/VR/driving_simulator.html)

Two types of high immersive VR were used, a driving simulator and a fixed-point VR. Witteveen+Bos created a high immersive driving simulator VR for the perspective as if you are driving on the road (see Figure 29). The VR was high immersive since it was an inclusive, extensive, surrounding and vivid representation. It is inclusive since the movements on the steering wheel match the movements in the virtual environment. However, the hands of the users are not visible in the VR which reduces the inclusiveness. The sound of cars was added to the VR to make the VR more extensive. VR goggles were used to give a surrounding representation. The VR was vivid by including a model with interactive traffic to the VR. Due to this model, the traffic drove in the VR and responded to the actions of the user.

The fixed-point VR was a bit less immersive in term of inclusiveness. Witteveen+Bos created the free movement VR with the perspective of the stakeholders looking at the road. The stakeholders could choose the position. A sound tool was used to let the inhabitant experience the amount of noise produced by the cars on the highway and to experience the reduction of sound.

Besides that, the VR was used to make visualisations and an online platform. For example, a movie of how the project looks when driving instead of using the driving simulator itself. Table 7 shows the estimated number of VR use.

Table 7, the estimated number of VR use by the project manager.

Type of VR	Estimated use
Driving simulator	Three times.
Fixed point VR	Five times at stakeholder information meetings. 50% of the regular conversations with important stakeholders.

7.1.2 Application of Systems Engineering in the stakeholder process

In the CRS five statuses were used, honoured, unhonoured, unhonoured but secured, being discussed and cancelled.

Two remarks are placed on the use of these statuses.

1. The status unhonoured but secured is confusing.
2. The status requirement cancelled should not be used.

When a status is unhonoured, it means that it is not part of the design. When a requirement is secured, it is already covered in the design by another requirement or by legislation. Therefore, the word unhonoured gives a wrong expectation. The status cancelled should not be used since this makes the traceability difficult.

The label being discussed can be used during the stakeholder process since it indicates that the contracting authority is processing these requirements. 46 requirements are being discussed at the moment. For the analysis, these requirements were labelled as not processed since these requirements do not have a status honoured/ unhonoured or secured yet. At the moment there are 121 requirements with the status cancelled. The Requirements with this status can be classified under the other categories. Four of them are secured in honoured requirements, and one of them is referred to in the customer requirement as honoured under a specific condition and should, therefore, have the status conditionally honoured. The requirements are labelled accordingly. The explanation on the honoration decision is not always in line with the status given. A few requirements that have the status unhonoured are explained as being secured. For the analysis, these requirements were labelled as secured.

Table 8 shows the status of the customer requirements after the adjustment. 109 desires are not processed yet. Three needs do not have a honoration advise by Witteveen+Bos.

Table 8, status customer requirements A9 project after adjustment.

Source	Not processed	Honoured	Unhonoured	Secured
Contracting authority	15	193	122	75
Public organisations	88	186	60	31
Private organisation	2	14	1	1
Private parties	4	5	1	0
Total (789)	**109**	**398**	**184**	**107**

The customer desires were translated to SMART customer requirements. When the customer requirement is approved, it gets the status definite. 161 of the 398 honoured requirements have a definite status. The requirements with a definite status are SMART. Therefore, it is argued that in general SE was applied well resulting in a SMART CRS document.

However, the contracting authority mentioned that the needs were not one to one traceable during the concept design only after finalising the customer requirement specification. It is essential that the customer needs are documented and traceable during this phase as well.

7.1.3 Application of interactive stakeholder management process

The stakeholders were involved in different ways. Many stakeholders visited the online platform. Stakeholders were able to influence the design at an early stage. During the stakeholder meetings, stakeholders were allowed to give desires which were used in the design and the inhabitants of the municipality of Amstelveen were allowed to vote which design of a bridge they favoured.

7.1.4 Advantages of using VR

One pro of VR mentioned by all interviewees was fewer objections against the project. In total 21 pros were mentioned which can be found in Appendix D. The pros related to the improvement of stakeholder satisfaction, improvement of the design and efficiency will be discussed in 7.2.4, 7.2.5 and 7.2.6 respectively.

7.1.5 Disadvantages of using VR

Six cons were mentioned during the interviews. Three of these cons are regarded as extra risks for the stakeholder process and will be discussed in the cross-case analysis in chapter 10. One con is discussed at the efficiency, and the other two cons are discussed below. 1) The contractor will use the contract to make the final design. The parts that are present in the VR but are not in the contract will not be designed or designed differently in the final design. The contractor might interpret a requirement differently than how it is visualised in the VR (mentioned by the contracting authority and the process manager) and 2) Showing an image which might deviate from the final design of the project.

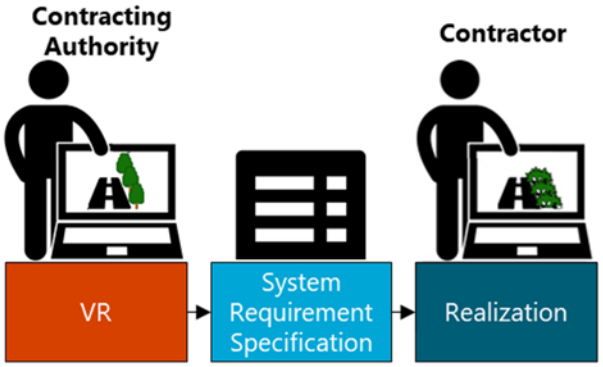

Figure 30 Difference between visualisation in Virtual Reality and final design.

These two problems indicate that the specification of the project in the contract is essential. The VR is used to make a concept design and is adjusted based on the needs of the stakeholder. However, the system specification is used by the contractor to create the final design. The contractor might interpret the specification different than how it is interpreted and implemented in the design of the VR. This difference will result in a difference in the final project design and the VR design (see Figure 30). Even when there is little design freedom for the contractor the design of the VR will never be entirely the same as the VR presented.

7.2 Stakeholder satisfaction

Most stakeholders support the design. The municipality of Amstelveen voted in favour of the plan twice with 35 votes against two. Seven objections were made of which three are resolved, four groups of stakeholders still have objections against the projects. The main reason why stakeholders are not satisfied is mostly related to that the tunnel in the original project plan was a better alternative for the stakeholders.

Three pros mentioned by the interviewees directly indicate that the use of VR resulted in more satisfied stakeholders.

1. Fewer objections against the project.
2. More satisfaction over the project.
3. More satisfaction over the process.

The higher satisfaction is caused by a better understanding of the project. The contracting authority argued that stakeholders were more satisfied with the project because they better understood the project. According to the important stakeholder when people understand how the future project will look like they might be less dissatisfied with the nuisance during construction. Table 9 shows the pros of using VR relating to a better understanding of the project.

Table 9, pros of VR that relate to the success factors of the stakeholder process for the A9 project.

The success factor for stakeholder satisfaction	Pros VR use
Understand the project	Using VR is a good way to provide information. Due to the VR people better understand the project. Many stakeholders cannot read 2D drawings but do understand the VR. VR enables it to present the mental image of the project to the stakeholder. VR makes it possible to experience the future project from the perspective that the stakeholder wants to see. Stakeholders are often interested in their perspective and can see the effect of the project on their living environment. Due to VR stakeholders realise what the impact of the project on their interest.

It is argued that the use of VR leads to more satisfaction over the A9 project. The interviewees directly indicate that there was more satisfaction over the process and the project due to the use of VR. The better understanding of the project partly causes more satisfaction over the project.

7.3 Improvement of the design

Four pros of using VR were mentioned in the interviews which indicate that the use of VR improved the design.

1. Better insight into opportunities in the project for the stakeholder.
2. Stakeholders can better formulate their desires
3. Better decision making due to better communication with the minister.
4. Ability to validate needs of stakeholders in virtual reality.

VR makes it possible to verify and validate the needs of stakeholders (See Figure 31). The process manager mentioned the ability to give the stakeholder insight into the consequence of their desire as a pro. Showing how a desire is implemented in VR is verification of a desire. Validation of a desire is also mentioned as a pro by the process manager. By implementing a desire in VR, a stakeholder can validate if the implementation is what he or she desired.

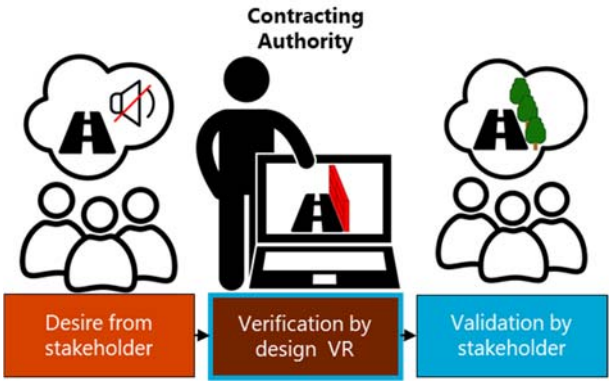

Figure 31 Verification and validation by using VR.

The process manager mentioned that he is not sure if more elements were brought in due to the use of VR. He gave an example that indicated that verification and validation of needs could result in fewer customer requirements in the design. The Municipality had a desire for a bridge with a span of 25-meter. After visualising the desire in VR, the desire was dropped. The purpose of this desire which was to see the other side which was already met with a span of less than 25-meter.

During the stakeholder process, different customer requirements are granted. Due to this, it will become difficult for stakeholders to foresee how requirements are implemented in the design. VR can be used to show the implemented requirements to stakeholders to validate that all the honoured requirements are present in the design.

The customer requirements have led to 245 System requirements of which 25 are still under discussion, and 12 have an empty status. Table 10 gives an overview of the source of the system requirements. Seven customer requirements were indicated as being out of scope and honoured. This indicated that there was scope added to the project by the stakeholders.

Table 10, number of system requirements as a result of customer requirements

Source	System Requirements
Contracting authority	50
Public organisations	175
Private organisation	14
Private parties	6
Total	**245**

The overall quality of the requirements is high. The verification and validation of needs contributed to the high quality of customer requirements. The number of requirements implemented might not be larger.

7.4 The efficiency

The contracting authority indicated that using VR in the stakeholder process is efficient because it helps people in understanding the project. It takes less time to clarify the project. The project manager agrees that the VR contributed a lot but indicated that making the VR took a lot of time.

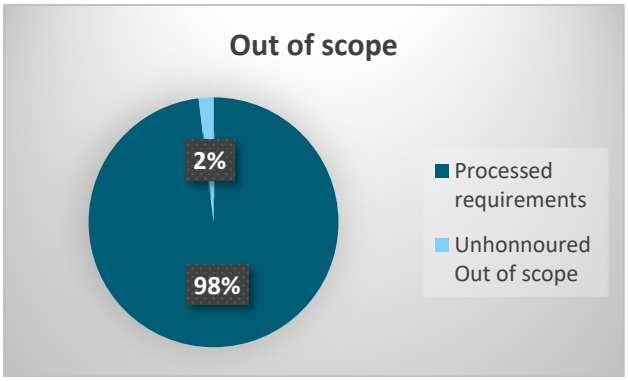

Figure 32 Percentage of out of scope requirements of the total number of processed requirements A9 project.

Only 13 customer requirements are unhonoured with the reason of being out of scope. In total 680 requirements were processed. According to Baarends (2015), 5% of requirements out of scope is reasonable. The low amount of only 2% is out of scope indicates that there is a low number of irrelevant requirements (See Figure 32). This results in a low amount of waste of over-production, transportation and over-processing.

Waste of waiting is present in the process. 63 requirements are waiting to be processed by the contracting authority. No defects of the VR were mentioned in the CRS document nor during the interview. The contracting authority did mention the file sizes of VR being huge as a con which might result in excessive information storage.

There is a low amount of waste present in the CRS document. Together with the project manager and contracting authority indicating that the VR contributed to the efficiency, it is argued that the use of VR improved the efficiency of the stakeholder process in the A9 project.

7.5 Limitations

The contracting authority for Witteveen+Bos was RWS. RWS did most of the process management of project which results in only one project leader from Witteveen+Bos to interview. Besides the stakeholder process, the VR was also used to validate the road design. This relates to technical requirements which are out of the scope of this thesis but might influence the efficiency of using VR.

7.6 Conclusion

The A9 project was a complex project; a dynamic stakeholder process was used to deal with the complexity. All the interviewees mentioned that the stakeholder process was seen as successful.

Stakeholders were involved in different ways and were able to influence the design at an early stage during stakeholder meetings. In general, SE was applied well in the stakeholder process resulting in a SMART CRS document. However, there is scope for improvement for the statuses used during the honoration process and the traceability during the concept design.

Three purposes for using VR were mentioned by the contracting authority and the process manager. The purpose mentioned by both the contracting authority and the project manager was to create support for the project. Two purposes mentioned by the process manager relate to *substance*. The VR

was supposed to make difficult information easy to understand and shows the effects of the project from the perspective of the stakeholder.

Two types of high immersive VR were used. Furthermore, visualisations of these VR's were used on stakeholder meetings and the online platform.

21 pros and six cons of using VR were mentioned during the interviews (See appendix D&E). The cons indicate that the specification of the project in the contract is essential. The VR is used to make a concept design and is adjusted based on the validated needs of the stakeholder. However, the system specification is used by the contractor to create the final design.

The use of VR led to more satisfaction over the stakeholder process and the project, partly caused by the contribution of VR to *substance*, people had a better understanding of the project.

The use of VR led to an improvement of the design for the A9 project. The use of VR contributed to *top-down specification*; it was possible to verify and validate the needs of stakeholders which led to better decision making. The number of requirements implemented might not be larger, but the quality of the honoured requirements is.

The use of VR improved the efficiency of the stakeholder process in the A9 project. The project manager and contracting authority indicated that the VR contributed to the efficiency because it helped people in understanding the project. and there is a low amount of waste present in the CRS document.

7.7 Recommendations

Below the recommendations for improvements are given. The project manager of Witteveen+Bos considered the recommendations useful.

7.7.1 Improve traceability of customer requirements in the concept phase

Currently, the customer requirement is adjusted, and when It is SMART it gets the status definite, this makes it untraceable what the original desire was. It is recommended to show the original desire given by the stakeholder in the CRS document. Use the original text as desire and make a separate column with the definite customer requirement. This contributes to *explicit working* since it makes it better traceable what the origin of the customer requirement is. The original desire explains the customer requirement and with that reduces the chance of misinterpretation of the customer requirement created by the process manager.

7.7.2 Validate the honoured customer requirements with VR if possible.

When evaluating the customer requirements, one should indicate whether it is possible to visualise the customer requirement in VR for all the requirements that have the advice to be honoured. VR can be then be used to verify and validate customer requirements. This contributes to *top-down specification*.

7.7.3 Specify the use of VR in the contract.

The contractor is obliged to follow the contract not obliged to use the VR. According to the contracting authority, everything that is not specified in the contract will be built as cheap as possible by the contractor. Because of this, parts of the project are presented less beautiful in the VR to prevent false expectations. It is recommended that the contractor will present the final design in VR as well. When the use of VR is specified in the contract, the contractor can show the detailed and better looking final design in the same way as the concept design was presented.

8 CASE STUDY VESTDIJK PROJECT

This chapter follows the same structure as chapter 7 and elaborates on the added value of VR in a dynamic stakeholder process for the Vestdijk project by making use of the framework discussed in chapter 6.2.

Project description

In 2013 the municipality presented the vision on the future mobility of Eindhoven. Part of this vision was reducing the car traffic in the city centre of Eindhoven (Manders, van Hal, Kerkdijk, Hommes, Willemsen, & Gijsbers, April 2013). Reducing the car traffic at the Vestdijk, which is a street located in the city centre, was part of this vision. In 2016 after an air quality study the mission of the project was extended since the air pollution in Eindhoven had to be reduced. This air pollution problem partly created by the traffic surpasses the EU norms. The money came temporarily available to reduce this problem which gave the project more urgency. To solve the air pollution problem, the municipality of Eindhoven decided to reduce the number of cars on the Vestdijk by reducing the number of traffic lanes on the Vestdijk by one. Improving the air quality and reducing the amount of traffic by removing one traffic lane were the goals of the Vestdijk project. In March 2018 the municipality agreed on the final design.

The project was seen as a complex project, although one of the project managers mentioned that the technical part of the project was not difficult. The contracting authority mentioned that the junctions were complex and the other project managers mentioned the time pressure as complex. Several examples given by the interviewees indicated that both dynamic and detail complexity were present in the project.

Three examples given by the interviewees indicate that there is limited understanding and that there are project changes over time, which are characteristics of dynamic complexity. Scope changes (mentioned by the project managers), having many stakeholders with different views on the project (mentioned by all the interviewees) and contradicting project tasks of reducing traffic and accessibility of the city centre (mentioned by the contracting authority and project managers).

One example given by the project manager indicates that the project consisted of interrelated parts which is a characteristic of detail complexity. Managing different companies and integrating different disciplines.

Dynamic management was required to deal with the complexity of the project. A dynamic stakeholder process was used. The municipality only wanted to execute the project when they knew what the stakeholders desired in the project. The stakeholders were allowed to give desires for the project, and a SE approach was used to manage all the information about the project.

8.1 Dynamic stakeholder process

Figure 33 visualises the dynamic stakeholder process of the Vestdijk, which is explained on the next page.

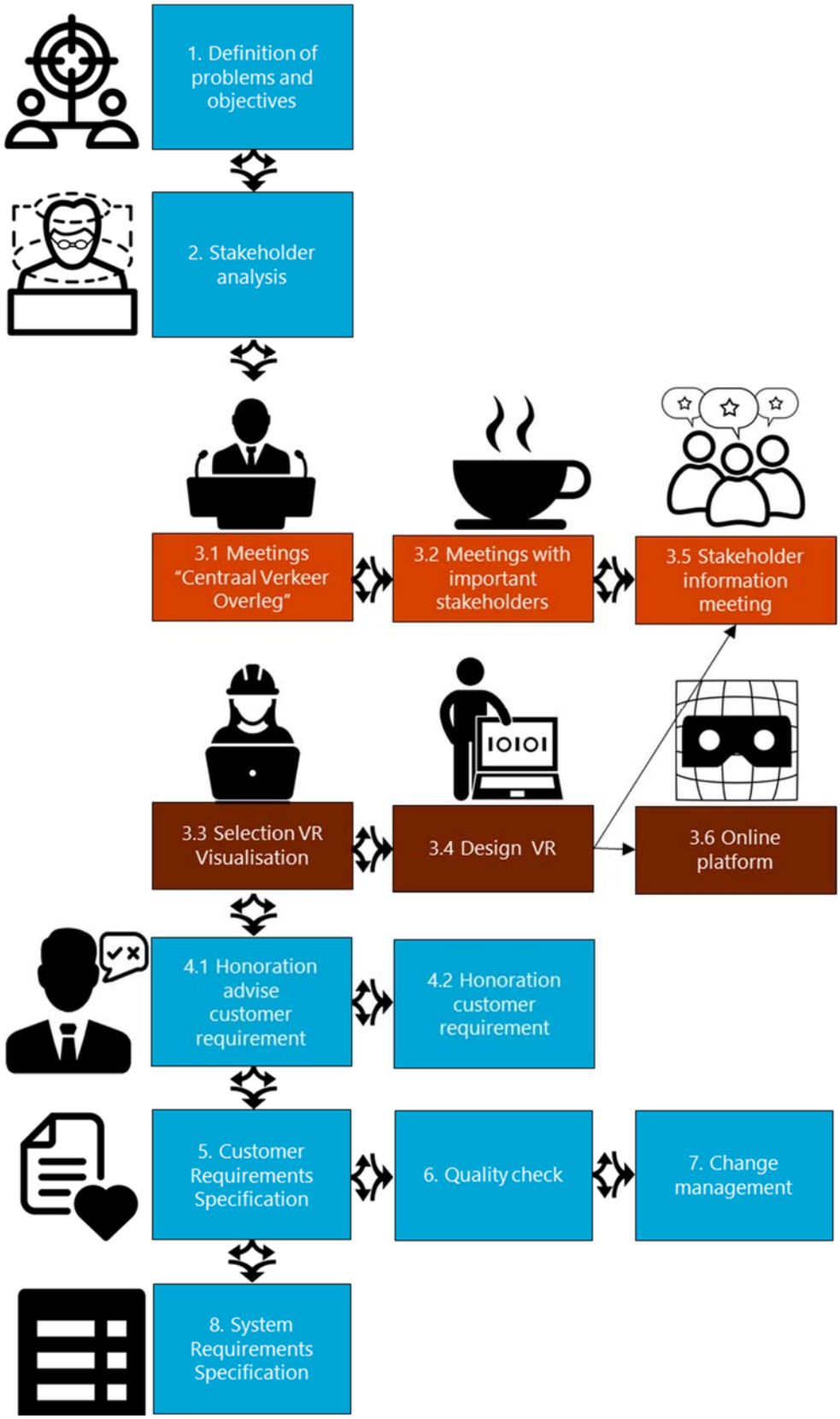

Figure 33 Stakeholder process Vestdijk

Since SE was used the six different steps of the CRS process discussed in chapter 3.3 are present in the stakeholder process.

