Master thesis project

VIRTUAL DESIGN AND CONSTRUCTION IN CIVIL ENGINEERING PROJECTS

An analysis and guideline to the application of the iRoom at Royal HaskoningDHV

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Preface

This report is my final examination of the MSc program Systems Engineering, Policy and Management (SEPAM). In my thesis project I wanted to perform a research in the field of project and process management. Royal HaskoningDHV has given me the opportunity to execute a research on the application of Virtual Design and Construction (VDC). I was instantly intrigued by VDC from the basic concept. With VDC many facets of a project are brought together and made understandable to stakeholders in the iRoom. The interdisciplinary nature on the interface between technology and management makes this topic cover the core of what I learned from the faculty of Technology, Policy and Management. Therefore I am Johan Hekker from Royal HaskongingDHV truly grateful for the assignment of this project.

Despite the fact I spend hours alone with ups and downs on my thesis, I could not have completed my project without the contribution of others. First, I like to thank all involved projects leaders at Royal HaskoningDHV that allowed me to make my observations in the iRoom and conduct interviews with their clients. Not only they were open for improvement, but by letting me analyse their cases they were also given a vulnerable position. Without this empirical data, I could have not completed my research. In addition, I really enjoyed attending the various iRoom sessions I was invited to. I also liked to found out that the participants gladly gave their opinion on the use of the iRoom. For this I want to thank all interviewees for their input.

In particular, I was very pleased with the daily assistance I was given at Royal HaskoningDHV. The critical and thoughtful views from Martien Reniers and Johan Hekker often helped me in making my own choices. I also enjoyed our discussions on the application of VDC. With this, I want to thank Martien and Johan for their involvement in my thesis.

Finally, I am also grateful for the various contributions I have given from my graduation committee, consisting of Paulien Herder, Stephan Lukosch and Haiko van der Voort. I want to thank all of them for the feedback I received during my project.

Delft, 31 Januari 2013
Mark van Rijsbergen

Executive Summary

Research problem and design

This thesis examines the application of Virtual Design and Construction (VDC) in civil engineer projects at Royal HaskoningDHV. This collaborative design method makes use of the multi-screen iRoom and allows different stakeholders to simultaneously describe, present and evaluate a project on product, organisation and process perspectives (Kunz & Fischer, 2012). The method is used by Royal HaskoningDHV to involve problem owners into the design process. It is expected that this method enlarges shared understanding among problems owners and helps in the management of organisational complexity in civil engineering projects.

The application of VDC at Royal HaskoningDHV responds to a changed design and engineering task. This arises from the policy of public parties to increasingly assign the market earlier (Leidraad SE, 2009). The focus in this changing design and engineering challenge lies more on specifying the actual design question and to lesser extent on the development of the technical solution. The complexity in this changing design and engineering challenge lies on how to achieve shared understanding among the problem owners on the design task. The application of VDC also confronts Royal HaskoningDHV with the challenges in collaborative design (Piirainen, Kolfschoten, & Lukosch, 2012).

This thesis focusses on the challenge of shared understanding and strives to manage organisational complexity encountered in civil engineering projects. The research is performed using a literature study, observations in the iRoom and interviews with problem owners. From this gaps and potentials for improvement for the application of VDC are identified. Finally, a guideline for the application of VDC is proposed to prepare future iRoom sessions.

Research results

For the research five civil engineering projects were selected that used VDC in the iRoom that ranged from upon the research phase till the final design phase.

Observations showed that the application of VDC differs considerably between each of these observed projects. A lack of structure and guidance in the application was observed. However, the application remains successful, especially for the conceptualisation and examination of design alternatives in collaboration with problem owners. By using visualisation it was shown that the iRoom helped in solving spatial design problems in collaboration with the problem owners. However, the use of metrics remains limited in most of the sessions. Also the design activities followed not always followed logical steps. Despite this, all sessions managed to provide a contribution relative the objective of the project and resulted in enlarged shared understanding among the problem owners.

From these cases nine problem owners were interviewed on their experiences and expectations. All problems owners had very positive expectations to the use of VDC in their projects. They expected a contribution to the perception, information exchange and the decision making. Often the iRoom was motivated to collaboratively examine and develop possible solutions for the design task. The experiences ranged from very positive to the level that participants had higher expectations from the session. The iRoom was considered useful to develop a supported solution for the design and to examine spatial limitations in the projects. The use of visualisation on the multi-screen Smartboards contributed most to these results. It was considered that the iRoom helped in creating a shared understanding among problem owners.

The case analysis showed that a lack of exchange in design methods, tools and approach currently exist. Therefore guidelines and tools should be developed to prepare future iRoom sessions. Most notable gap was seen in the limited use of metrics. The steps of issue formulation and system analysis and modelling are undeveloped and considered limited.

Proposed guidelines

In order to make optimal use of VDC there must be a clear objective defined to the project. The design task on the other hand must be suited for treatment in the iRoom and is required to contain some sort of organisational complexity and technical complexity which allows visualisations.

This application is proposed to consist of three phases: preparation of VDC, application of VDC and the evaluation of VDC. These phases are considered to be present in every VDC application. During the preparation phase a plan of action and POP models should be developed in cooperation with iRoom experts and facilitators. The application of VDC in the iRoom is suggested to consist of the seven logical steps of SE by Sage and Armstrong (2000). These steps can be taken in one or multiple iRoom sessions. After the application the session should be evaluated with the involved problem owners.

Within the application of the iRoom various trade-offs exists. At first it must be considered how many iRoom session will be performed for the project. The number of iRoom session is strongly dependent upon the scale of the project, the technical complexity and the amount of stakeholders involved in the project. Based upon the amount of sessions the design activities should be considered per session.

Conclusion

From this thesis, the conclusion can be made that the application of VDC contributes to a shared understanding with problems owners to manage organisational complexity. The case studies provided in this thesis demonstrated this expectation. Through actively involving problem owners in the iRoom the understanding and perception on the design task is enlarged. The application of VDC currently lacks on structure and can improve by using the guidelines that are proposed in this research.

The application of VDC brings also different approach in the development of engineering projects for Royal HaskoningDHV. Through the application of VDC a shift is made from pure engineering to the facilitation of design and decision making processes. As a result Royal HaskoningDHV has to focus more on the process perspective discipline.

Recommendations

Some recommendations are given on the application of VDC and should be considered by Royal HaskoningDHV to further enhance the application of the iRoom. The following recommendations are short term as these can be made instantly within future application of VDC.

- *Define clear objectives to iRoom sessions;*
- *Manage expectations of problem owners;*
- *More focus on the process perspective in application of VDC;*
- *Make use of logical design steps;*
- *Consult and use iRoom experts and facilitators.*

In addition, recommendations are given for further research and development. These are recommendations are considered long term.

- *Development of standardised adaptable POP models;*
- *Development of explicit design activities;*
- *Integration of POP models.*

Content

Chapter 1 Introduction

Projects in the civil engineering sector often result in large cost overruns. On average civil engineering projects in the Netherlands, completed in the period between 1991 and 2009, overrun by 16.5% (Cantarelli, Molin, van Wee, & Flyvbjerg, 2012). It turned out that cost overrun occur most, on average 19.7 %, in the pre-construction phase. This is the phase between the formal decision to build and the start of the construction. These overruns can have different possible explanations and are stated to be the result of misconceived estimates, the rough and "indicative" character during project development, optimistic behaviour and the deliberately to get the project proposal accepted.

Royal HaskoningDHV (RHDHV), a consultancy and engineering firm, is often involved in the development of these civil engineering projects during this pre-construction phase. In the recent years they are confronted with a changing design and engineering challenge. This due to a change in procurement policy of contracting authorities that results in the earlier involvement of market parties. These developments have led to the application of Systems Engineering (SE) in the Dutch civil engineering sector (Leidraad SE, 2009).