1. Definition of problems and objectives:
   The client defined the mission, vision and the ambition of the project.
2. Stakeholder analysis:
   A stakeholder analysis was done to see how to manage the stakeholders in the process.
3. Collect customer requirements:

3.1 Meetings "Centraal Verkeer Overleg":
There was a meeting with the "Centraal Verkeer Overleg" which are all important stakeholders concerning traffic such as the emergency services but also organisations such as organisations for Taxies, cyclists and the disability union. One of the important stakeholders was present at these meeting. These meetings included a small presentation from the municipality.

3.2 Meetings Important stakeholder:
The important stakeholders had direct contact with the municipality about their desires. The important stakeholders mentioned that they did not use the VR.

3.3 Selection VR visualisation:
A selection which of the approved customer requirements by the client. These requirements were visualised in VR by Witteveen+Bos.

3.4 Design VR:
Witteveen+Bos made the design of the VR. Specific questions were shown in the VR such as, "more greenery and water. What do you think?"

3.5 Stakeholder information meeting:
The VR was used on stakeholder information meeting mainly for inhabitants. A high immersive VR was presented to inform the stakeholders present at the information meetings. Input for the project could be given face-to-face.

3.6 Online platform:
The online VR platform was used in parallel with the stakeholder information meetings. The lower immersive VR was presented on an online platform. Stakeholders were able to leave comments on this online platform. When submitting comments on the online platform stakeholders had to give their email, postcode, occupation and had to categorise the theme of their desires.

4. Honoration customer requirements:

4.1 Honoration advise customer requirements:
Witteveen+Bos manually put the desires given by the stakeholders into a database. Witteveen+Bos clustered all the desires into themes to give a honoration advice.

4.2 Honoration customer requirements:
The themes were discussed with the municipality who honoured the requirements.

5. Customer requirements specification:
   The CRS was made, and decisions were feedback per theme to the stakeholders. The process then continues at step 3 until the moment that the customer requirements specification is terminated.
6. Quality check.
7. Change management.
8. System requirements specification:
   The online platform was closed. All the honoured customer requirements were then transcribed to system requirements which were used to make design alternatives. The contracting authority selected one concept design and the system specification for this concept design was the basis for the assignment put to tender.

8.1.1 Application of the Virtual Reality tool in the stakeholder process

The interviewees mentioned eight purposes of using VR (See Table 11).

Table 11, the purpose of using Virtual Reality.

Interviewee	The goal of using Virtual Reality
Contracting Authority & Project managers	1. Give insight into the consequences of the project.
	2. Give the opportunity to give input for the project.
	3. Involve more stakeholders.
Contracting Authority	4. Give insight into possible future situations.
	5. Fast involvement of many stakeholders.
Project Managers	6. Clear communication.
	7. Make difficult information easy to understand.
	8. View the project from the stakeholder's perspective.

Two of these purposes relates to *substance* (See chapter 4.2.4). The VR was supposed to make difficult information easy to understand. It gives insight into the possible future situation, shows the effects of the project from the perspective of the stakeholder and gives insight into the consequences. One of the purposes relates to *progress*. VR was supposed to result in fast involvement. Two of the purposes relates to *openness*. VR was supposed to result in more stakeholders involved with the opportunity to deliver input. The application of VR was seen as successful, and the Contracting Authority mentioned the effectiveness of the tool as one of the advantages.

Figure 34 High immersive VR setup used in the Vestdijk project. Left image retrieved from Amanda Gregor (2017). (https://pbs.twimg.com/media/DAmrel2XcAA-n83.jpg:large). Right image retrieved from Witteveen+Bos. (N.d.). (http://bim.Witteveen+Bos.com/VR/ehv_vestdijk.html)

Two types of high immersive VR were used 1) a high immersive VR on stakeholder information meetings and 2) a VR on an online platform. Witteveen+Bos created a high immersive VR for the perspective from the road (see Figure 34). The VR was high immersive since it was an inclusive, extensive, surrounding and vivid representation. It was inclusive by using a controller to move in the virtual environment. During the project, the sound was added to make the VR more extensive. VR goggles were used to give a surrounding representation. One can view the whole project area with a 360-degree view. The VR was vivid the objects moved in the VR.

Compared to the high immersive VR used on the stakeholder information meeting the online VR was less immersive. The online VR was less inclusive since the points in the VR were fixed. One can teleport to the different points. The online VR was less extensive since there is no sound on the online platform. How surrounding the representation is depends on the device used to view the online VR. When using VR goggles at home one has a high surrounding experience, but one can also use a computer screen which makes the VR less immersive. The online VR is less vivid since the objects in the VR do not move.

8.1.2 Application of Systems Engineering in the stakeholder process

During the interview with the important stakeholders, several specific examples of customer needs were given that were not present in the CRS. These examples indicate that not all the desires of stakeholders are present in the CRS document, indicating that the CRS document is incomplete.

Table 12 shows the status of the customer requirements. 550 desires are not processed yet. 412 desires do not have a honoration advise by Witteveen+Bos and eight desires that are processed without advice from Witteveen+Bos. From the requirements that still need to be assessed 52% are requirements given by inhabitants on the online platform.

Table 12, the status of the customer requirements

Source	Honoured	Unhonoured	Not processed
Contracting authority	24	0	46
Private organisations	2	1	31
Private parties	1	1	79
Stakeholder meeting	17	25	109
Inhabitants	18	57	285
Total (696)	**62**	**84**	**550**

For some requirements, the honoration decision was made, but the requirements were not processed. For example, the Contracting Authority mentioned during the interview that some stakeholders had the desire to build a tunnel under the Vestdijk which was not possible due to the costs. In the CRS three desires for a tunnel were indeed present, but two of them did not have a honoration decision.

Witteveen+Bos regarded all the input given by the stakeholders as customer requirements. This is an incorrect way of processing desires. As mentioned in the literature, to create requirements that a designer can use, unstructured ideas of stakeholders must be translated into problems, objectives and needs (Nicholas & Steyn, 2012). With the SE method honoured customer requirements are translated to system requirements. The input from the stakeholders that were honoured was directly translated to system requirements. Several customer requirements that are not directly related to each other are combined into one system requirement (see Table 13). This makes traceability difficult; it is not clear which customer requirement led to the system requirement.

Table 13, example translation of customer desire given on the online platform to a system requirement.

System requirement	Honoured customer desire
The vegetation present needs to be maintained.	It is delightful that there is paid attention to create more vegetation and more space for cyclists and pedestrians in the Hertoghstraat and the Vestdijk.
	Maintain Gleditsia as trees in the City Centre.

The processing of the customer requirements can be improved (see Table 14). There is one unhonoured customer requirement translated to a system requirement; unhonoured customer requirements must not be translated to system requirements.

Table 14, an example of incorrect processing of customer requirements.

System requirement	Customer requirement	Status
The standard profile for restructuring the Vestdijk: I. Pedestrian area with an adaptable width. II. Cyclists area with a width of at least 4,00 m (5,00 m where possible). III. Greenspace area with a width of 3,00 m. IV. Bus traffic lane with a width of 3,20 m. V. Car traffic lane with a width of 3,00 m. VI. Pedestrian area with an adaptable width.	Due to the increasing speed of cyclists, it does not seem desirable to me to apply only one cyclist lane. Traffic incidents will occur more frequently, and the consequences will be more substantial.	Unhonoured
	The Cyclists area with two directions is too narrow in the Virtual Reality; the width needs to be increased.	Honoured
	Room for the events DDW, Kingsday, Marathon, Carnaval and glow are boundary conditions for the project.	Honoured

Sixteen honoured customer requirements were not translated to a system requirement. One of these requirements is a desire that was categorised as being a question (see Table 15).

Table 15, example translation of honoured customer requirement KE0091 that we regarded as a question.

Customer desire	Status
Will you further discourage the use of the route from the south to the Vestdijk?	Honoured.

Given that the final design of the project is already delivered the CRS should have been completed, all the input should have been processed, and the honoured customer requirements should have been translated to system requirements.

This chapter indicated that the SE method was not applied well. Not all the desires are present in the CRS document. All the unstructured input was regarded as customer requirements resulting in low-quality customer requirements. Much input was not processed, the input that had a honoration advice was not translated to SMART system requirements, and there is only partly *worked explicitly*. The system requirements do not directly relate to the customer requirements. As a result, the CRS document is out of date and incomplete. One of the important stakeholders mentioned that a protest statement is made to clarify which requirements were not honoured. This could have been avoided when all the requirements were processed via the SE method.

8.1.3 Application of interactive stakeholder management process

During the Vestdijk project, people were free to give comments on the VR. The project managers and contracting authority indicated that it is better to have more desires. One of the project managers indicated that this makes it possible to combine desires and to see what is important. The other project manager indicated that at a certain point it does not matter to have more desires since you already know all the arguments.

One of the reactions on the online platform indicates that he did not understand the use of the online platform since everything was already decided. This reaction indicates that at least this stakeholder did not understand how the process was organized. Which is in conflicts with *openness*.

8.1.4 Advantages of using VR

Two pros of VR were mentioned by all interviewees 1) a better understanding of the project and 2) the ability to view the project from different perspectives. In total 40 pros were mentioned which can be found in Appendix D. The pros related to the improvement of stakeholder satisfaction, improvement of the design and efficiency are discussed in 9.2.4, 9.2.5 and 9.2.6 respectively.

8.1.5 Disadvantages of using VR

Fourteen cons were mentioned during the interviews. Six of these cons are regarded as extra risks for the stakeholder process and are discussed in the cross-case analysis (see chapter 10). The other cons are discussed below.

Higher costs of using VR were mentioned by both the contracting authority and the project managers. The high costs are partly the result of implementing new technology. The project managers mentioned that the costs have already decreased significantly after this project.

The usability issue of the immersive VR technology was mentioned by the contracting authority. However, he mentioned that it is only an issue for part of the participants. Further development of VR might resolve this issue in the future.

As mentioned in the literature there is a tension between the number of requirements and the efficiency. One of the project managers indicated the issue that when more desires are collected, you must be capable of processing all these desires. The cons of the project managers further indicate that there are difficulties in collecting and interpreting the data. According to the contracting authority having more desires makes it possible to combine desires. However, combing these desires can be challenging, incorrect and time-consuming. One project manager indicated that you have to be careful in assigning an absolute value to a desire since people can abuse the online platform for their interest. One of the project managers indicated that quantification might result in standard solutions only.

Another issue is that the use of VR might result in loss of vision when the desires of the stakeholders do not comply with the vision. The vision of the municipality aspires a greater goal which satisfies the stakeholders in the future. One of the important stakeholders indicated that the vision of reducing the number of cars in the city centre did not comply with the desire of the stakeholders to be able to reach the city centre by car. After stakeholders complained, the municipality reopened the Hertoghstraat. This example illustrates that when the municipality focuses on maximising the desires of the current stakeholders, it can result in deviation from the vision.

8.2 Stakeholder satisfaction

In general, the interviewees mentioned that the stakeholders were satisfied with the process. During the interviews with the important stakeholders, three factors were mentioned that reduced the satisfaction over the process. 1) Not enough specific feedback 2) A grey compromise was made according to one stakeholder. 3) Abuse of power occurred in the project, the retailer's association talked to the alderman and realised a late change in the design.

Three pros of using VR were mentioned which directly indicate that there was more satisfaction due to the use of VR.

1. More enthusiasm and fun.
2. More satisfaction due to the possibility to give input.
3. More support.

The project manager mentioned that 70-80% of the stakeholder satisfaction over the process is determined by the amount and quality of information, understanding the complexity of the project, feeling that it is possible to impact the project and feeling of being heard. Table 16 shows the pros of using VR that relate to these factors that cause satisfaction over the stakeholder process.

Table 16, pros of VR that relate to the success factors of the stakeholder process for the Vestdijk project.

Factors stakeholder satisfaction	Pros VR use
A lot of high-quality information is accessible.	Due to VR stakeholders had more information available about the project. It made it possible to view the project from different perspectives. "View the project from your own garden" or "View the project as a traffic user". Effects such as the amount of traffic, air quality, the effect of light could be shown. There was more accessibility of information due to the use of the online platform.
Understand the complexity of the project	Due to the VR people better understand the project. The VR can make stakeholders realise what the impact of the project is on their interest. The VR helps to understand the scale of the project. Many stakeholders cannot read drawings but do understand the VR. The VR can give better insight into opportunities in the project for the stakeholder. Besides an understanding of the project itself, stakeholders understand the arguments of other stakeholders better due to VR. This results in more substantive discussions between stakeholders.
Ability to influence the design.	Due to VR stakeholders better understand the solution space of the project. Stakeholders were able to give propositions for alternative solutions.
The feeling of being heard	Due to VR, there is a better understanding of the decisions made.

Regarding, the better understanding there are still several wishes in the CRS project with questions and remarks to further understand the project. For example, not understanding the scale used to visualise the air pollution and the wish for a more precise map.

Given the higher satisfaction over the process mentioned by the interviewees and the relation between factors of process satisfaction and the pros of using VR, it is argued that use of VR contributes to the satisfaction over the process. All the interviewees mentioned that when the satisfaction over the process is higher the satisfaction over the project will increase as well. In general, the interviewees mentioned that most of the stakeholders were satisfied with the project, including the municipality and the board.

8.3 Improvement of the design

Nine pros of using VR were mentioned in the interviews which indicate that the use of VR improved the design.

1. More stakeholders involved.
2. Better representation of stakeholders.
3. Better insight into opportunities in the project for the stakeholder.
4. A better understanding of the arguments of other stakeholders makes the solution space clearer. Therefore, stakeholders can give propositions for alternative solutions.
5. More input from stakeholders for the design.
6. The quality of the input of the stakeholders is higher and are therefore more useful for the designers.
7. More info about the stakeholder that gives the desire.
8. A better understanding of stakeholders desires.
9. Including the VR in the design method results in better interpretation and implementation of the needs than having a separate CRS document.

The Contracting Authority indicated that the design is filled in with the customer needs and that the involvement of stakeholders has led to a better design. He indicated that, at the start of the project the focus was mobility but that due to customer needs, flexible spaces, water and more plants were added to the scope of the project. Nine customer requirements were indicated as being out of scope honoured. This shows that there is indeed scope added to the project. However, these requirements are not all transcribed to system requirements and do not include requirements on the subjects flexible spaces, water and more plants. This makes it not possible to confirm the allegation of the contracting authority.

As already mentioned 8.1.2., the input given by stakeholders was regarded as customer requirements. There was little guidance on the online platform to help stakeholders in writing desires resulting in the examples given in Table 17.

Table 17, examples of customer requirements present in the customer requirement specification and proposed categorization.

Number	Translation customer requirement	Regarded as
KE0079	Create a tunnel under the Vestdijk for the transit traffic (like the A2 Maastricht) or redirect the traffic via other roads (But this is a difficult option since there are not many options). Remove the ugly bus lane from the Vestdijk and replace it with a tram between the Bastion Hotel/ van der Valk hotel and the city centre side of the central station. This will give the city centre a more mature streetscape with authentic trams through the city (like the city of Milan). Do not allow any cars on the Vestdijk and include the area between the 18 Septemberplein and the Pullman Hotel to the city centre. This area can optionally be extended up to the Studenthotel. Improve the hospitality at the Stationsplein.	Multiple needs.
KE0248	More space for the bus stop at the 18 Septemberplein to make it accessible for wheelchairs.	Need.
KE0334	Compliments! Implement now!	Objective.
KE0449	In the 360 view, I do not see a way to enter the Heuvel garage. Is this right?	Question.

To evaluate the improvement of the design the author of this thesis manually clustered all the desires as needs, problems and objectives. Table 12 shows examples of customer requirements of these different categories. KE0334 is regarded as an objective since it is not a desire for something in the project. KE0079 is regarded as multiple desires; this is translated to multiple customer requirements. Table 18 shows the number of needs, the number of problems or objectives and the number of questions in the CRS after clustering.

Table 18, the status of desires after categorization.

Source	Needs temporary situation	Needs final project	Questions	Problems or Objectives
Contracting authority	0	23	1	23
Private organizations	1	24	3	8
Private parties	2	53	7	23
Stakeholder meetings	1	84	21	40
Inhabitants	17	279	61	113
Total (784)	**21**	**463**	**93**	**207**

The client indicated in the interview that 65-70% of all desires were useful. It is considered that questions do not contribute to an improvement of the final design. Figure 35 shows that 59% of the input are needs for something in the final project.

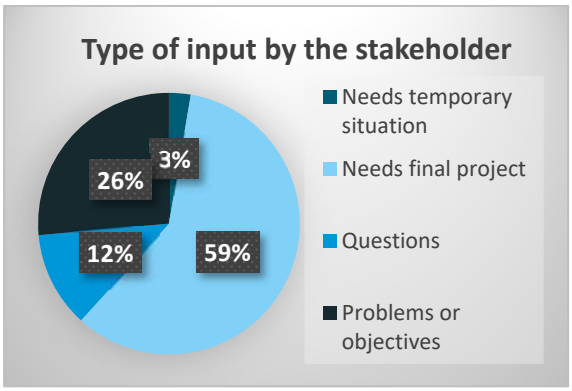

Figure 35 Type of input by the stakeholder

This is a high number of customer requirements for the project. 26% of the input are problems or objectives. This results in 85% of input that might be useful for the designers.

Table 19, the status of the customer needs.

Source	Honoured	Unhonoured	Not processed
Contracting authority	13	0	10
Private organisations	2	1	21
Private parties	1	2	43
Stakeholder meeting	15	21	48
Inhabitants	16	77	193
Total (463)	**47**	**101**	**315**

Table 19 shows the status of the 463 customer needs. From the 315 requirements that were not processed. 109 are processed by Witteveen+Bos from which 45 have the advice to honour. This indicates that approximately 41% of the processed customer needs is regarded as being useful for the design by Witteveen+Bos. Together with the problems or objectives that might be useful for the design, this is a high number of useful customer requirements.

The client indicated that approximately 50% more needs were interpreted into the design due to the use of VR. 24% of all the honoured customer requirements present in the system requirements are input from inhabitants on the VR platform. Figure 36 shows the percentage of honoured customer requirements in the system requirements. 5% was direct input on the VR.