With these developments concerning Royal HaskoningDHV recently introduced Virtual Design & Construction (VDC) and the iRoom. Through using this method they aim to provide an added value to their clients in the development of civil engineering projects. On the other hand they expect to obtain more control on the policy uncertainties and decision making by involving problem owners in the design process.

However, these expectations cannot be substantiated yet. Therefore in my thesis I will position myself in the perspective of the problem owners and research the application and added value of the VDC in civil engineering projects. In addition, the coherence between VDC and Systems Engineering (SE) is taken into account. The aim of this thesis project is to set a first step in creating a scientific understanding on the application and added value of the iRoom in civil engineering projects. With this understanding, a guideline for the application of VDC at Royal HaskoningDHV is developed. These guidelines strive to improve shared understanding and manage organisation complexity in civil engineering projects.

The research is solely conducted at the consultancy and engineering firm Royal HaskoningDHV. This company provides services and innovative solutions in environment and sustainability, general buildings, manufacturing and industrial process, urban and regional development and water. The range of services covers the entire project cycle, including management consultancy, advice, design and engineering, project management, contract management and asset management (Royal HaskoningDHV, 2012). Royal HaskoningDHV is relevant for this research in several ways. At first this company acts in a multi-actor environment and plays a role in the development of large engineering projects. By this Royal HaskoningDHV provides the relevance for this thesis project. Secondly, this company is one of the first engineering firms to apply VDC in their projects as it demands for more effective design processes. By this the company can provide access to iRoom sessions and cases.

Looking at the structure of this thesis. First, the research problem *(Chapter 2)* is explored and the design of this research is presented *(Chapter 3)*. Then a literature study *(Chapter 4)* regarding the use of VDC is provided. The following chapters examine the use of VDC at Royal HaskoningDHV and present the results of iRoom observations *(Chapter 5)*, interviews *(Chapter 6)* and the outcome of a gap analysis *(Chapter 7).* Based upon the gained knowledge a guideline for the application of VDC is developed *(Chapter 8)*. The thesis concludes by providing recommendations and an answer to the research question *(Chapter 9)*.

Chapter 2

Research Problem

This chapter identifies the problem this research will focus on. The previous chapter already provided to this with a short introduction. Here the problem is further examined by starting with an exploration to the backgrounds of this research *(Section 2.1)*. The knowledge gaps and problems that derive from this exploration are then scoped to the problem this research will cover *(Section. 2.2)*.

2.1 Problem exploration

Traditional design and engineering processes in the civil engineering sector are evolving. Due to a number of reasons this has led to an changing design and engineering challenge. This section will give an exploration to the problem and gives insight in the measures taken by Royal HaskoningDHV.

The main reason for the evolving design and engineering processes is that public parties, such as Rijkswaterstaat and ProRail, in civil engineering projects increasingly concentrate on specifying problems and purchasing products and services (Leidraad SE, 2009). The Dutch government requires to involve and assign private parties more and earlier in the design and engineering processes (Rijkswaterstaat, 2008). This change in policy has resulted in the use of integrated contracts such as, Design & Construct (D&C) and Design, Build, Finance, Maintain (DBFM). By this contractors and engineering firms are given the challenge to tackle an integral responsibility in these projects (Leidraad SE, 2009). In theory these contracts should give the opportunity to come up with more effective solutions. In practice the lowest price is often decisive in project tendering procedures (Aanbestedingsinstituut Bouw & Infra, 2010; Siebrand, 2010). Besides, the use of these contracts still leads to design and implementation conflicts and it is estimated that the failure costs in the civil engineering sector are on average 10,5 % (Busker, 2011).

Due to these integrated contacts, projects are tendered earlier in design and engineering processes and this has resulted in a shift in the role of engineering firms, such as Royal HaskoningDHV. Traditionally this company is involved in the development of tender specifications, where nowadays they are increasingly assigned earlier in civil engineering projects. On the other side the responsibility of contractors shifted from the realisation of tender specification towards design due to the larger scope of integrated contracts and includes the traditional role of engineering firms (DHV, 2010). These market developments give Royal HaskoningDHV the possibility to achieve assignments in earlier project phases, but give simultaneously the threat that they are driven out of the design process by contractors.

Besides these reasons, civil engineering project are increasingly encountered with societal, economic and spatial aspects that increase the complexity in the design process. Infrastructure is often realized in environments with many stakeholders and conflicting interests, such as urban areas. In addition, sustainability is higher on the political agenda due to the increasing awareness that the capacity of our environment is limited (Agentschap NL, 2011). It is expected by Royal HaskoningDHV that infrastructure requires a more sustainable integration in the environment (DHV, 2010). These developments make the decision making process a more time-consuming task as the creation of support among stakeholders is more challenging. Contradictory, projects are increasingly under pressure as civil engineering projects have to be realised in shorter periods against the lowest possible price and it becomes common practise to deposit project risks at the market.

Due to this Royal HaskoningDHV is confronted with a changing design and engineering challenge as they have to deal with different tasks and responsibilities that traditionally belonged to their client. The focus in this changing design task lies more and more on the specification of the actual design question and to a lesser extent on the development of the technical solution (Leidraad SE, 2009). As public clients, or problem owners, consult engineering firms earlier in the design process makes them also involved and responsible in the early decision making. This gives the importance to deal with the needs of the involved stakeholders to develop a product that is in conformity its desired function.

The complexity in this changing design and engineering challenge is on how to create a shared understanding on the design question. Objectives of problem owners are often not entirely clear, especially in the early phases of these projects (Leidraad SE, 2009). Besides, due to the often conflicting interests of interdependent stakeholders and the long duration of civil engineering projects, objectives can change. This results in an organisational complexity and gives importance to the interaction between client and market to ensure a mutual agreement and commitment throughout the design task. Projects that involve both complex physical-technical systems and networks of interdependent actors can also be referred as sociotechnical systems (De Bruijn & Herder, 2009). In this type of systems the complexity in the design task is both on the hard system engineering discipline and the more soft and process oriented system discipline. To develop these sociotechnical systems they suggest that both a system and actor perspective must be used alongside each other.

To respond to this changing design and engineering challenge Royal HaskoningDHV is constantly seeking for improvements to organise their design and engineering processes more effective and efficient. This eventually has resulted in the application of Virtual Design and Construction (VDC) and the iRoom at Royal HaskoningDHV.

> ❖ **Definition: Virtual Design & Construction (VDC)**
>
> *´Virtual Design & Construction is the use of multi-disciplinary performance models of design-construction projects, including the Product (i.e., facilities), Work Processes and Organisation of the design - construction - operation team in order to support business objectives.´ (CIFE, 2012; Kunz & Fischer, 2012)*

Virtual Design & Construction is developed by the Stanford University. The method was developed originally for thee Architecture, Engineering and Construction (AEC) industry. However, this collaborative design method is generic and can be applied in other, such as the civil engineering, projects as well. VDC strongly emphasizes the use of models and visualisations that can be presented to and evaluated by multiple stakeholders (Kunz & Fischer, 2012). Royal HaskoningDHV is progressive with the use of this method as is one of its early adapters in the market. The method makes use of the multi-screen iRoom which allows different stakeholders to simultaneously describe, present and evaluate a project on product, organisation and process (POP) perspectives and models.

Royal HaskoningDHV currently has implemented the iRoom in several of their offices. The implementation of VDC is continuing in small steps forward. Previous research at Royal HaskoningDHV showed that the method currently cannot be seen as a fully thought-out approach and that the level of visualisations on organisation and process remains limited and has most potential for improvement (Schrama, 2011). Another research at Royal HaskoningDHV stated "VDC is already a structured way of working with the POP model, it can develop by using the possibilities Systems Engineering (SE) delivers to further structure the design and engineering process" (Freerks, 2011). Implementing SE activities into VDC will give the opportunity to align projects better to stakeholder needs and requirements. On the other hand implementing VDC principles into SE will also deliver possibilities for improvement.