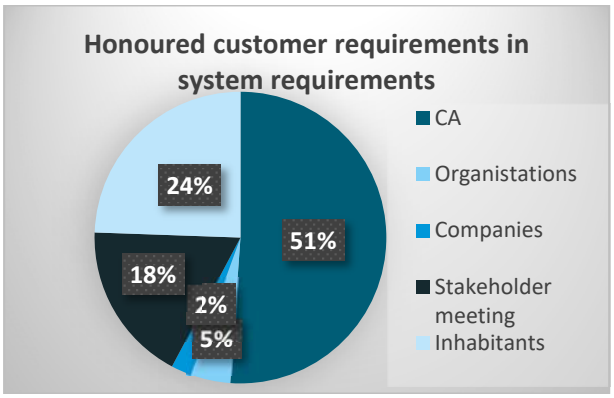

Figure 36 percentage of Honoured customer requirements in the system requirements

Figure 37 shows the number of customer requirements given by the stakeholder category per system requirement. One of these system requirements was the direct result of the VR platform, one of the system requirements are a direct input from stakeholder meeting and four of the system requirements are a direct input from the contracting authority. For the other system requirements, it is not traceable how the customer requirements relate to the system requirements. These requirements are constructed from multiple desires partly given at stakeholder meetings, partly given by the client and partly given on the online platform. Furthermore, the system requirements do not directly relate to the customer requirements. Because of this, it is hard to evaluate how much influence the stakeholders had on the design. For example, if the system requirement was already the result of the desire of the client then although the requirement of the stakeholder is honoured, and combined in the system requirement, the desire of the stakeholders did not improve the design since the system requirement already existed. Together with the incomplete CRS document, it is therefore difficult to validate the allegation that the use of VR improved the design.

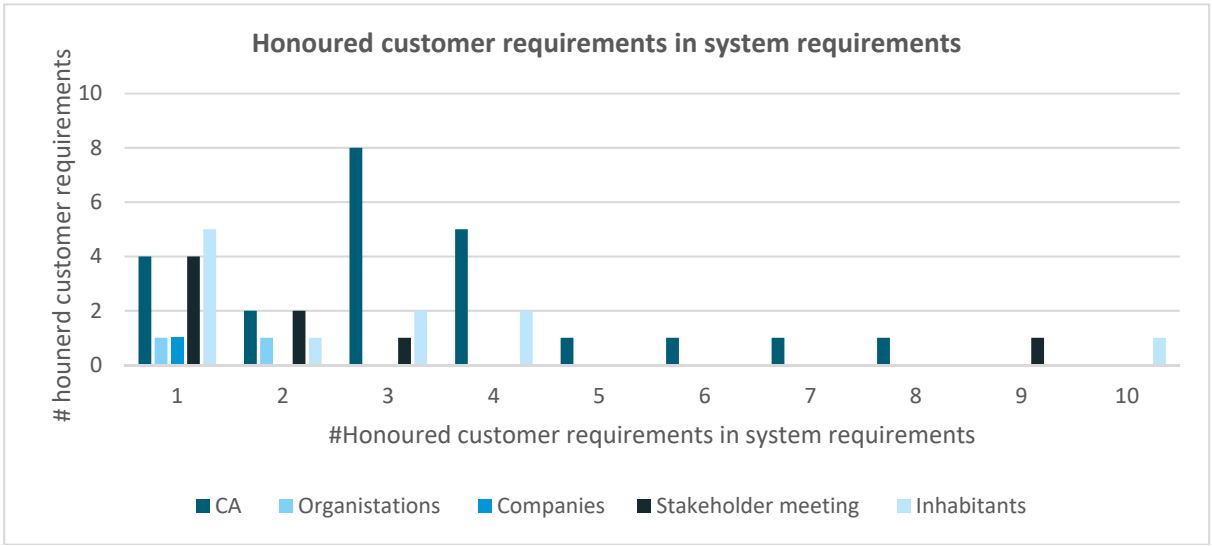

Figure 37 Honoured customer requirements per system requirement.

8.4 The efficiency

Eight pros of using VR were mentioned which indicate that the use of VR improves the efficiency of the stakeholder process.

1. Efficient process, a fast way to identify and collect desires of stakeholders.
2. Know the project goals faster.
3. Fast exchange of information.
4. Fast recognition of customer needs.
5. Fast collection of desires.
6. Fewer protests due to better understanding.
7. Reduced costs of late changes in the design.
8. Reduced design costs.

One of the disadvantages that was mentioned are the costs of using VR. According to the interviewees, using VR is efficient in terms of time. However, the process might not be efficient regarding the budget. The project managers did mention that the costs already dropped significantly which improves this aspect of efficiency in the future. The efficiency of VR must be seen in a broader context. When the use of VR results in a lower amount of protests, it can save a lot of money and time. Furthermore, the project managers mentioned two efficiency advantages which relate to the design process instead of the stakeholder process. Implementing the use of VR in the design method can reduce the design costs and failure costs caused by late changes in the design.
However, looking at the CRS document, several types of waste present in the stakeholder process can be identified. From the processed requirements 38% was unhonoured and out of scope (see Figure 38). This percentage is higher than the 5% assumed reasonable by Baarends (2015) and indicates that waste of overproduction, transportation and over-processing. Some stakeholders had particular questions about objects missing in the VR which can be seen as waste of overproduction.

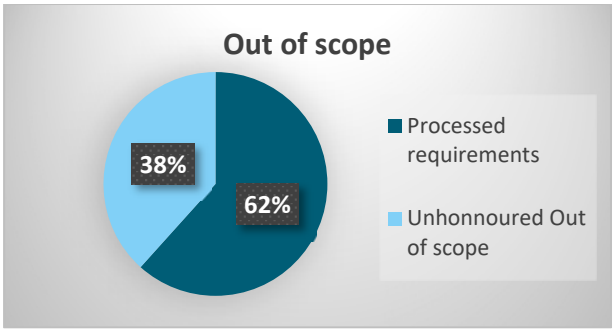

Figure 38 Percentage of out of scope requirements of the total number of processed requirements Vestdijk project.

Due to the out of date CRS, it is hard to assess the waste of waiting and the waste of talent since it is unclear what happened to the requirements that are not processed. 412 requirements are waiting to be processed by Witteveen+Bos, and 146 requirements have advice from Witteveen+Bos and are waiting to be assessed by the municipality.

Waste of defects was present due to the use of VR. The Contracting Authority indicated that there was an incorrect curb in the VR model. Other defects mentioned in the CRS document were wrong car directions, a tree in front of the garage entrance, incorrect link to the newsletter and an indication that the website is not working.

When the use of an online platform reduces the number of people that travel to a physical stakeholder meeting, the waste of motion is reduced.

Although the interviews indicate that the use of VR improves the efficiency there is a lot of waste present in the CRS document indicate that the stakeholder process in itself was not efficient.

8.5 Limitations

As mentioned in the previous chapters the analysis is more difficult due to the incomplete CRS document. The incomplete document makes it hard to confirm the allegations made by the interviewees.

Another aspect that makes the validation difficult is that it is not clear what requirements were the result of using VR. For example, the VR was only used at a few stakeholder meetings. Furthermore, when the VR was not used at the stakeholder meeting, it does not necessarily mean that the use of VR did not influence the result of the stakeholder information meeting since people might have used the online platform before the stakeholder meeting.

The important stakeholders interviewed did not use the online platform. This reduces the quality of their input for this research. The contracting authority indicated that with hindsight he would have liked to apply the VR at the important stakeholder meetings as well.

The municipality temporary closed one traffic lane with a barrier to show the effects of the project in practice. The consequences of this temporary situation were measured and communicated to the stakeholders. The effects of taking such a temporary measure on the stakeholder process are unclear. A temporary measure might result in a sense of urgency, made it possible to measure consequences, allows people to experience the new situation and give feedback on this situation. However, the temporary measure might result in a negative view on the project due to the chaos that occurred when the temporary situation was put into practice. For example, traffic problems that occurred in the neighbouring streets. This makes the evaluation of the effect that VR had on the process more difficult.

For the evaluation of the improvement of the design, the desires were manually classified as needs temporary situation, needs final project, questions and problems or objectives. This classification is based on the author's interpretation of the desires and might deviate somewhat if an expert made the classification.

The interviews were held in the native language, which was Dutch. The results of the interviews are translated. Therefore, the meaning of a translation might slightly deviate from the original sentence.

8.6 Conclusion

The Vestdijk project was a complex project. A dynamic stakeholder process was used to deal with the complexity. The interviewees mentioned that most of the stakeholders were satisfied with the stakeholder process although a few risks of stakeholder involvement did occur.

Stakeholders were involved in different ways. Stakeholders could influence the design via stakeholder meetings or the online platform. The stakeholders delivered much input for the project. Witteveen+Bos regarded all the input given by the stakeholders as customer requirements. Multiple different requirements were transferred to system requirements which reduced the traceability. Many requirements did not have a status although the final design is already finished and not all the honoured customer needs were translated to system requirements. This indicates that there is only partly worked explicitly and that the SE method was not applied well which resulted in an out of date and incomplete CRS document.

Eight different purposes of using VR were mentioned by the interviewees of which give insight in consequences of the project, give the opportunity to give input and involve more stakeholders were mentioned by both the project managers and the contracting authority. Two types of VR were used in the process, a low immersive VR on the online platform and a high immersive VR during stakeholder information meeting.

40 pros and 14 cons of using VR were mentioned during the interviews (See appendix D&E). Three cons indicate that there is a need for better interfaces in VR to collect desires, better methods to process the collected data and research methods on how to interpret the data. The interviewees mentioned a tension between using customer requirements and having a vision. A design should not be focused on purely maximising the satisfaction of the stakeholders since this results in loss of vision.

The use of VR created more satisfaction for the stakeholders about the process partly due to a lot of high-quality information is accessible, understanding of the complexity of the project, the ability to influence the design and the feeling of being heard. The use of VR improved the satisfaction over the process and the project for the Vestdijk project.

Due to the incomplete CRS document and not traceable customer requirements it is difficult to validate the allegations made by the interviewees that the use of VR improved the design.

According to all the interviewees using VR is efficient regarding time. The efficiency regarding money is still unclear and should be evaluated in a broader context to take the advantages regarding reducing failure costs and design costs for the design process into account. During the validation session, the project manager argued that the cost of the total process was considered lower due to fewer protests.

The stakeholder process itself was not efficient. Several types of waste were present which further stresses the need for better interfaces and better methods to process the collected data to enhances the efficiency.

8.7 Recommendations

Below nine recommendations for improvements are given. The project manager of Witteveen+Bos considered the recommendations useful. Especially the recommendation of transcription to desire and specific feedback. These recommendations are currently applied in a new VR project. Recommendation 8.7.4 is considered an ongoing process where there will always be room for improvement.

8.7.1 Transcribe the desires to a customer requirements

In this transcription step, the unstructured ideas of stakeholders must be translated into problems, objectives and needs. Transcribing needs to SMART customer requirements will make them useful for the designers. In this transcription step, it is possible to cluster multiple desires into one customer requirement when the desires are the same. Combining needs results in fewer customer requirements than customer needs. However, the desires must all directly relate to the customer requirement. This contributes to *explicit working*; it is better traceable where a design decision comes from. One can see which stakeholders desired the customer requirement. This will improve the traceability which customer desire led to which system requirement.

8.7.2 Validation of customer requirements.

The use of VR can reduce the problem of wrong interpretation of the desire and incorrect transcription of the desire to a customer requirement. Customer requirements can be validated by implementing the temporary new honoured customer requirements in the VR. This contributes to *top-down specification*. In the CRS document for the Vestdijk project, several desires were present for a wider cycling lane. These wishes could be translated to a SMART customer requirement, for example, the width of the cycling path needs to be 4,00m. This customer requirement can then be temporarily honoured and visualised in the VR design. In this way, the stakeholder that gave the desire can validate if this customer requirement satisfies the customer needs.

8.7.3 Give specific feedback

One of the stakeholders mentioned that he would have liked more specific feedback. The stakeholders have the right to know what happened with their input. Since there is made use of a system engineering method, one can automatically send feedback when a honoration decision is made. This contributes to *explicit working*.

8.7.4 Improve the quality of the input

Processing all the requirements can be much work when collecting hundreds of desires. Interfaces can be used to reduces the processing that needs to be done by the client and Witteveen+Bos. Developing good interfaces was mentioned by one of the project managers as being essential but still difficult. Interfaces are used to get more structured input from the stakeholder. Suggested improvements are:

1. Limit the number of characters that a stakeholder is allowed to use to describe their desire.
2. Let stakeholders indicate the theme of their desire.
3. Let stakeholder classify their input as a need, question, or objective/ problem.
4. Help stakeholders in writing SMART needs.

The latter can be helpful to educate stakeholders how to write customer requirements that are useful for the designers. These interfaces might reduce the processing time to create customer requirements.

8.7.5 Information about the stakeholder

Using VR on an online platform creates the possibility to gather more information about the stakeholder. The project managers mentioned more information about the stakeholders as one of the advantages. Information such as how satisfied stakeholders are with the current design can be useful for the stakeholder process. This can be used as an indication for the overall project satisfaction and can be helpful in classifying the stakeholders to prepare for a stakeholder management strategy.

8.7.6 Further research into methods to process the data

It is recommended to do further research in data analysis options that might reduce the processing time. Suggested improvements are:

1. Use software that can automatically cluster or filter the data collected which makes the processing easier.
2. Let stakeholders cluster and prioritise the desires of others.

8.7.7 Further research in interpreting the qualitative as quantitative data

Quantifying the qualitative data requires research methods on how to deal with and interpret the data. In the Vestdijk project, the client assumed that having more responses indicates what the critical issues for the project are. However, this can be risky and can be an incorrect measurement of importance. For example, how many reactions are needed to have a good sample of the population and how many reactions make something important. Further research into research methods is necessary for proper interpretation of the data.

8.7.8 Use the virtual reality tool in communication with important stakeholders

The VR tool was only used in the communication with the inhabitants. The contracting authority indicated that the use of VR could have been beneficial in the communication with the important stakeholders. When the VR is available, it is recommended to use the VR in these conversations as well.

8.7.9 Be specific about the boundary conditions due to the vision

To solve the tension between using customer requirements and vision it is recommended to explicitly specifying the boundary conditions for the project. The project is structured top-down and starts with a client that has a mission, vision and ambition. This contributes to *top-down specification*. The vision must be communicated, and it must be clear to the stakeholders what the consequence of the vision is on the project.

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9 CASE STUDY ZAANENSTRAAT

This chapter follows the same structure as chapter 7 & 8 and elaborates on the added value of VR in a dynamic stakeholder process for the Zaanenstraat project by making use of the framework discussed in chapter 6.2.

Project description

In 2016 the municipality of Haarlem presented the vision on the design of public spaces in the "Handboek Inrichting Openbare Ruimte (HIOR)" (van Esterik, Sillmann, van der Stelt, Meuleman, & Kippersluis, 15 January 2016). Part of this vision was a preferred profile design for neighbourhoods in Haarlem including the "Indische buurt" in which the Zaanenstraat is located. The sewage system of the Zaanenstraat needs to be renewed. The Zaanenstraat used to be a beautiful street with many trees on each side of the road. The trees were cleared since they were infected with a disease. Inhabitants would like to have these trees in the street again, but that is not possible due to the cables and pipes placed in the area. The Zaanenstraat is a busy road in a surrounding with many residents. The stakeholders often notice speeding cars on the road. Besides that, there is an issue of not enough parking spaces. Redesigning 500 meters of the Zaanenstraat and redesigning the sewage system where the goals of the Zaanenstraat project. Witteveen+Bos was contracted to design and execute the project; process management was part of the assignment as well. Currently, the project is being executed.

Several examples given by the interviewees indicated that both dynamic and detail complexity were present in the project. Two examples indicate that there was a limited understanding and that the project changed over time which are characteristics of dynamic complexity. The team that was responsible for redesigning the road was unaware that another team was assigned to design a new sewage system under the road. One of the requirements given by the municipality turned out to be impossible. These factors resulted in the need for adjustment of the plan and dilemmas how to redesign the street. There were many desires for the project, but there was not enough room to fulfil all customer needs.

One example given by the project manager indicates that the project consisted of interrelated parts, which is a characteristic of detail complexity. The interfaces between the system of cables and pipes and the road system made the project more complex. There used to be wide sidewalks at each side of the road. As a result, the cables and pipes are present under the full width of the sidewalks. The soil structure in the area is complex as well which makes it difficult to construct a sewage system.

Dynamic management was required to deal with the complexity of the project. However not all the requirements were present for a dynamic stakeholder process. Some elements of SE were present, but SE was not explicitly used.

9.1 Dynamic stakeholder process

Figure 39 visualises the stakeholder process of the Zaanenstraat, which is explained on the next page. As mentioned in 3.3 there is no single outcome of each process step. Every step in the process is broadly explored, after which decisions are made to narrow it down and the next step of the process starts (van Oosterhout, 2010). It is not a linear process the outcome of one step can influence the work in the previous step.

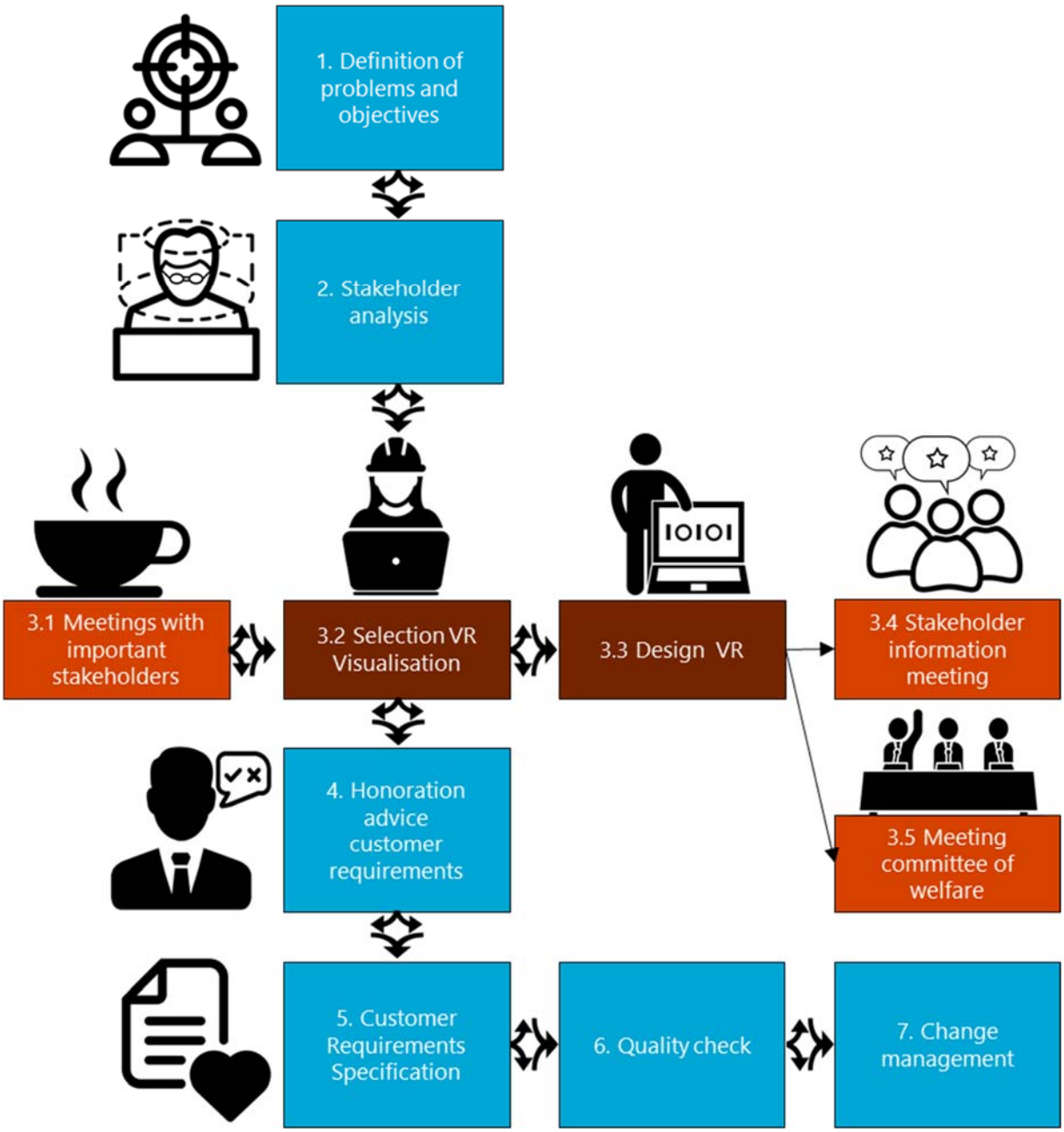

Figure 39 Stakeholder process Zaanenstraat

1. Definition of problems and objectives:
   The municipality did an exploration for the scope and vision for the project. Requirements that needed to be fulfilled were made based on this exploration. The municipality registered the vision in the HIOR. The HIOR forms the boundary conditions for the project and gives the desired standard profiles for redesigning roads in the municipality.
2. Stakeholder analysis:
   A stakeholder analysis was done to see how to manage the stakeholders in the process.
3. Collect customer requirements:

3.1 Meetings with important stakeholders:
Meetings were held with the important stakeholders. Witteveen+Bos manually put the desires given by the stakeholders into a database.

3.2 Selection VR visualisation:
Witteveen+Bos selected what to visualise in VR.

3.3 Design VR:
Witteveen+Bos made a design based on the HIOR. The concept design for the project was made in 2D. The design was adjusted with honoured requirements. A 3D model was made based on the concept design which was used to make the VR.

3.4 Stakeholder information meeting:
The VR was showed on a stakeholder information meeting for all the stakeholders in November 2016 (Gregor, 2017). This stakeholder information meeting was planned to be an input session for stakeholders. The stakeholders could first look at the VR and afterwards discuss their needs or remarks with the project manager. Desires of the stakeholders were written down by Witteveen+Bos. Several follow-up meetings were held to inform stakeholders how their input was used (Gregor, 2017) A presentation session was organised the day before publishing the preliminary design. In this presentation session, the result of the design was shown, and feedback was given what was done with the customer requirements.

3.5 Meeting committee of welfare:
Meeting with the "Adviescommissie ruimtelijke kwaliteit" (ARK) a committee of welfare was held. The committee can add requirements to the design and needs to approve the design. The VR was used during this meeting.

4. Honoration advise customer requirements:
   A honoration advise was given by Witteveen+Bos. The needs were often discussed with the municipality.
5. Customer Requirements specification:
   The customer requirements were documented in the CRS document.
6. Quality check.
7. Change management.

9.1.1 Application of the Virtual Reality tool in the stakeholder process

Four purposes of using VR were mentioned by the interviewees (See Table 20).

Table 20, the purpose of using Virtual Reality.

Interviewee	The goal of using Virtual Reality
Contracting Authority & Project manager	1. Pilot project.
	2. Give a better impression of the future project to the stakeholders.
Project Manager	3. Improve communication with the stakeholders.
	4. Improve communication with the ARK.

Three of these purposes relates to *substance*. The VR was supposed to give a better impression of the project and improve the communication. The application of VR was seen as successful by the important stakeholder. It was used to make the concept design of the project to start the conversation with the stakeholders.

Figure 40 High immersive VR setup used in the Zaanenstraat project. Left image retrieved from DignaBrand (2016). (https://pbs.twimg.com/media/CwSJPE8XEAAqCXr.jpg:large). Right image retrieved from Witteveen+Bos. (N.d.). (http://bim.Witteveen+Bos.com/VR/hlm_zaanenstraat.html)

A high immersive VR on stakeholder information meetings (see Figure 40). The VR was high immersive since it was an inclusive, extensive, surrounding and vivid representation. VR goggles were used to give a surrounding representation. One can view the whole project area with a 360-degree view. The VR was vivid, some moving cars that represented the amount during rush hour were implemented in the VR. The quality of the VR was not very high; there were no façade details on the building. However, according to the project manager, the quality of the VR was high enough that people could recognise the street from their own home. Fixed points were used, the VR was showed from the front door of the stakeholders (Gregor, 2017). When using fixed points, the movements in the real world and VR do not match which makes the experience less extensive. There was no sound added to the VR which makes the VR less inclusive. Two design alternatives were shown to the stakeholders. A display was placed on the table so that people could see what the one using the goggles was looking at. At a few stakeholder meetings, Google Cardboards were used instead of the VR goggles. With the use of Google Cardboards, the VR was somewhat less immersive. This VR did not have moving objects which makes the experience less vivid. Table 21 indicates the estimated used number of the different types of VR.

Table 21, the estimated number of VR use by the project manager.

Type of VR	Estimated user number
High immersive VR	Two times stakeholder information meeting
Fixed point VR.	One-time ARK

9.1.2 Application of Systems Engineering in the stakeholder process

In the stakeholder process elements of SE were used. The CRS process was used to translate all the desires of the stakeholders to customer requirements.

The information from the stakeholders is documented in the CRS database by W+B, the data from stakeholders were clustered in three columns:

1. Questions or remarks about the project.
2. What the stakeholder finds important in the project.
3. What makes the project a success according to the stakeholder.

As mentioned in chapter 3.3.3., the unstructured ideas need to be translated into problems, objectives and needs (Nicholas & Steyn, 2012). The classification above can be seen as a way to structure the ideas into problems, needs and objectives.

Witteveen+Bos used this to write customer requirements per stakeholder. However, several customer requirements written by Witteveen+Bos are not derived from the clustered data. This is incorrect since the customer requirements are not well-founded in this way. Some customer requirements have multiple desires in the customer requirement which is not confirming the SE stakeholder management principles.

The important stakeholder indicated that he desired a pedestrian island in the middle of the road. This customer requirement is present as an honoured requirement in the CRS document by another stakeholder but not as a requirement from the important stakeholder. For the traceability and justification of the design, it would be better to have this desire two times in the CRS document and both marked as honoured customer requirements.

The customer requirements generated by Witteveen+Bos all got an honoration advice and are discussed with the municipality. However, the honoured customer requirements are not transcribed to system requirements. This makes it untraceable if the needs are actually implemented in the design. Table 22 shows the advice given to all the customer requirements. The requirements that are being discussed with the municipality are marked as not processed.

Table 22, advise customer requirements Zaanenstraat project.

Source	Not processed	Honoured	Unhonoured	Secured
Public organisations	0	9	0	0
Private organisation	1	6	1	0
Private parties	4	10	2	0
Inhabitants	18	42	29	1
Total (124)	23	67	32	1

One of the causes of the process being unsuccessful mentioned by the process manager was that the needs of the contracting authority were not clear. The project manager indicated that there was insufficient alignment with the municipality about the priorities and goals for the project. There are no requirements from the Contracting Authority present in the CRS document as well.

The project manager indicated that due to VR strategic spots were located to design docking stations for electric cars. The contracting authority indicated that due to VR people realised that if the width of the sidewalk is reduced, they did not want to see the cars. These examples of customer needs were mentioned during the interview but are not present in the CRS. These examples indicate that not all the desires of stakeholders are present in the CRS document, indicating that the CRS document is incomplete.

9.1.3 Application of interactive stakeholder management process

Since complaints were expected, an interactive stakeholder management approach was used to reduce the number of objections. As mentioned by the project manager, the stakeholders were given the opportunity to give input on topics that they find important. The idea of the process was to have an input session and a presentation session. Approximately 100 stakeholders attended the information meeting (Gregor, 2017). During the stakeholder process, 36 stakeholders gave desires to Witteveen+Bos which resulted in 124 customer requirements.

9.1.4 Advantages of using VR

One pro of VR mentioned by all interviewees was a better understanding of the project. Many stakeholders cannot read 2D drawings. In total 26 pros were mentioned which can be found in Appendix D. The pros related to the improvement of stakeholder satisfaction, improvement of the design and efficiency will be discussed in 9.2.4, 9.2.5 and 9.2.6 respectively.

9.1.5 Disadvantages of using VR

Two cons were mentioned during the interviews. One of the cons mentioned by the important stakeholder is that people might interpret the VR as reality. This con is regarded as extra risks for the stakeholder process and will be discussed in the cross-case analysis (see chapter 10). The other disadvantage, mentioned by both the contracting authority and the project managers, is that there is no budget available to increase investments in the stakeholder process. However, the implementation of the new environmental code will change the budget allocation of the contracting authority from a budget per sector to a budget per area. The implementation of the new environmental code introduces a new goal for the stakeholder process which is the allocation of budget to the project. According to the project manager, this creates opportunities for VR, since VR can be used to verify which sector benefits from the project and can be used to visualise the solution space. This can be useful to determine who has to pay for the project.

9.2 Stakeholder satisfaction

The stakeholder process was seen as unsuccessful by the Project manager. There were many objections, and the process took much time. The project manager indicated that the process manager of the contracting authority gave too much freedom when presenting the design. Due to the open attitude of the process manager, the presentation session changed into an input session which resulted in a lot of official objections to the project.

The contracting authority doubted whether the objections on the project had anything to do with the use of VR. It might be that due to the use of VR people are more critical about specific elements in the preliminary design. According to the contracting authority, people understood that the project makes the street beautiful due to the use of VR. The people had worse expectations for the project. The project manager indicated that he does not think that the use of VR created more support for the project. He did indicate that due to the possibility to give input stakeholders are more favourable. The important stakeholder mentioned that the stakeholders appreciated the effort taken by Witteveen+Bos to involve them.

Two pros of using VR were mentioned which directly indicate that there was more satisfaction over the stakeholder process due to the use of VR.
Stakeholders enjoyed using VR.
VR created a more satisfying stakeholder process, a nice ambience with interaction.

Table 23 shows the other pros of using VR that relate to the factors that caused satisfaction over the Zaanenstraat process.

Table 23, pros of VR that relate to factors of more satisfaction over the Zaanenstraat project.

Factors stakeholder satisfaction	Pros VR use
Understand design decisions	Many stakeholders cannot read 2D drawings. VR makes it possible to present the mental image that the project manager has in his head to the stakeholders. Some elements and effect are hard to explain to a stakeholder, VR can help to visualise these elements and effects. For example, VR can be used how a tree would look like and what the effect of the tree is on the amount of light in the street. Besides that, high immersive VR helps to understand the scale of the project. The project can be shown from different perspectives; this helps stakeholders to identify if their interest is hurt or whether they benefit from the project. VR can help Stakeholders to identify alternative solutions for the project that they find acceptable. The effect of the desires of the stakeholders can be visualised, and design alternatives can be discussed. Showing effects and alternatives help stakeholders to understand the project and to understand the decisions made.
Understand the stakeholders	VR creates a common language among stakeholders; it helps stakeholders to understand each other. It prevents misunderstandings and helps with talking about the same topic. Due to this, there is a more substantive and factual discussion between stakeholders. Stakeholders are better capable of clarifying their desires and interest. The desires of the stakeholders can be identified faster by the project managers, and the solution space can be discovered.

The use of VR created more satisfaction over the process partly due to a better understanding of design decisions and a better understanding of stakeholders. Whether this also created more satisfaction over the project is hard to validate since the contracting authority, and important stakeholder both think that the use of VR let to more satisfaction over the project but the project manager doubts whether the use of VR created more support for the project.

9.3 Improvement of the design

Four pros of using VR were mentioned in the interviews which indicate that the use of VR improved the design.

1. VR helps stakeholders to generate ideas.
2. VR helps stakeholders to identify alternative solutions for the project that they find acceptable.
3. VR gives the ability to discover the solution space.
4. VR enables more substantive discussions about the project with the committee of welfare.

The quality of the requirements is high. According to Gregor (2017) due to the use of VR, the feedback was constructive and detailed, instead of being oppositional or indifferent. Looking at the overview of the customer requirements shows that the honoured customer requirements consist of top requirements that give the objective of the project such as create a safe Zaanenstraat. However, far more specific SMART requirements are present as well. With these specific honoured customer requirements, the profile of the Zaanenstraat desired by the stakeholders can be determined.

The project manager indicated a few examples of improvement of the design due to the use of VR.

1. Due to the use of VR, a parking space which was removed in the concept design was brought back into the design. In the CRS document, this desire is being honoured.
2. Due to the use of VR, the stakeholders could give more detailed information about the parking situation in an early stage resulting in the further investigation for alternative loading and unloading facilities for the companies. In the CRS document, this desire is under discussion.

However, because the system requirements are missing it is hard to evaluate how much influence the stakeholders had on the design.

9.4 Efficiency

One pro of using VR was mentioned which indicate that the use of VR improves the efficiency of the stakeholder process.

1. Faster identification of desires of stakeholders.

According to the project manager, stakeholders gave specific desires which would otherwise only heard as objections on the concept design. According to the contracting authority, the efficiency of the VR depends on the type of VR used an example was given that there was only one VR goggle available for a stakeholder meeting with 35 people, which result in an inefficient process regarding time.

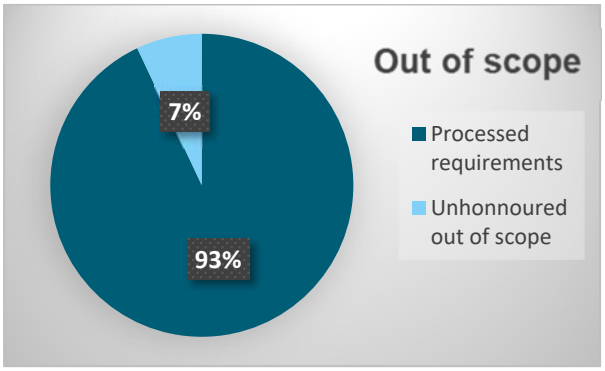

Figure 41, the percentage of out of scope requirements of the total number of processed requirements Zaanenstraat project.

Looking at the CRS document several types of waste can be identified for the stakeholder process itself. From the processed requirements 7% was unhonoured out of scope (see Figure 41). This is slightly higher than the 5% assumed reasonable by Baarends (2015), which indicates that waste of overproduction, transportation and over-processing is present. Waste of waiting is present in the process as well 23 requirements are waiting to be processed by the contracting authority. Waste of talent might be present as well a few stakeholders are asking for more involvement on a specific topic.

Because the project was a pilot, there was not much to say about the costs of using VR. However, the project manager indicates that the use of VR increased the efficiency regarding time. The stakeholder process itself was inefficient there was more waste present than assumed reasonable.

9.5 Limitations

For the Zaanenstraat SE was not used. Due to this, there is only an overview available of the requirements that have a honoration advice not a final overview of the requirements that were used in the design. Due to this, the honoration advice is used to evaluate the project although it is reckoned that there are requirements that have advice to honour which in the design phase turned out to be impossible.

9.6 Conclusion

The Zaanenstraat project was a complex project, to deal with the complexity interactive stakeholder management was used but SE was not explicitly used in the stakeholder process. The stakeholder process was seen as unsuccessful by the Project manager. There were many objections, and the process took much time.

Stakeholders were involved in different ways. Stakeholders could influence the design via stakeholder meetings. Although SE was not explicitly used some elements of SE were applied in the stakeholder process and a CRS document was made. Not all the customer requirements in this document were well-founded by the desires of stakeholders, and some requirements were missing. The honoured customer requirements are not translated to system requirements which makes it difficult to validate if the use of VR contributed to the improvement of the design. It is untraceable which customer requirements were implemented in the design.

Four purposes for using VR were mentioned by the contracting authority and the process manager. Pilot project and giving a better impression to stakeholders what the future project will look like where mentioned by both. A high immersive VR was used on stakeholder information meetings.

26 Pros and two cons of using VR were mentioned during the interview (See appendix D&E). One con is regarded as extra risks. The other con indicates that there is no budget available to increase investments in the stakeholder process, although the project might benefit from it.

The use of VR created more satisfaction over the process partly due to a better understanding of design decisions and a better understanding of stakeholders. Two of the three interviewees think that this resulted in more satisfaction over the project as well.

The quality of the customer requirements is high, the pros of using VR and examples given during the interview also indicate an improvement of the design. However, because the system requirements are missing it is hard to evaluate how much influence the stakeholders had on the design.

One of the pros of VR indicates that the use of VR increased the efficiency regarding time. The use of VR resulted in faster identification of the desires of stakeholders. The process itself had slightly more waste of overproduction, transportation and over-processing than is assumed reasonable.

9.7 Recommendations

9.7.1 Combine the budgets for the project and process

As mentioned in 3.2.1 on of the key principles of SE is *Optimisation throughout the lifecycle*. In the interviews was mentioned that the government does not have the budget for improvement of the stakeholder process. Having a good stakeholder process can reduce failure costs and improve the design. Having separate budgets for process and project gives the incentive to do the stakeholder process itself as efficient as possible. The focus on the cost of the process discourages investments in tools for the stakeholder process that are not efficient regarding the process but can save money in the design phase of the project. Cost optimisation should be based on the whole lifecycle of the project. The municipality must assign one budget for developing the whole project. As mentioned in 3.3.1, the project manager must allocate the resources needed for the process.

9.7.2 Evaluation of the quality of the process

The recommendation that is provided in chapter 9.7.1 can result in loss of control on the process by the municipality. To prevent that this recommendation actually leads to fewer investments in the process. The costs of the process must be monitored, and the municipality can evaluate the quality of the stakeholder process. A committee of welfare is appointed by the municipality to check if designs are in line with the vision of the municipality. It is recommended to do a same kind of audit for the stakeholder process. The municipality can evaluate if all the important stakeholders are included and evaluate the quality of the customer requirements.

9.7.3 Use System Engineering to deal with complex projects

Although the Zaanenstraat was a complex project, there was no SE used to deal with the complexity. One of the causes of the stakeholder process being unsuccessful were unclear needs of the contracting authority and insufficient alignment. When using SE the project, this problem would have been reduced due to *top-down specification*. The project starts with a client that has a mission, vision and ambition.

10 CROSS CASE ANALYSIS

The cross-case analysis is used to compare the different case study and construct more general conclusions about the aspects influenced by the use of VR. First, the predefined aspects of added value are evaluated. After which the structure used to evaluate the added value is adjusted into a decision-making framework for the use of a tool in the stakeholder process. The goals and success factors mentioned by the stakeholders are discussed. The success factors for the stakeholder process mentioned by the interviewees are combined in general success factors for the stakeholder process. These success factors are the means to satisfy the goal of the stakeholder process. The framework is explained from right to left, starting with the goal of the stakeholder process. After which the success factors to these goals are determined. The influence of dynamic stakeholder management on these success factors is elaborated on. With this framework first the intended use of VR is discussed after which the actual result of using VR and future possibilities for using VR.

10.1 Evaluation of the dynamic stakeholder process with Virtual Reality

Two of the stakeholder processes where seen as successful. Below the application of dynamic management and the influence of VR on the predefined aspects of added value are discussed.

10.1.1 Application of dynamic management

Although the Zaanenstraat was a complex project, there was no SE used to deal with the complexity. The Zaanenstraat project was the only project where the stakeholder process was seen as unsuccessful. Although SE was not applied well in the Vestdijk project, the overall satisfaction with the process is high. However, some remarks were made by the important stakeholder which indicates that more *explicit working* and better feedback could have further increased the stakeholder satisfaction. For the A9 project, SE was applied well in the stakeholder process resulting in a SMART CRS document.

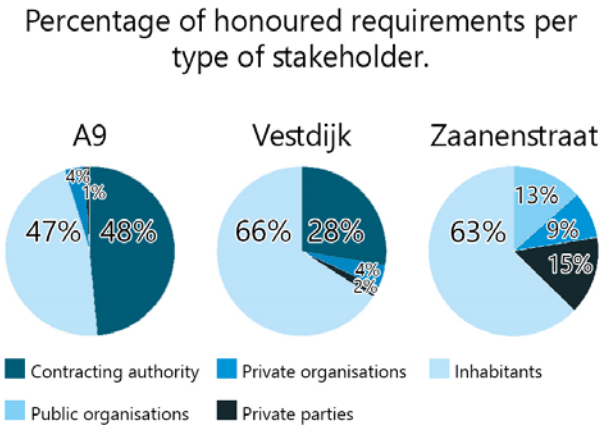

Figure 42, the percentage of honoured requirements per type of stakeholder.

In all the projects people were involved in different ways and were allowed to influence the design. Figure 42 shows the percentage of honoured requirements per type of stakeholder. There were no honoured requirements of the contracting authority present for the Zaanenstraat project (see Figure 42). There are no requirements given by inhabitants present in the figure for the A9 project. The municipality processes the requirements of inhabitants, due to that, the honoured requirements of inhabitants are registered under public organisations.