❖ **Definition: System Engineering (SE)**

'An interdisciplinary approach and means to enable the realization of successful systems. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.' (INCOSE, 2004)

The application of Systems Engineering (SE) gets an increasing support in the civil engineering sector and is more and more applied (Leidraad SE, 2009). Royal HaskoningDHV considers SE as an methodology that gives them the ability to apply a structured approach to translate the needs of clients into concrete actions and products (DHV, 2012a). The use of SE corresponds to the evolving market in which private parties are involved in earlier stages of a project. However, basic techniques such as proper specification, verification and validation can still be improved significantly (Leidraad SE, 2009). The application of SE is therefore still an undergoing development within the sector and there are different variations on the use and definitions.

It is shown that the use of integrated design approaches, such as VDC, have most value in the early stages in engineering projects (AIA, 2007). Also in the Oil and Gas industry it is shown, as can be seen in Figure 2.1, that a good project definition has most impact on the value of projects (Hutchinson & Wabeke, 2006). The application of VDC responds to this as it strives to help in the development of a good project definition.

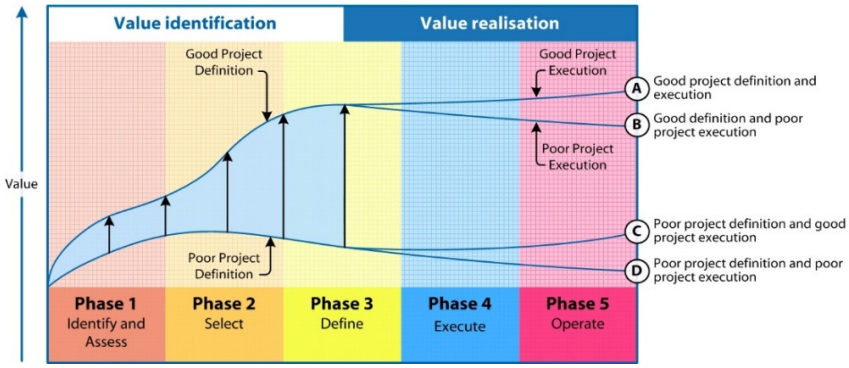


FIGURE 2.1 The influence of value creation in projects (Hutchinson & Wabeke, 2006)

VDC can only contribute to the value of projects if the application is successful. It can be expected that wrong implementation of the method can result in an opposite effect. In the literature it is shown that collaborative design contains various challenges as is shown by Piirainen et al. (2012). They identify the following challenges for collaborative design:

1. *Finding the right problem:* Assuming a holistic outlook to the problem, accounting for the interplay between the artifact and its environment, as well as finding satisfying balance between individual requirements early on in the project.
2. *Ensuring understanding:* Choosing a representation to support mutual understanding of the problem and the design choices concerning the artifact, and to support emergence of the intended behavior of the artifact
3. *Balancing rigor and relevance:* Choosing methods and representations that support both the technical design and the communication with users and stakeholders, to bridge the communication gap and avoid 'translation errors' from requirements to design and from design to user feedback for design iterations.
4. *Organization and management of design:* Organizing collaboration and communication using methods and tools to support stakeholder involvement and flexible collaboration, getting the right information to the right people at the right time.
5. *Ensuring ownership:* Listening to the intended users throughout the design process and helping the owners learn to perform and adapt the existing structures to accommodate the artifact.

2.2 Research scope

The scope of this research is situated within the problem description as described in the previous section. To further define the scope, this section will elaborate on what part of this problem is addressed in this research.

- *Virtual Design and Construction in the iRoom*
  Central in this research is the application of Virtual Design and Construction. In this approach iRoom sessions are used to facilitate the collaboration with problem owners and other main stakeholders. The method is only shortly implemented in several projects at Royal HaskoningDHV. Current practise at Royal HaskoningDHV proved promising, but further experience, research and development is needed to fully utilize the method. Currently the method lacks on structure and it is expected that it could method can be further enhanced.. This research focusses on the application of Virtual Design and Construction using the iRoom at Royal HaskoningDHV.