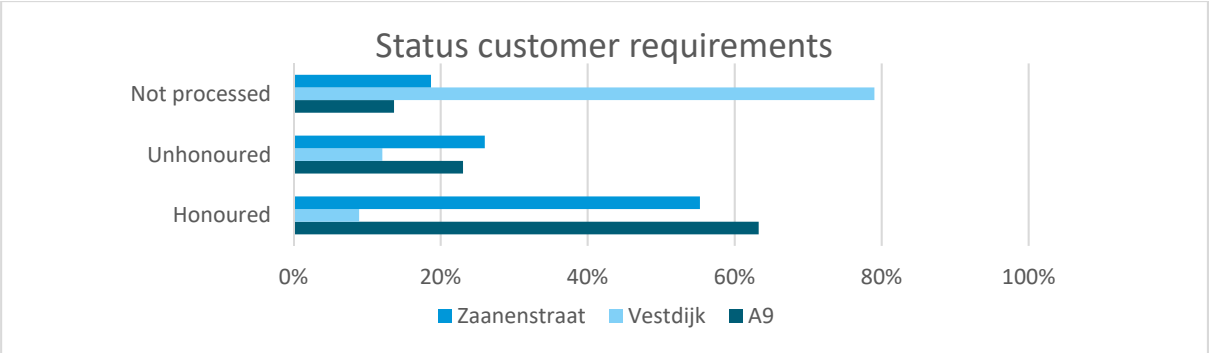

Figure 43, the status of the customer requirements

Figure 43 shows the status of the customer requirements. The amount of knowledge and experience of the stakeholders used in the design of the Vestdijk project is questioned. Approximately 9% of all the customer requirements are honoured. The project manager stated that at a certain point it does not matter to have more desires since you already know all the arguments. This might be the explanation of the high percentage of not processed requirements.

10.1.2 Influence of VR on the predefined aspects of added value.

In the case study four values were evaluated (see Table 24).

Table 24, the effect of using VR on the predefined aspects of added value.

	Effect of using VR in the project		
Predefined aspect added value	**A9**	**Vestdijk**	**Zaanenstraat**
Satisfaction over the project	++	++	+
Satisfaction over the process	++	++	++
Improvement of the design	+	-	+
- Number of honoured requirements	-	?	?
- Quality of the requirements	++	-	+
Efficiency	+	0	0
-Costs	?	?	?
-Time	+	+ +	+
-Process	+	- -	-

The use of VR resulted in more satisfaction over the project, fewer objections for the A9 project and more support for the Vestdijk project. For the Zaanenstraat project, the project manager doubts whether the use of VR led to more support. In all the cases, the satisfaction over the process was higher due to the use of VR. Stakeholders enjoy the process more due to the use of VR.

There is a clear difference in the improvement of the design per project. Where the improvement of the design of the Vestdijk depends on the number of requirements given and the improvement of the design for the other projects is caused by the higher quality of the customer requirements.

As mentioned in the problem description, the stakeholder process is often inefficient. Two of the three stakeholder process were inefficient. The A9 process was very efficient with a low amount of waste and only 2% of requirements being out of scope. For the Vestdijk project, the process itself was highly inefficient with a lot of waste present, 38% of the requirements were out of scope, and 79% of the requirements are waiting to be assessed. The inefficiency of this process can partly be explained by wrong processing of the requirements and much freedom for the stakeholders resulting in the extensive

input. The efficiency of the process relates to the number of requirements and the quality of these requirements.

The use of VR in the stakeholder process increased the efficiency regarding time in all projects. For the Vestdijk project, several pros of using VR indicate faster recognition and collection of requirements. Due to this desires from stakeholders for the project are clear earlier in the process. For the Zaanenstraat faster identification of desires is mentioned as a pro as well. For the A9 the time efficiency regards the time it took to clarify the project to the stakeholders. The efficiency regarding costs of VR is still unclear. Further research is needed to evaluate the cost efficiency. This cost efficiency must be evaluated in a broad context since the benefits of using VR in the stakeholder process can lie outside the stakeholder process itself. The use of VR might reduce the costs related to protest or reduce design and failure costs.

10.2 Decision making Framework for using a tool in a dynamic stakeholder process

The framework provided in chapter 6.2 is extended into a decision-making framework which makes clear what the use of a tool contributes to the stakeholder process. The goals and success factors of the stakeholder process are based on the interviews. The contribution of dynamic management to the success factors is discussed on the success factors is discussed.

10.2.1 The goal of the stakeholder process

The different interviewees mentioned eight different goals of the stakeholder process (see Table 25).

Table 25, the purpose of using Virtual Reality.

Interviewee	The goal of the stakeholder process
Contracting Authority	1. Allow stakeholders to influence the design with desires.
	2. Appreciated stakeholder involvement.
	3. Involve stakeholders in the project.
	4. The stakeholders understand the project.
Project managers	5. Creating support for the project.
	6. Satisfied stakeholders
	7. Having desires of a representative group of all stakeholders
Important stakeholders	8. That the stakeholders have a feeling of being heard.

Involving stakeholders in the project and allowing them to influence the design is not seen as a goal of the stakeholder process but as a mean. Other interviewees mention both as success factors. With a dynamic stakeholder process, stakeholders are involved by satisfying the key elements of interactive stakeholder management, and stakeholders can influence the design by translating desires to SMART customer requirements making use of SE. The designers of the project can use customer requirements to improve the design.

That the stakeholders understand the project and create a feeling of being heard are seen as a mean of stakeholder satisfaction, not as an end. These are mentioned by another interviewee as a success factor as well. Having desires of a representative group of all stakeholders is one of the risk events of the stakeholder process that can reduce stakeholder satisfaction.

The three goals remaining for the stakeholder process are appreciated stakeholder involvement, satisfied stakeholder, and create support for the project. It is argued that this can be seen as satisfaction over the process and satisfaction over the project. This is used as the output for the stakeholder process (see Figure 44).

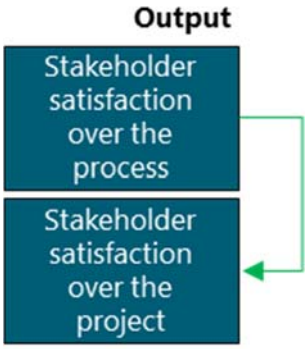

Figure 44 Output stakeholder process.

However, it is reckoned that support for the project can be reached without stakeholder satisfaction over the project for example by compensating stakeholder. The interviewees did not mention the other goal of the stakeholder process, determined in this thesis, to improve the design. One of the project managers stated that it was absolutely a big advantage if the stakeholder process improves the design but it is not the priority of the stakeholder process. This indicates that co-creation with the stakeholders is not seen as one of the goals of the stakeholder process.

10.2.2 Success factors for the stakeholder process

Several factors were mentioned by the interviewees which makes a stakeholder process successful (See Appendix I). Some of the success factors mentioned by the interviewees are key elements of the dynamic stakeholder process (See Table 26).

Table 26, success factors mentioned in the interviews that indicate key elements of dynamic stakeholder management

Key element dynamic stakeholder management	Success factors mentioned by the interviewees
A central position for customer needs	Using the desires of stakeholders as requirements.
Explicit working	Feedback on decisions and input.
	Transparency about decisions and problems.
Openness	Ability to influence the design.
	Possibility to give input.
	Communication aimed at specific stakeholders.
Progress	Early involvement of stakeholders.
Substance	Clear communication.
	A lot of high-quality information accessible.
	Warning the environment for nuisance.

The remaining success factors were clustered resulting in three general success factors that contribute to the success of the stakeholder process. As mentioned in section 10.2.1. the improvement of the design is not seen as the goal of the stakeholder process. However, stakeholders can have valuable information (Rydin, 2007). Co-creation with the stakeholders can result in better outcomes at lower costs (Bason, 2010). Although the interviewees do not see the improvement of the design as a goal, it is argued that stakeholder involvement can result in a better design and thus lead to more satisfaction over the project. Therefore, the improvement of the design is added as success factors for the stakeholder process.

Together with the improvement of the design, this results in four general success factors for the stakeholder process that lead to more satisfaction over the process and project (see Figure 45).

1. Create project understanding.

2. Create a feeling of being heard.
3. Satisfy boundary conditions.
4. Improvement of the design.

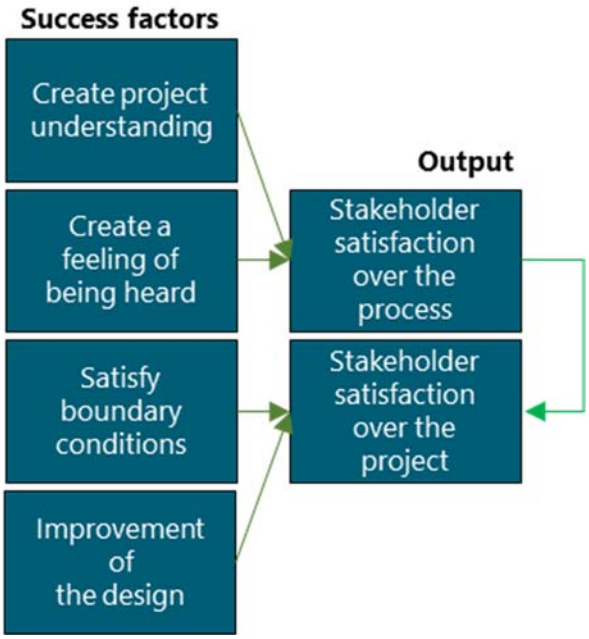

Figure 45, success factors that improve the output.

Satisfying these success factors will result in more satisfaction over the process and the project. Project understanding includes that stakeholders understand the complexity of the project, the impact of the project on their interest and understands the design decisions. The feeling of being heard includes showing compassion to stakeholders.

10.2.3 The contribution of dynamic stakeholder process to the success factors.

Figure 46 shows the contribution of dynamic management to the success factors which is elaborated on below. The input for the dynamic stakeholder process is the detail level of the design and the type of stakeholder. The detail level of design can be the project assignment, project start, concept design, preliminary design or final design. The types of stakeholders used in this thesis are, acquaintance, sleeping giant, saviour, friend, tripwire, timebomb, saboteur and irritant. Besides that, the stakeholder can differ in terms of culture.

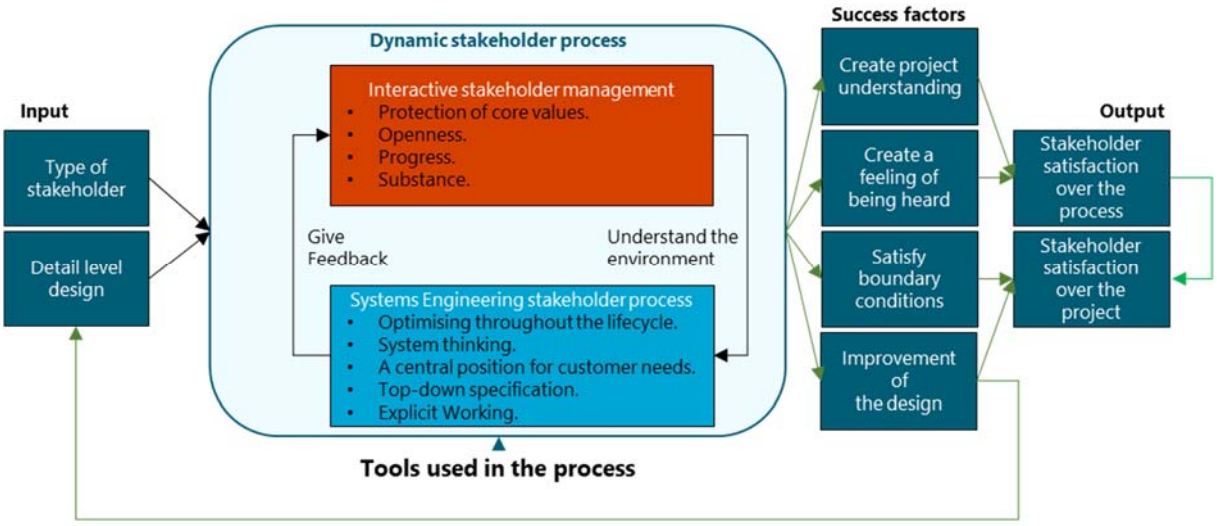

Figure 46, the contribution of the dynamic stakeholder process to the success factors.

Create project understanding

Dynamic stakeholder management contributes to the project understanding due to *substance* and *explicit working*. *Substance* is created with clear communication with the stakeholders and providing high-quality information. The decisions made during the project are understood due to the *explicit working*.

Create a feeling of being heard

Dynamic stakeholder management contributes to the feeling of being heard due to *openness*, *protection of core values* and *explicit working.* The stakeholders can address specific topics they find important. The core values of all stakeholders are protected, and compassion is showed to the stakeholders who lost in the process. Due to *explicit working* stakeholders will know what happened with their input for the project.

Satisfy boundary conditions

Dynamic stakeholder management contributes to satisfying boundary conditions due to *top-down specification.* The project is structured top-down and starts with a client that has a mission, vision and ambition. When honouring the customer requirement, the requirements are checked on satisfying the boundary conditions.

Improvement of the design

Dynamic stakeholder management contributes to the improvement of the design due to the *protection of core values*, *openness*, *progress*, *substance*, *optimising throughout the lifecycle*, *System thinking, a central position for customer needs*, *top-down specification* and *explicit working.* By satisfying the key elements, the stakeholder process is appealing to join and is available for all the relevant stakeholders. These stakeholders will deliver valuable input on items which they find important. The stakeholder process results in specific customer requirements with which the design of the project can be improved.

10.2.4 Threats to the dynamic stakeholder process

All the threats for the stakeholder process identified from the literature were reckoned by the interviewees. One additional risk was identified during the interviews. Two important stakeholders mentioned a risk that when people are allowed to influence the design. When a stubborn stakeholder has an idea for the project that is not supported by others or not possible in the project. It can happen that these stakeholders are sore losers and cannot deal with their idea not being implemented which result in a dissatisfied stakeholder. This threat is defined as a sore loser and is added as an extra risk to the framework.

The chances of a risk occurring depend on the project. According to one of the contracting authorities, the communication and participation tools used in the process are determined by the estimations of the risks of involving stakeholders. Therefore, it is essential to know on which risks VR can have an effect. Which risks can be reduced, avoided by using VR and which risks can be expected due to use.

10.3 Evaluation of the use of Virtual Reality in the stakeholder process

The framework is constructed will now be used to show what the contribution of the different types of VR is to the stakeholder process (Figure 47, decision framework tool used in the dynamic stakeholder process.Figure 47).

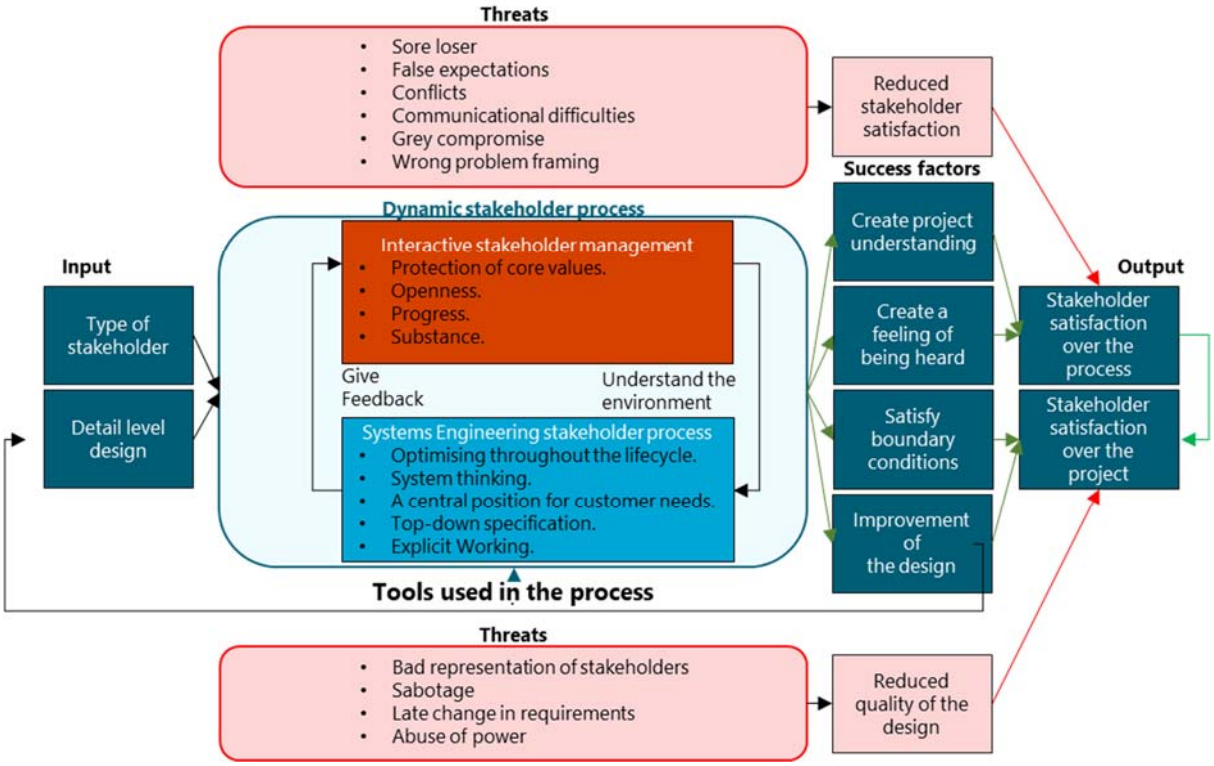

Figure 47, decision framework tool used in the dynamic stakeholder process.

10.4 The intended use of VR in the dynamic stakeholder process

For the A9 project, the VR was mainly used for meetings with important stakeholders. For the Vestdijk project, the VR was not used for meetings with important stakeholders. VR was mainly used in the communication with the inhabitants.

For the Vestdijk project, VR was used in the project start to make a concept design. In the Zaanenstraat and in the A9 project it was used in the concept design phase to make the preliminary design.

In all the projects a high immersive VR was used that supposed to contribute to *substance* (See chapter 4.2.4) and make difficult information easier to understand. The high immersive VR was used for important stakeholders.

In the Vestdijk project, besides the high immersive VR, a VR on an online platform was used that supposed to contribute to *Substance, progress* and *openness* (see chapter 4.2.2 & 4.2.3). The VR was supposed to result in more stakeholders involved and fast involvement.

10.5 The actual use of VR in the dynamic stakeholder process

The application of VR was seen as successful in all the cases. The use of VR is evaluated by using the decision-making framework.

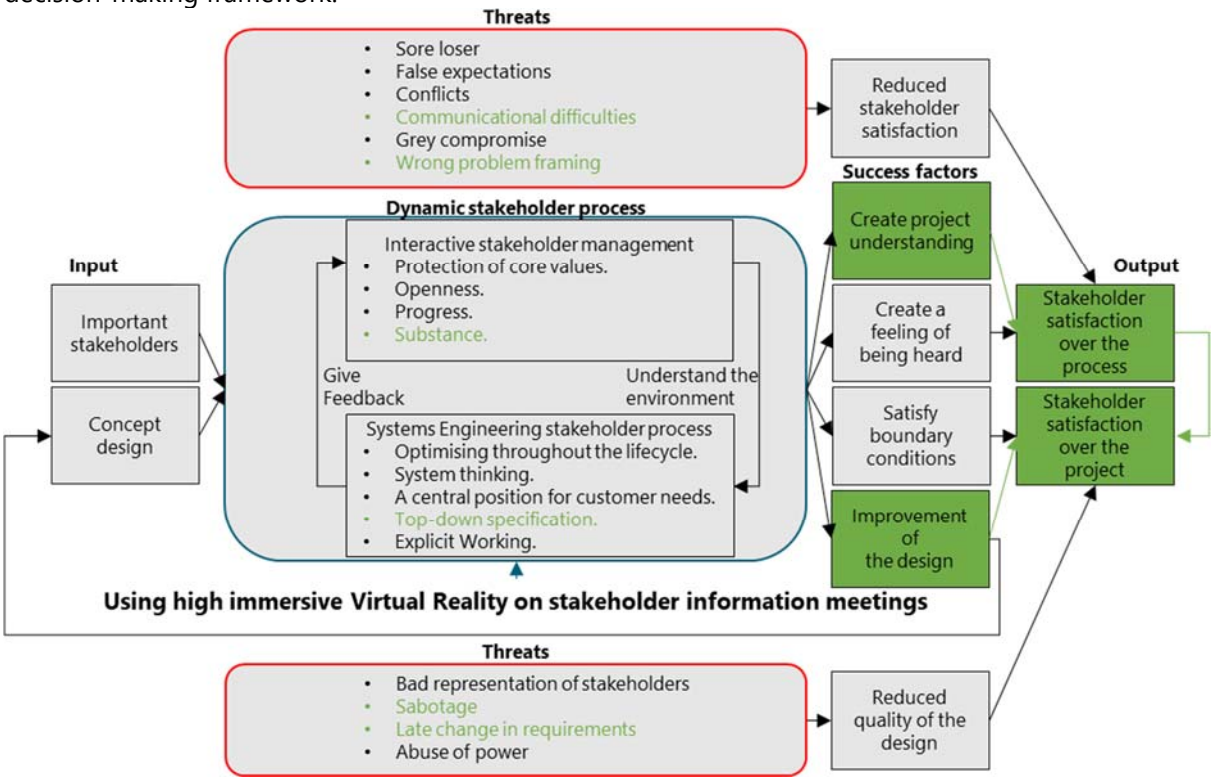

Figure 48, the contribution of Virtual Reality to the dynamic stakeholder process of the A9 project.

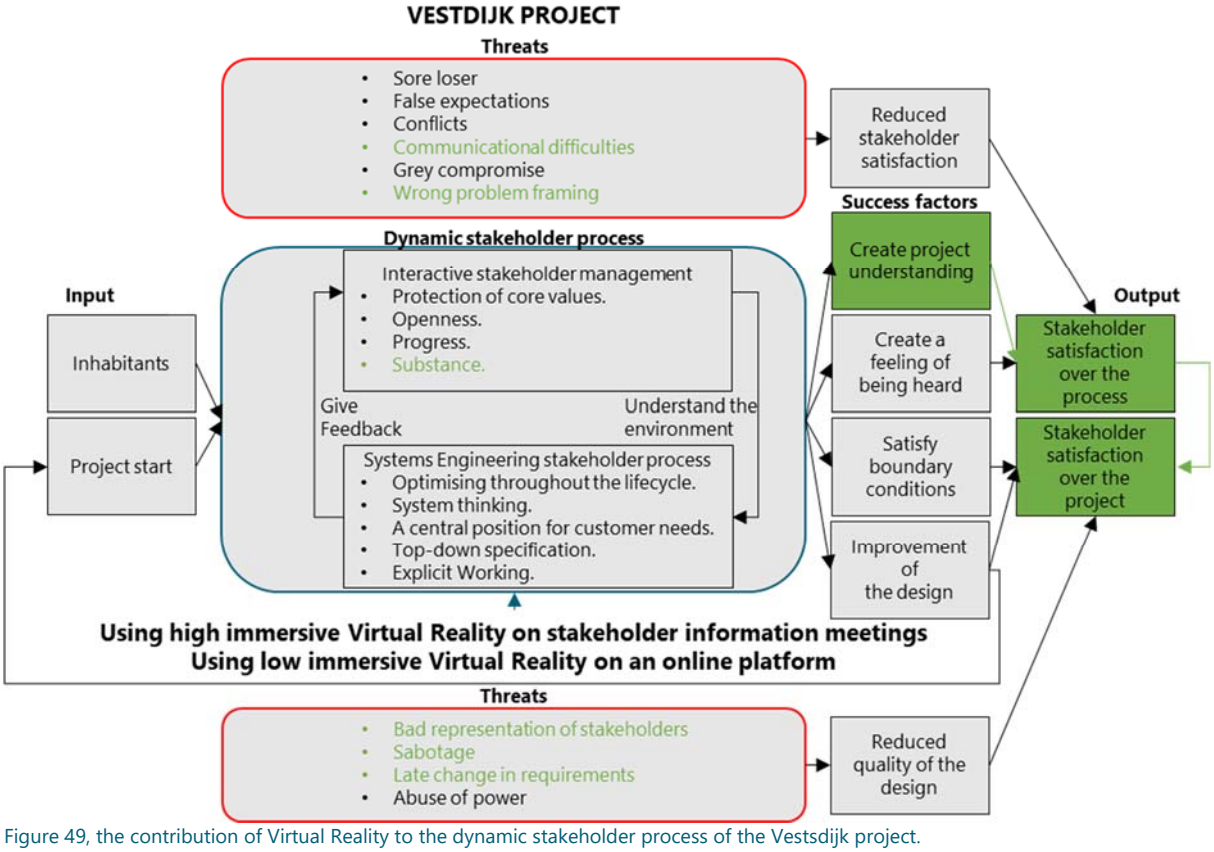

Figure 49, the contribution of Virtual Reality to the dynamic stakeholder process of the Vestsdijk project.

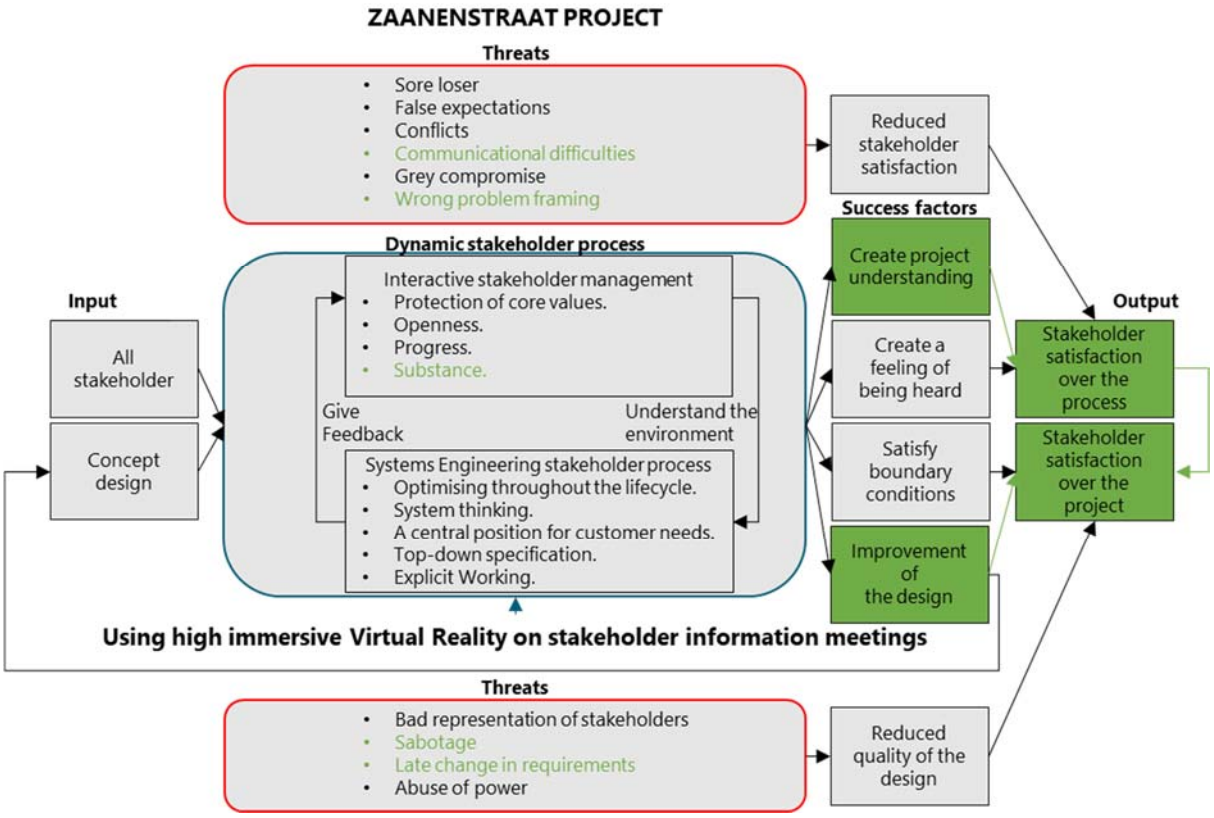

Figure 50, the contribution of Virtual Reality to the dynamic stakeholder process of the Zaanenstraat project.

Create project understanding

For all projects, the use of high immersive VR contributed to the *substance*. Interviewees of all projects mentioned that VR resulted in better understanding of the project. Many stakeholders cannot read 2D drawings but do understand the VR. With VR it is possible to look at the project from different perspectives. Stakeholders are often interested in their perspective and can see the effect of the project on their living environment. Showing the perspective of the stakeholder helped the stakeholders to identify if their interest was hurt or whether they benefited from the project. With the high immersive VR, it was possible to experience the effects of the future project such as the number of cars, the effect of light and sound. Besides that, high immersive VR helped stakeholders to understand the scale of the project.

For the Vestdijk project, the use of a low immersive VR on an online platform contributed to the *substance* as well. The stakeholders had more availability of information about the project and could easier understand the project.

Improvement of the design

For all the projects the interviews mentioned that the use of VR created better insight into opportunities for the project and contributed to *substance*. VR creates a common language among stakeholders; it helps stakeholders to understand each other. It prevents misunderstandings and helps with talking about the same topic. Due to this, there is a more substantive and factual discussion between stakeholders. Stakeholders are better capable of clarifying their desires and interest resulting in a better understanding of the stakeholders.

For the A9 project, the use of VR contributed to *top-down specification* which improves the SE stakeholder process as well. The VR was used to verify and validate customer requirements which might even have caused a lower number of total requirements. However, the quality of these requirements is higher, and therefore the use of VR did contribute to the improvement of the design

For the Vestdijk project, the use of the online platform contributed to substances which result in a more substantive and factual discussion between stakeholders. Besides that, the use of the online platform contributed to openness and progress. More stakeholders were involved faster. However, not all input by these stakeholders was processed, and the amount of input by the stakeholders used in the design is questioned. All the unstructured input was regarded as customer requirements resulting in low-quality customer requirements. The input that had a honoration advice was not translated to SMART system requirements, and there is only partly *worked explicitly*. As a result, the CRS document is out of date and incomplete, and only ten system requirements were present with which the design can be improved.

Create a feeling of being heard

For the Vestdijk project, the use of VR on an online platform contributed to the *openness.* Due to the use of a VR on an online platform, more people gave input on the project which can contribute to the feeling of being heard. However, not all the desires of stakeholders were processed. When people do not get feedback on their desires the feeling of being heard will decrease. When feedback is given to the stakeholders, it can help stakeholders to understand the decision made.

10.5.1 Evaluation of threats

The evaluation of threats is based on the framework discussed with the seven interviewees (see Appendix J).

New risks introduced by using VR

One of the success factors mentioned by the interviewees was creating a realistic image of the project. False expectations must be prevented. Two additional risks for the stakeholder process when using VR were identified. 1) Level of detail of the VR and 2) errors in de VR (see chapter 5.4.3). The VR can be better looking than the project will in the real situation and people might assume that it is the final design (Koekoek, 2017). That people might interpret the VR as the final design is confirmed in the interviews. That stakeholders are critical of errors in the VR is confirmed in the Vestdijk project. In the CRS document of the Vestdijk project very specific remarks are present about objects missing in the VR.

These two risks can be seen as additional risk causes for false expectations. Many interviewees reckon the risk of a better-looking VR than reality. One project manager indicates that the interfaces must make clear that the VR is not the final design. All the contracting authorities did, however, indicate that the false expectations are reduced since people understand the project better. To prevent that stakeholders assume that the VR is the final project it is possible to show alternatives in VR. One of the contracting authorities indicated that showing alternatives can help to reduce people getting stuck on one alternative of the project.

Risks reduced by using VR

Three or more stakeholders indicated that the following risks are reduced by using VR. The risks are elaborated on below.

Table 27, risks reduced by the use of Virtual Reality in the stakeholder process.

	Risk reduced by	Mentioned by
Bad representation of stakeholders	VR on an online platform	All interviewees.
Communicational difficulties	Both types of VR	Three contracting authorities. Two project managers.
A late change in requirements	Both types of VR	Two contracting authorities. Two project managers.
Wrong problem framing	Both types of VR	One contracting authority. Two project managers.
Sabotage	Both types of VR	One contracting authority. Two project managers.

Bad representation of stakeholders

VR on an online platform can reduce the risk of bad representation; it is doubted whether the use of the VR at a stakeholder meeting will be the reason for people to go to the stakeholder meeting. It is reckoned that it is more fun and might, therefore, keep people longer involved in the process. The use of an online VR will increase the number of participants since people can visit the VR from home and at any time.

Communicational difficulties

Both types of VR can be used to reduce the risk of communicational difficulties are reduced by using VR since communication is easier with VR. This is in line with literature indicating an improvement of communication due to shared knowledge (Koekoek, 2017). However, it is mentioned by different interviewees that these two groups often do not show up at the stakeholder meetings since they assume that they do not understand the *substance* or are not interested in participating. One of the contracting authorities questioned whether the use of VR on a stakeholder meeting would take away this assumption.

A late change in requirements

Both types of VR can be used to reduce the risk of a late change in requirements. Stakeholders can be involved earlier in the design phase. The VR can be used in an early stage, and people can react to the first visualisations of the project. In the traditional way of involving stakeholders, they only react after showing and explaining the design. The desires of stakeholders will be clear earlier in the project and stakeholders can generate many ideas. Furthermore, people can experience the effects of the project. Using VR results in a more substantive discussion early on.

Wrong problem framing

One of the contracting authorities indicated that the use of VR makes the problems for the project clear. The project manager of the Vestdijk indicated that due to the use of VR more problems can be identified in an early stage using the data from the stakeholders. When using an online VR, the risk of wrong problem framing can occur due to wrong interpretation of the data. However, it gives a complete image of all problems in the environment which reduces the total risks of wrong problem framing.

Sabotage

Both types of VR can be used to reduce the risk of sabotage. One of the pros of using VR is a better understanding of the project. According to one of the project managers when people understand the project, they are more likely to accept the project even though they do not like the project.

10.6 Opportunities for using Virtual Reality

This research is an explanatory research into the added value of using VR in the stakeholder process of complex infrastructure projects. VR is yet only applied in several complex infrastructure projects. As discussed in the case study research there was room for improvement of the dynamic stakeholder process. Therefore, the added value of using VR can be larger than is concluded from this research. Below possible future use of VR is discussed which includes the recommendations given during the case study. This gives an indication of the possible future contribution of VR to the stakeholder process.

10.6.1 Input

The purpose of using a type of VR can depend on the detail level of the design and the type of stakeholder.

Detail level design.

With the use of a dynamic stakeholder process, the process starts with the mission, vision and ambition with which the contracting authority creates the project assignment (See figure 51). With dynamic stakeholder management stakeholders, it is recommended to involve the stakeholders during the entire project. To allow for the use of Virtual Reality in the stakeholder process of the entire project, the Contracting Authority must take additional measures. First, the budget for project and process needs to be combined to allow for investment in VR. Second, the use of VR must be specified in the contract.
As seen in the Vestdijk project the VR can be used at the project start to create a concept design. Just like the real project design the design of the VR can enhance during the project.

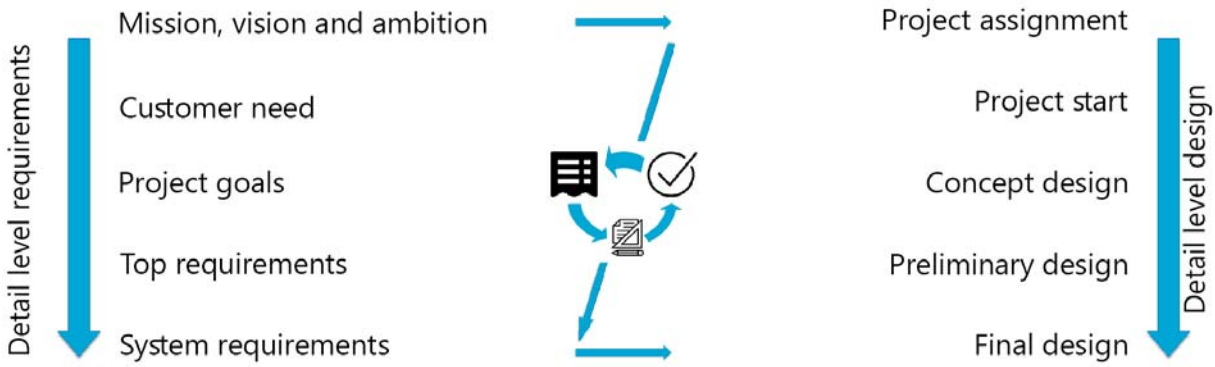

Figure 51, top-down specification

Type of stakeholder

In this thesis, the stakeholder model of Murray-Webster & Simon (2006) was used to categorize stakeholders (see Table 28). Different types of stakeholders ask for a different approach.

Table 28, stakeholder categories based on Murray-Webster & Simon (2006).

Category	Power	Interest	Attitude	Approach
Acquaintance	Low	Low	Positive	Inform them about the project.
Sleeping giant	High	Low	Positive	Engage them in the project.
Friend	Low	High	Positive	Use them for input on the project.
Saviour	High	High	Positive	Satisfy their needs.
Tripwire	Low	Low	Negative	Do not harm their core values.
Timebomb	High	Low	Negative	Satisfy their needs because these needs will keep their interest in the project low.
Irritant	Low	High	Negative	Do not harm their core values.
Saboteur	High	High	Negative	Try to change their attitude by engaging them in the project.

Type of VR

As mentioned the type of VR used can depend on the detail level design and the type of stakeholder. As mentioned in chapter 10.2.4. the type of VR depends on the risks of the stakeholder process as well. It is important to think of the type of VR necessary for the project.

The level of immersion required depends on the information needed by and from the stakeholders and the purpose for using the VR. A low immersive VR is cheaper and can be made available from home. Having a website for the project results in other benefits. Updates of the project can be given on the platform. When there are a lot of stakeholders present only one high immersive VR is not suitable for the meeting. It might be useful to invite specific stakeholders to stakeholder information meetings on specific topics.

A high immersive VR makes it possible to show more effects of the project such as the amount of traffic or the sound which is not possible with a low immersive VR. With the use of high immersive VR stakeholders can better experience the effects of the project, and the desires that the stakeholders give will be more constructive.

10.6.2 The possible future contribution of Virtual Reality to the dynamic stakeholder process

The use of VR contributes to substance. At the project start, a low immersive VR platform creates can contribute to openness and progress as well. With more involved stakeholders and more input as a result. Processing all this input can result in much work. Two project managers already indicated a risk during the interview that one does not know beforehand how many stakeholders will use the VR platform and one must have the capacity to process all the desires. When there is a big chance that there is no capability to process all the desires an online platform should not be used since this reduces the *explicit working*.

When using a low immersive VR on an online platform where people can give input, it is recommended store the original input. To improve the efficiency of the process stakeholders the quality of the input must be enhanced. This can be done by limiting the number of characters that the stakeholder is allowed to used and helping them write SMART requirements. Besides that, it can be useful to add the theme of the desire to enhance the processing speed of the input. It might be helpful if a stakeholder can classify their input themselves. All the input needs to be classified as needs, questions, problems and objectives. All the needs must be translated to customer requirements; this contributes to the *explicit working*.

Additional information about the stakeholder can be gathered on the online platform which can be useful for the stakeholder process. For example, let stakeholders indicate their satisfaction over the project. This information can help to classify the stakeholder and make a strategy for the stakeholder management and decided how the customer requirement must be processed. For example, when the information of the stakeholder indicated that the stakeholder is classified as a saboteur, the process manager must take additional effort to engage the stakeholder and satisfy their needs (see table 28). Due to this, it becomes clear what the boundary conditions of the project given by the stakeholders are; this contributes to *a central position for customer needs*.

For all the customer requirements with a honoration advice, it is recommended to validate the created customer requirements with the stakeholders by using VR. Customer requirement can be temporary honoured and can be put in the VR. The stakeholders can then validate that the customer requirement indeed satisfies their desires. The verification and validation contribute to *top-down specification*. For the verification and validation, it is recommended to use a high immersive VR since people then react as if they would in the real world.

For all the customer requirements that get another advice feedback must be provided so that people understand what happened with their desires.

10.6.3 The possible future contribution of Virtual Reality to the success factors

Below the possible contribution of VR to the success factors is elaborated on

Create project understanding

The use of VR is a good way to provide information. By using VR people can access more and better quality information. Therefore people easier understand the project.

Satisfy boundary conditions

The use of VR can possibly contribute to satisfying boundary conditions. By gathering more data from the stakeholders, one can better identify the boundaries of the project given by the stakeholder. However, a remark is made by one of the project managers that focussing too much on the current stakeholders can lead to loss of vision.

Create a feeling of being heard

The use of VR can possibly contribute to a feeling of being heard. Stakeholders had the opportunity to influence the design and stakeholder got feedback which makes them understand what happened with their desires. This can result in a feeling of being heard.

Improvement of the design

The use of VR can create better insight into opportunities for the project and creates a common language among stakeholders. Resulting in a more substantive and factual discussion between stakeholders. Stakeholders are better capable of clarifying their desires and interest resulting in a better understanding of the stakeholders.

By using a low immersive VR on an online platform, more stakeholders can be involved faster. Resulting in more input for the stakeholders. By using a high immersive VR to verify and validate requirements the quality of the customer requirements can be improved. Together this can result in a high number of high-quality customer requirements with which the design can be improved. Figure 52 shows the possible future contributions of VR to the dynamic stakeholder process.

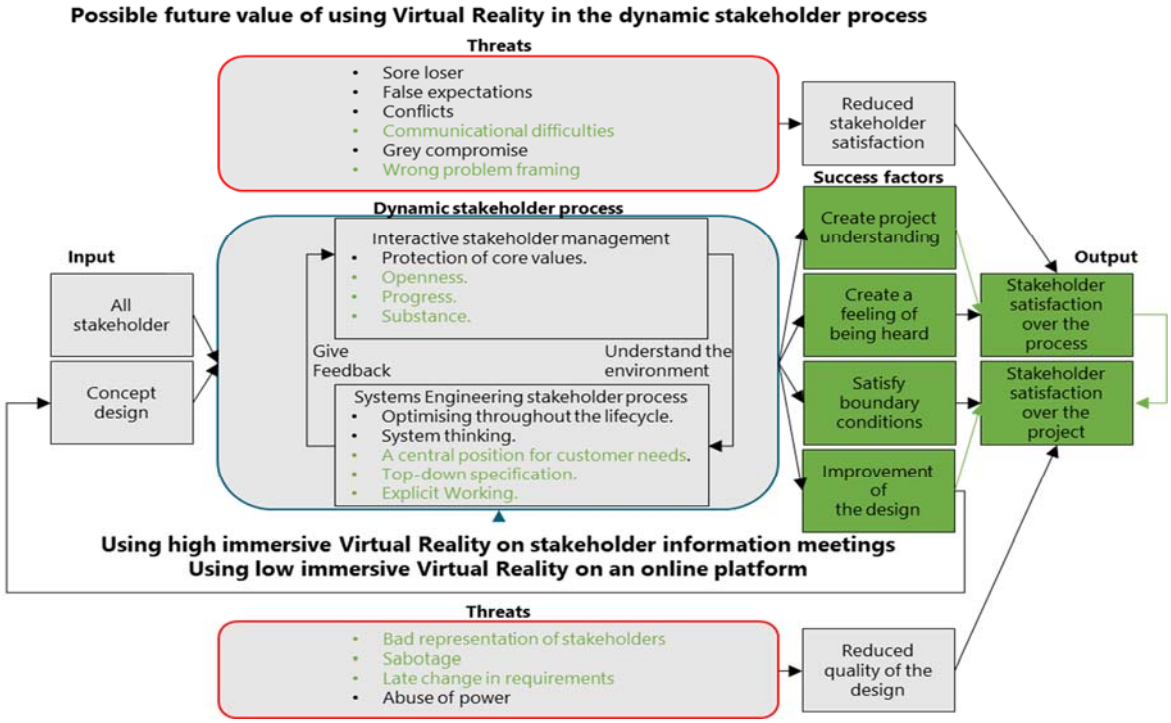

Figure 52, the possible future contribution of Virtual Reality to the dynamic stakeholder process.

11 CONCLUSIONS AND RECOMMENDATIONS

This thesis contains an exploratory research into the added value of using VR in the stakeholder process of complex infrastructure projects. The goal of this thesis is to give insight into how VR is applied in the stakeholder process of complex infrastructure projects and to show the added value resulting from this application. The main research question therefore was:

WHAT IS THE ADDED VALUE OF VIRTUAL REALITY IN THE STAKEHOLDER PROCESS OF COMPLEX INFRASTRUCTURE PROJECTS?

In this thesis, a framework was developed to evaluate the added value of using VR in the stakeholder process. The foreseen goal of the dynamic stakeholder process was to satisfy the stakeholders and to improve the design. Several threats were identified from the literature that can have a negative influence on these goals. Besides the threats, it is a challenge to have an efficient stakeholder process regarding cost and time (Hordijk, Sara, Sutherland & Scott, 2015). Improving the efficiency of the process can contribute to the goals of the dynamic stakeholder process.

11.1 Conclusions

The use of VR is seen as successful if the use contributes to improving the design, satisfying the stakeholder, improves the efficiency or helps to cope with threats concerning these goals. This has led to the five sub-questions answered below to evaluate the added value of using VR in the stakeholder process.

1) How is Virtual Reality applied in the stakeholder process for complex infrastructure projects?

To deal with complexity a dynamic stakeholder management process is required. A dynamic stakeholder process contains the following key elements of interactive stakeholder management *protection of core values*, *openness*, *progress* and *substance* which make a stakeholder process appealing to join and available for all the relevant stakeholders. The stakeholders will deliver valuable input on items which they find important. Together with the key elements of SE stakeholder process *optimising throughout the lifecycle*, *system thinking*, *a central position for customer needs*, *top-down specification* and *explicit working*, the dynamic stakeholder process results in specific customer requirements with which the design of the project can be improved.

Different types of VR are applied in the dynamic stakeholder process. High immersive VR on stakeholder information meetings are used to contribute to the *substance*. Low immersive VR on online platforms are used to contribute to the *openness*, *progress*, and *substance*.

2) Does the use of VR in the stakeholder process improve the project design?

The project design can be improved when valuable information which the stakeholders have is added to the design (Rydin, 2007). The use of VR contributes to the improvement of the design when the use of VR results in higher-quality customer requirements or results in more honoured customer requirements.

The use of VR improved the *substance* in all projects. The use of VR created better insight into opportunities and created a common language among stakeholders. Due to this, there is a more substantive and factual discussion between stakeholders. Stakeholders are better capable of clarifying their desires.

The quality of the customer requirements depends on the input of the stakeholder and the processing of this input. In the Vestdijk project, a low immersive VR was used on an online platform. The use of VR contributed to the *openness* and *progress* and resulted in much input for this project. This input must be

processed with the SE stakeholder process to create useful customer requirements for the designers. There is much room for improvement of the application of the SE stakeholder process. The SE stakeholder process resulted in low-quality customer requirements and an incomplete CRS document which makes it impossible to validate if the design was improved due to the use of VR.

In the A9 project, the use of VR resulted in improved quality of the customer requirements. The VR was used to verify and validate the customer requirements and contributed to *top-down specification*. This resulted in higher quality requirements, but it might have reduced the total number of customer requirements honoured.

The use of VR in the dynamic stakeholder process can improve the project design by having more input from stakeholders for the design. However, this input needs to be processed via the SE method to be useful for the designers. The use of VR in the dynamic stakeholder process can improve the design by using the VR to verify and validate the customer requirements. This results in higher quality customer requirements.

3) Does the use of VR in the stakeholder process lead to more stakeholder satisfaction?

In all cases, the satisfaction over the process was higher due to the use of VR. Stakeholders enjoy the process more due to the use of VR. The use of VR resulted in more satisfaction over the project, fewer objections for the A9 project and more support for the Vestdijk project. For the Zaanenstraat project, the project manager doubts whether the use of VR led to more support.

Four success factors were identified resulting in more satisfaction over the process and more satisfaction over the project of which improvement of the design was already discussed above. The other three success factors that contribute to satisfaction over the process and satisfaction about the project are project understanding, create a feeling of being heard and satisfy boundary conditions.

Interviewees of all projects mentioned that VR results in a better understanding of the project. As already mentioned the use of VR improved the *substance*. Many stakeholders cannot read 2D drawings but do understand the VR. The use of VR makes it possible to see the impact of the project from the perspective of the stakeholder. The use of an online VR can improve the understanding by making more information about the project available on the platform. The use of a high immersive VR can increase the understanding since it makes it possible to experience the effects of the future project such as the number of cars, the effect of light and sound. Besides that, high immersive VR helps stakeholders to understand the scale of the project.

The use of a VR on an online platform improves the *openness*. The feeling of being heard increases when people have more accessibility to the stakeholder process. However, in the Vestdijk project not all the input of the stakeholders was processed, this decreases the feeling of being heard. When feedback is given, the VR can help stakeholders to understand the decisions made and contribute to a feeling of being heard.

The use of VR in the dynamic stakeholder process can improve the stakeholder satisfaction due to a better understanding of the project when the input is processed, and feedback is given to the stakeholders it can in increase the satisfaction by creating a feeling of being heard as well.

4) Does the use of VR in the stakeholder process improve the efficiency?

The use of VR in the stakeholder processes increased the efficiency regarding time in all projects. The online VR in the Vestdijk project was used to contribute to *progress*. The use of VR was successful since it resulted in faster recognition and collection of requirements. For the Zaanenstraat faster identification of desires is mentioned as a pro for using VR as well. For the A9 the time efficiency regards the time it took to clarify the project to the stakeholders. The efficiency of the stakeholder process itself was insufficient for the use of VR on the online platform. The efficiency of the stakeholder process itself is more efficient with the high immersive VR. At the Vestdijk project, the extensive input can partly explain the inefficiency of the stakeholder process on the online platform, together with the mediocre application of system engineering stakeholder process.

The use of VR in the dynamic stakeholder process can improve the efficiency regarding time by using an online VR the stakeholder will give desires earlier and when using a high immersive clarifying the project takes less time.

5) Does the use of VR in the stakeholder process help to cope with the identified threats?

Based on the estimation of the chances of a risk of involving stakeholders occurring, one can decide which tool to use in the stakeholder process. The use of a low immersive VR on an online platform can reduce the risk of bad representation of stakeholders. The use of an online VR will increase the number of participants since people can visit the VR from home. The risk of wrong problem framing, communicational difficulties and late changes in requirements can be reduced with both types of VR.

The use of VR in the dynamic stakeholder process can reduce the risks of wrong problem framing, communicational difficulties and late changes in requirements. When using a VR on an online platform, the risk of bad representation of stakeholders can be reduced.

To conclude, ***WHAT IS THE ADDED VALUE OF VIRTUAL REALITY IN THE STAKEHOLDER PROCESS OF COMPLEX INFRASTRUCTURE PROJECTS?***

This research was conducted with the goal to elaborate on the use of VR in a dynamic stakeholder process and to discover the added value of using it. A framework was identified to evaluate the added value on the four aspects answered above. After the case study research, the framework was adjusted. In all cases, the improvement of the design is not seen as a goal of the stakeholder process. However, stakeholders can have valuable information (Rydin, 2007). Co-creation with the stakeholders can result in better outcomes at lower costs (Bason, 2010). Therefore, the improvement of the design is added as a success factor that leads to more satisfaction over the project. The goal of the stakeholder process is satisfaction over the process and satisfaction over the project.

Correct application of a dynamic stakeholder management process can contribute to these goals. The key principles of a dynamic stakeholder process are *protection of core values*, *openness*, *progress*, *substance*, *optimising throughout the lifecycle*, *system thinking*, *a central position for customer needs*, *top-down specification* and *explicit working*. Satisfying these key principles result in a stakeholder process appealing to join and available for all the relevant stakeholders. The stakeholders will deliver valuable input on items which they find important. The dynamic stakeholder management process then contributes to, project understanding, a feeling of being heard, satisfying the boundary conditions and the improvement of the design.

The use of VR can be applied in the dynamic stakeholder process and can contribute to the key elements of dynamic stakeholder management. To contribute to the success of the dynamic stakeholder process, it is important to consider the purpose of the VR and estimate the risks of the project. Based on this a

decision can be made which type of VR to use. A high immersive VR on stakeholder information meetings is used to contribute to the *substance*. Low immersive VR on online platforms is used to contribute to the *openness*, *progress*, and *substance*. Both types of VR can be used to reduce the risks of communicational difficulties, late changes in requirements, wrong problem framing and sabotage. A low immersive VR on an online platform reduces the risk of bad representation of stakeholders as well.

The use of both types of VR improved the *substance*. The interactive stakeholder management process was improved leading to a better project understanding. When VR is applied to improve the *openness* and *progress*, it requires thorough attention for the processing of the higher amount of data. The application of the SE stakeholder process left much room for improvement. Besides improving the interactive management, VR can also be used to verify and validate customer requirements which contribute to *top-down specification*.

11.2 Recommendations

In two of the three cases, SE was not applied well. Recommendations are given to improve the use of SE by improving on *explicit working*, *top-down specification*. The *explicit working* can be improved by improving the traceability of customer needs in the concept phase, transcribing the desires to customer requirements and giving specific feedback. The *top-down specification* can be improved by validating the customer requirements in VR if possible and by being specific on the boundary conditions. Furthermore, recommendations are given to improve the data gathering by improving the interfaces and improving the use of this data.

Further recommendations are given to the contracting authority to allow the adoption of VR. The budgets for the project and process need to be combined to allow investments in the stakeholder process for which the project benefits. The use of the decision-making framework is recommended to evaluate the use of Virtual Reality in future projects.

12 REFLECTION

This chapter includes the limitations of this research and the recommendations for further research.

12.1 Limitations

Four limitations are reckoned for this research.

12.1.1 The interviewees.

Originally the idea was to interview two project managers from Witteveen+Bos per project. However, this was not possible in the Zaanenstraat project and the Vestdijk project. In the Zaanenstraat project, the developer of the VR was not participating in the project. Three people of the contracting authority from the Zaanenstraat project were interviewed together. This was done because during the project the project managers changed. In the A9 project, RWS did most of the process management. This resulted in only one project leader per project from Witteveen+Bos to interview for these projects. The important stakeholders interviewed for the Vestdijk project, did not use the VR during the stakeholder. This reduces the quality of their input for this thesis.

12.1.2 Application of Systems Engineering

As mentioned before in two of the three projects there is much room for improvement of the SE stakeholder process. As mentioned the incomplete CRS document makes it hard to confirm the allegations made by the interviewees. For the Zaanenstraat SE was not used. Due to this, there is only an overview available of the requirements that have a honoration advice not a final overview of the requirements that were used in the design. Due to this, the honoration advice is used to evaluate the project although it is reckoned that there are requirements that have advice to honour which in the design phase turned out to be impossible.

12.1.3 Contribution Virtual Reality to the stakeholder process

VR is only a piece in the whole process it is not clear which honoured requirements were the result of using VR. For example, the VR was only used at a few stakeholder meetings. Furthermore, when the VR was not used at the stakeholder meeting, it does not necessarily mean that the use of VR did not influence the result of the stakeholder information meeting since people might have used the online platform before the stakeholder meeting.

12.1.4 Other factors influencing the stakeholder process

In the Vestdijk project, the municipality temporary closed one traffic lane with a barrier to show the effects of the project in practice. The effect of this measure on the stakeholder process is unclear which makes the evaluation of the effect that VR had on the process more difficult.

12.1.5 Processing data

To evaluate the improvement of the design in the Vestdijk project, the desires were manually classified as needs temporary situation, needs final project, questions and problems or objectives. This classification is based on the author's interpretation of the desires and might deviate somewhat if an expert made the classification. Furthermore, the categorisation of stakeholders is done by the author as well.

The interviews were held in the native language, which was Dutch. The results of the interviews are translated. The meaning of a translation might slightly deviate from the original sentence.

12.2 Further research

This research is explanatory research; further research is suggested to validate the framework used and to quantify the success factors.

The use of VR is still in development this research only explores the added value. Much is still unclear for instance what the added value of VR can be when dynamic stakeholder management is applied better.

The efficiency regarding costs is still unclear. Further research is needed to evaluate the cost efficiency. This cost efficiency must be evaluated in a broad context since the benefits of using VR in the stakeholder process can lie outside the stakeholder process itself. For example, in the A9 project, the VR was also used to validate technical requirements which are out of the scope of this thesis, but this might influence the efficiency of the VR.

Further research in data analysis is recommended as well. Several types of improvements can be thought of. For instance, use software that can automatically cluster or filter the data collected which makes the processing easier or let stakeholders cluster and prioritise the desires of others. These options might improve the efficiency.

Further research is needed on the interpretation of the gathered input from stakeholders. Quantifying the qualitative data requires research methods on how to deal with and interpret the data. In the Vestdijk project, the client assumed that having more responses indicates what the critical issues for the project are. However, this can be risky and can be an incorrect measurement of importance. For example, how many reactions are needed to have a good sample of the population and how many reactions make something important. Further research into research methods is necessary for proper interpretation of the data.

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14 APPENDICES

14.1 Appendix A: Keywords

Relevant keywords to this thesis are given in table 19.

Table Relevant keywords

Concept	Keyword
Dynamic infrastructure management	Dynamic environments.
	Landscape planning.
	Urban planning.
Systems Engineering stakeholder process	Optimisation throughout the life cycle.
	System thinking.
	Top-down specification.
	Explicit Working.
	Validation.
	Verification.
	Customer requirements.
	Systems requirements.
	Customer requirements.
	Requirements engineering.
	Stakeholder analysis.
Interactive stakeholder management process	Interactive process.
	Communication medium.
	E-governance.
	Civic participation.
	Planning support system.
	Customer desires.
	Expectation management.
	Forms of participation.
	Geographic communities.
	Lay knowledge.
	Participatory planning.
	process management.
	Stakeholder attitude.
	Stakeholder interest.
	Stakeholder power.
	Stakeholder engagement.
	Stakeholder satisfaction.
Virtual Reality	Immersion.
	Simulation.
	User interfaces.
	Virtual Design and Construction.
	virtual environment.
	Communication environment.
	user experience.

14.2 Appendix B: Test interview

A test was held to validate the questionnaire and discuss this with the supervisors. The first question used in the test interview turned out to be confusing. The order of the questions was shuffled to make the structure of the conversation in a more logical order. The satisfaction over the project is now asked before the improvement of the design to prevent the interviewee from talking about satisfaction when the improvement is evaluated. The improvement of the design is asked in term of number of honoured requirement and quality of the requirements.

Based on the test interview seven additional questions where added to the questionnaire.

Three extra questions about the context of the project. First, a question was added to the interview to indicate in which phase the project is and when the interviewee was involved. Second, a question whether people are satisfied with the project. Third, a question if the project is seen as complex. This question is added to verify that the projects selected are complex.

Three extra questions where added about the use of VR.
First, the evaluation of pros and cons of using VR. Second, if the use of VR is seen as succesfull. Third, the evaluation of type of VR used and the advantage of this type of VR.

One extra question was added to let the interviewee identify extra risks for the stakeholder process when using VR first.

The test interview was used together with the literature study to identify themes for the analysis. This resulted in the follow themes.

1. Background: Project goal
2. Background: VR purpose
3. Background: Elaboration project
4. Background: Elaboration success stakeholder process
5. Pros of using VR in the stakeholder process.
6. Cons of using VR in the stakeholder process.
7. Stakeholder satisfaction.
8. Improvement of the design.
9. Efficient process.
10. Risks: risks of involving stakeholders.
11. Risks: measures to avoid.
12. Risks: measures to reduce.
13. Risks: negative influence on risk event.

14.3 Appendix C: Interview procedure

Interview Contracting Authority & Project managers

Below an indication is given of the interview questions asked during the interview. The interview is however response, the interview will not be the same with a different interviewee since the questions depend on the answers of the interviewee.

Elaboration project:

1. What was the main objective of the project?
2. Did you consider this project complex and what made this project complex?
3. In which phase of the project where you included?
4. What is the current phase of the project?
5. How satisfied are you with the final design?

Elaboration stakeholder process:

6. When do you consider a stakeholder process to be successful?
7. Do you consider the stakeholder process of this project successful?

Elaboration VR stakeholder process
(Explanation VR)

8. What was the purpose for using VR in the stakeholder process?
9. When do you consider the use of VR in this process successful?
10. Different types of VR are used for example, a driving simulator, a website where you can walk trough a simulation or the use of VR glasses. What are the benefits of using these different types of VR?
11. What were the advantages of using VR in the stakeholder process for this project and what are the disadvantages?

Added value VR to stakeholder satisfaction over the process

12. Did the use of VR increased the satisfaction over the stakeholder process?
13. Can you illustrate this with an example?
14. Did the use of VR also increased the satisfaction over the final design of this project?
15. Can you elaborate on that?

Added value VR to improve the design

16. Did the use of VR in the stakeholder process resulted in a higher number of honoured customer requirements for this project?
17. can you elaborate why you think that?
18. Did the use of VR in the stakeholder process resulted in a higher quality of the customer requirements for this project?
19. Do you think that these requirements add value to the final design of the project?

Added value VR to efficiency

20. Does the use VR in the stakeholder process improves the efficiency of the stakeholder process in terms of time and budget and can you elaborate why you think that?

Added value VR coping with threats
(Explanation risk bow-tie for the involvement of stakeholders)

21. Did one of these risks fired?
22. Do you think that VR can be a measure to avoid, reduce or transfer these risks and can you elaborate why you think that?
23. Do you think that using VR in the stakeholder process introduces new risks?

Interview important stakeholder

Elaboration project:

1. What was the main objective of the project?
2. Did you consider this project complex and what made this project complex?
3. Wat do you consider the problems of the vestdijk project?
4. How satisfied are you with the final design?

Elaboration stakeholder process:

5. In which phase of the project did you participate?
6. What made you interested in the project?
7. Do you consider the stakeholder process successful and why?
8. Where there any conflicts with other stakeholders in the process?
9. Did you had the feeling that you could influence the design?
10. Is any information you provided used in the project?

Elaboration VR stakeholder process
(Explanation VR)

11. Do you consider the use of VR in this process successful?
12. Different types of VR can be used for example a website like google street view where you can walk through a simulation or the use of VR glasses. What are the benefits of using these different types of VR?
13. What were the advantages of using VR in the stakeholder process for this project and what are the disadvantages?

Added value VR to stakeholder satisfaction over the process

14. Did the use of VR increased your satisfaction over the stakeholder process?
15. Can you illustrate this with an example?
16. Did the use of VR also increased the satisfaction over the final design of this project?
17. Can you elaborate on that?

Added value VR to improve the design

18. Did the use of VR increased the ability to improve the design by giving requirements?

Added value VR coping with threats

19. Do you see any risks in using VR to involve stakeholders

14.4 Appendix D: Pros of using VR

The tables below show the pros mentioned during the interviews per project.

A9 Project

Table 29 Pros of using VR A9 project

Interviewee	Pros VR use
All interviewees	1. Fewer objections against the project.
Contracting Authority & Important stakeholder	2. Experience the future project.
	3. More interest in participation.
	4. Ability to view a project from different perspectives.
Contracting Authority	5. Better decision making due to better communication with the minister.
	6. Ability to present the mental image that you have about the project to the stakeholder.
	7. More satisfaction over the project.
	7. A better understanding of the project. Many stakeholders cannot read 2D drawings.
	8. Better insight into opportunities in the project for the stakeholder.
	9. Stakeholders can better formulate their desires.
	10. Ability to switch from current to future situation makes it easy to understand the project.
	11. Possibility to give the stakeholder insight into the effects of the project on their living environment.
Project Manager	12. More satisfaction over the process.
	13. Good provision of information.
	15. Ability to give the stakeholder insight in consequence of their desire.
	16. Ability to visualise the implemented needs.
	17. Ability to validate needs of stakeholders in Virtual Reality.
Important stakeholder	18. Stakeholders will show more leniency during the discussion.

Vestdijk Project

Table 30 Pros of using VR Vestdijk project

Interviewee	Pros VR use
All interviewees	1. A better understanding of the project. Many stakeholders cannot read 2D drawings.
	2. Ability to view the project from different perspectives. "View the project from your own garden" or "View the project as a traffic user".
Contracting Authority & Project Manager	3. Interesting technology which can motivate stakeholders to participate in the process.
	4. The quality of the input of the stakeholders is higher and are therefore more useful for the designers.
	5. More substantive discussions between stakeholders.
	6. More input from stakeholders for the design.

	7. More enthusiasm and fun.
	8. More transparency.
	9. A better representation of stakeholders.
Contracting Authority & Important stakeholder	10. Ability to visualise effects such as the amount of traffic, air quality, effect of light.
	11. Stakeholders can understand the impact of the project on their interest.
Contracting Authority	12. Efficient process, a fast way to identify and collect desires of stakeholders.
	13. Effective tool.
	14. A better understanding of stakeholder desires.
	15. Ability to visualise and experience the future project.
	16. Improves the understanding of the scale of the project.
	17. Ability to give more information about the project.
	18. More stakeholders involved.
	19. Better insight into opportunities in the project for the stakeholder.
	20. More satisfaction due to the possibility to give input.
	21. Fast recognition of customer needs.
	22. A better understanding of the decisions made.
	23. A better understanding of the arguments of other stakeholders makes the solution space clearer. Therefore, stakeholders can give propositions for alternative solutions.
	24. Fast exchange of information.
Project Manager	24. Approximately four to five times more stakeholders involved than with traditional stakeholder involvement.
	25. Involvement of different types of stakeholders when using an online VR.
	26. More balance between positive and negative views on the project.
	27. More info about the stakeholders that give desires.
	28. Neat feedback is possible.
	29. More accessibility of information when using an online VR.
	31. More support.
	32. More positive feedback
	33. Better accessibility of information by using an online Virtual Reality.
	34. More honoured customer requirements.
	35. Including the VR in the design method results in better interpretation and implementation of the desires than having a separate CRS document.
	36. Reduced costs of late changes in the design.
	37. Reduced design costs.
	38. Know the project goals faster.
Important stakeholder	39. Fewer protests due to better understanding.
	40. Fast collection of desires.

Zaanenstraat Project

Table 31 Pros of using VR Zaanenstraat project

Interviewee	Pros VR use
All interviewees	1. A better understanding of the project. Many stakeholders cannot read 2D drawings.
Contracting Authority & Project Manager	2. Ability to view a project from different perspectives.
	3. Ability to visualise effects such as the amount of traffic and effect of light.
	4. Helps stakeholders clarify their desires and interests.
	5. Stakeholders enjoyed using VR.
Project manager & Important stakeholder	6. More substantive discussions between stakeholders.
Contracting Authority	7. Some elements of the design are hard to imagine, VR can help to give an image of these elements.
	8. Helps stakeholders to understand each other.
	9. Ability to show the effect of a desire on the project.
	10. All the stakeholders wanted to try the VR.
	11. Ability to discuss design alternatives
	12. Ability to show stakeholders if the project hurts their interest.
	13. Ability to show stakeholders that they benefit from the project.
	14. Ability to show stakeholders that not all the needs can be honoured in the project.
	15. Helps stakeholders to identify alternative solutions for the project that they find acceptable.
	16. Improves the understanding of the scale of the project.
	17. More factual discussions
Project Manager	18. Ability to present the mental image that you have of the project to the stakeholder.
	19. Prevents misunderstandings helps with talking about the same topic.
	20. Ability to discover the solution space.
	21. Enables more substantive discussions about the project with the committee of welfare.
	22. Faster identification of desires of stakeholders.
	23. Creates a common language.
	24. VR created a more satisfying stakeholder process, a nice ambience with interaction.
Important stakeholder	25. Helps stakeholders to generate ideas.
	26. Helps stakeholders to understand decisions.

14.5 Appendix E: cons of using VR

The tables below show the cons mentioned during the interviews per project.

A9 project

Table 32, cons of using VR A9 project

Interviewee	Cons VR use
Contracting Authority & Project Managers	1. The contractor will use the contract to make the final design. The parts that are present in the VR but are not in the contract will not be designed or designed differently in the final design. The contractor might interpret a requirement differently than how it is visualized in the VR.
Project Managers & Important stakeholders	2. Showing an image which might deviates from the final design of the project
Project Managers	3. You must be sure that the elements placed in the VR can actually be built otherwise it will result in false expectations.
Contracting Authority	4. The VR might look more beautiful than that the project is in reality which will result in false expectations.
	5. The file sizes of the VR are huge.
Important stakeholders	6. Experiencing a project in VR is not the same as experiencing the project in real life.

Vestdijk project

Table 33 Cons of using VR Vestdijk project

Interviewee	Cons VR use
Contracting Authority & Project Managers	1. Higher costs of using VR.
Project Managers & Important stakeholders	2. When using an online VR more stakeholders will participate which can lead to more discussions.
Project Managers	3. It is difficult to make good interfaces to collect desires in VR.
	4. When VR is used to collect more desires capacity is needed to process all the desires.
	5. Quantification might result in standard solutions only.
	6. When VR is used to collect more desires, research methods are required to deal with the data.
	7. People might interpret the concept design used in the VR as being the final design which results in false expectations.
	8. Stakeholders can mobilize protest groups when using an online VR.
	9. When there is no strong vision the use of VR can lead to a grey compromise.
	10. When using an online VR more stakeholders will participate which might result in deviation from the project goal.
Contracting Authority	11. Using VR in a late phase can lead to late design changes.
	12. Usability issues with immersive VR.
Important stakeholders	13. Unnecessary worries about the project.
	14. Can lead to deviation from the vision.

Zaanenstraat project

Table 34, cons of using VR Zaanenstraat project

Interviewee	Cons VR use
Contracting Authority & Project Managers	1. Budgets of projects are coupled to the design of the projects, there is no budget available for increasing the investment in the stakeholder process.
Important stakeholders	2. Stakeholders might interpret the VR as the final design.

14.6 Appendix F: Success factors stakeholder process

Table 35, important aspects to have a successful stakeholder process.

Interviewee	Important aspects	Classification
All interviewees	Understand project.	Create project understanding.
Project managers & important stakeholders	Feedback on decisions and input.	System engineering stakeholder process.
	Clear communication.	Interactive stakeholder management process.
	Creating a realistic image of the project, no false expectations.	Project risk.
Contracting Authority	Early involvement of stakeholders.	Interactive stakeholder management process.
	Transparency about decisions and problems.	System engineering stakeholder process.
Project managers	Understanding impact of the project on own interest.	Create project understanding.
	Ability to influence the design.	Interactive stakeholder management process.
	Understand the complexity of the project	Create project understanding.
	Possibility to give input.	Interactive stakeholder management process.
	Using the desires of stakeholders as requirements for the project.	System engineering stakeholder process.
	A lot of high-quality information is accessible.	Interactive stakeholder management process.
	Communication aimed at specific stakeholders.	Interactive stakeholder management process.
	Clear boundary conditions for the project.	Satisfy boundary conditions
	Satisfying boundary conditions.	Satisfy boundary conditions
	Showing that you will make the best possible plan within the boundaries.	Satisfy boundary conditions
	Listening to the stakeholders.	Understand the project environment.
	Understand the stakeholders	Understand the project environment.
	Getting to know the project environment.	Understand the project environment.
	Satisfy vision of the contracting authority.	Satisfy boundary conditions
	The feeling of being heard	Create a feeling of being heard.
Important stakeholders	Proportionate influence on the design by stakeholders.	Project Risk.
	Satisfying vision of the project.	Satisfy boundary conditions

	Showing compassion to stakeholders.	Create a feeling of being heard.
	Warning the environment for nuisance	Interactive stakeholder management process
	Understand design decisions	Create project understanding

14.7 Appendix G: Risk framework

This appendix shows the evaluation of the risks by the interviewees (see Figure 53)

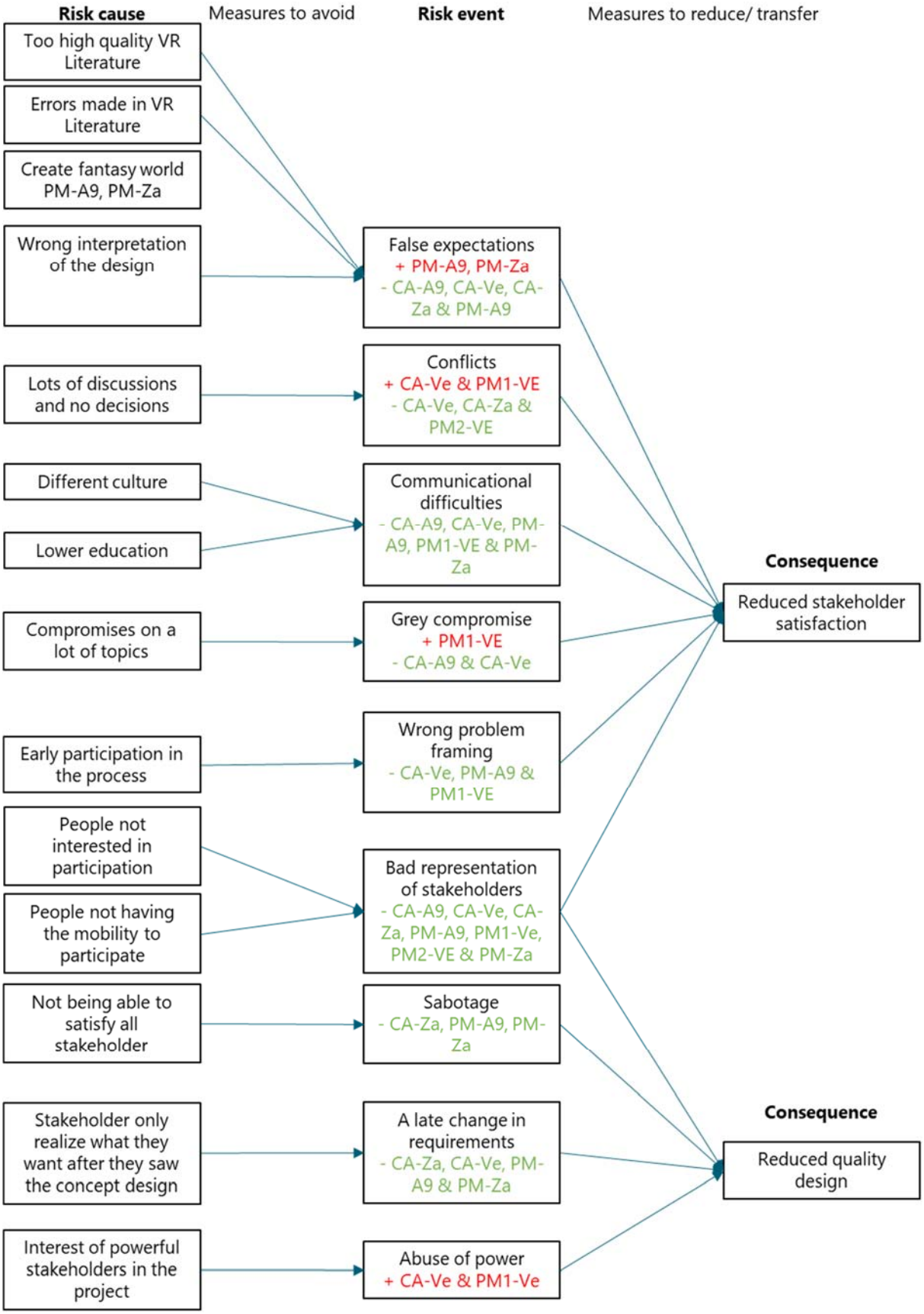

Figure 53, risk evaluation by the interviewees.

14.8 Appendix H: Informed consent

The first form was signed by all the contracting authorities and project managers the second form was signed by all the impotant stakeholders.

Informed consent form

This document gives you information about the interview about "The added value of the use of Virtual Reality in the stakeholder process". Before the interview begins, it is important that you learn about the procedure followed in this interview and that you give your informed consent for voluntary participation. Please read this document carefully.

Aim of the interview

The aim of this interview is to collect data on the value of using VR in the stakeholder process for complex infrastructure projects. The data is collected by Remco Oudshoorn, master student Construction Management and Engineering of the Delft University of Technology (TU Delft), and is used in his master thesis. The master thesis is written under supervision of Prof. dr. ir. M.J.C.M. Hertogh, Dr. ir. M.G.C. Bosch-Rekveldt, Dr. S.G. Lukosch working at the TU Delft and Ir. W. van der Woerdt employee of Witteveen+Bos.

Procedure

The interview consists of three parts. In the first part Remco will ask questions to elaborate on the context of the specific project. In the second part of the interview you are asked about the effect of the use of Virtual Reality in the stakeholder process on values that we find important for a successful stakeholder process. In the third part, Remco will hand you a bowtie diagram with the general risks of involving stakeholders in an infrastructure project and will explain this. You will be asked to read these risks carefully and elaborate on the effect that using Virtual Reality in the stakeholder process has on these risks. In other words, does the use of VR in the stakeholder process let you avoid these risks in a project or for example, does it cause additional risks. One might also think that some of these risks are reduced or transferred by using Virtual Reality in the stakeholder process.

Risks of participating in this interview

Participating in this interview does not involve any risks or detrimental side effects.

Duration

The interview will take approximately 60 minutes.

Voluntary

Your participation is completely voluntary. You can refuse to participate in the interview without giving any reason and you can stop your participation at any time during the interview. You can also withdraw your permission to use your interview data up to 24 hours after the interview is finished. All this will have no negative consequences whatsoever.

Confidentiality

All research conducted by students of the TU Delft adheres to the Code of Ethics. The audio of this interview is recorded. The audio recording is only used by members of the thesis committee to make a transcript for further analysis. The information that we collect from this interview is used for writing a master's thesis.

Further information

If you want more information about this interview or the thesis you can ask Remco Oudshoorn (contact email: Remco.oudshoorn@Witteveen+Bos.com). If you have any complaints about this interview, please contact one of the supervisors: Ir. W. van der Woerdt (wim.van.der.woerdt@Witteveen+Bos.com) or Dr. ir. M.G.C. Bosch-Rekveldt (m.g.c.bosch-rekveldt@tudelft.nl).

INFORMED CONSENT FORM

This document gives you information about the interview about "The added value of the use of Virtual Reality in the stakeholder process". Before the interview begins, it is important that you learn about the procedure followed in this interview and that you give your informed consent for voluntary participation. Please read this document carefully.

Aim of the interview

The aim of this interview is to collect data on the value of using VR in the stakeholder process for complex infrastructure projects. The data is collected by Remco Oudshoorn, master student Construction Management and Engineering of the Delft University of Technology (TU Delft), and is used in his master thesis. The master thesis is written under supervision of Prof. dr. ir. M.J.C.M. Hertogh, Dr. ir. M.G.C. Bosch-Rekveldt, Dr. S.G. Lukosch working at the TU Delft and Ir. W. van der Woerdt employee of Witteveen+Bos.

Procedure

During the interview Remco will ask questions to elaborate on the context of the specific project and the effect of the use of Virtual Reality in the stakeholder process on values that we find important for a successful stakeholder process.

Risks of participating in this interview

Participating in this interview does not involve any risks or detrimental side effects.

Duration

The interview will take approximately 30 minutes.

Voluntary

Your participation is completely voluntary. You can refuse to participate in the interview without giving any reason and you can stop your participation at any time during the interview. You can also withdraw your permission to use your interview data up to 24 hours after the interview is finished. All this will have no negative consequences whatsoever.

Confidentiality

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Further information

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