- *Civil engineering projects in the Netherlands*
  Virtual Design and Construction was developed by the Stanford University originally for the Architecture, Engineering and Construction (AEC) industry. Royal HaskoningDHV also first applied the VDC method initially at their buildings department. Now the method is more widely used throughout the company in other sectors. This Dutch civil engineering sector is confronted with different challenges, as introduced in the problem exploration. The challenges could require a different implementation of VDC. Therefore the research is scoped on the use of Virtual Design and Construction in the Dutch civil engineering sector.

- *From the project assignment until the tender specification*
  The research is scoped from upon the project assignment until the tender specification in civil engineering projects. This scope corresponds with the main design task of engineering firms in civil engineering projects. In addition, it is expected that the application of VDC is most valuable during these phases. The scope is visualised in the following figure.

FIGURE 2.2 Scope of research

- *Shared understanding with public problem owners*
  As Royal HaskoningDHV is increasingly assigned by public parties in earlier project phases confronts them with different tasks and responsibilities. Important aspect in the earlier phases is to acquire a shared understanding with the problem owners on these projects. It is expected that by involving problem owners more closely with the use VDC in projects, policy uncertainties and organisational complexity becomes more manageable. In addition, objectives of problem owners are often unclear and can change throughout the process. On that account this research will focus on how to contribute to a shared understanding with public problem owners. This corresponds to the one of the challenges in collaborative design mentioned in the problem exploration.

Chapter 3 Research design

The previous chapter presented the problem that is covered in this research. This chapter presents and discusses the research design. At first the research questions are presented *(Section 3.1)*. This is followed by an overview of the research deliverables *(Section 3.2)* this thesis contains. The following section present the research approach *(Section 3.3)* and an overview of the methods for data collection and analysis *(Section 3.4)*. Finally, the relevance of this research is discussed *(Section ☒)*.

3.1 Research questions

This section will present the research question and sub-objectives for this research. Based upon the problem statement the following research question is formulated:

HOW CAN THE APPLICATION OF VIRTUAL DESIGN AND CONSTRUCTION ACHIEVE A SHARED UNDERSTANDING WITH PROBLEM OWNERS IN CIVIL ENGINEERING PROJECTS TO MANAGE ORGANISATIONAL COMPLEXITY?

In order to provide an answer to this main research question the following more concise sub-questions are formulated:

RQ1: *What is the use of VDC in civil engineering projects and what is the coherence with Systems Engineering?*

RQ2: *How is VDC currently applied in the iRoom and what are the results of this method?*

RQ3: *What are the experiences and expectations of problem owners on the application of VDC in the iRoom?*

RQ4: *What best practises and lessons learned can be identified from the application VDC in the iRoom at Royal HaskoningDHV?*

RQ5: *What guidelines can be made for the application of VDC to achieve a shared understanding with problem owners in civil engineering projects?*

RQ6: *How can the provided guidelines be evaluated in future application of VDC in the iRoom?*

3.2 Research deliverables

In order to meet to the research questions as mentioned above, this thesis delivers the following products:

- A theoretical framework which presents an overview of the concept of VDC, the use in the civil engineering sector and the coherence with SE, derived using academic literature and guidelines commonly used in the civil engineering sector;
- A case study analysis on the use and added value of the VDC, examined using iRoom observations and interviews, which can be used by Royal HaskoningDHV to reflect on this method;
- A gap analysis that defines the lessons learned and potentials for improvement, which can be used by Royal HaskoningDHV further enhance this method;
- A guideline for the application of VDC, which can be used by Royal HaskoningDHV to develop and prepare future iRoom sessions for explicit projects with the aim to achieve a shared understanding with problem owners.
- An evaluation scheme that can be used to evaluate future application of VDC and the guidelines provided by this research.

In addition to the contents of this thesis, a public presentation of the research results is given.

3.3 Research approach

To explain how this thesis provides an answer to the research question, this section discusses the approach of this research. The following figure schematically presents the research questions in relation to the applied methods for data collection and analysis.

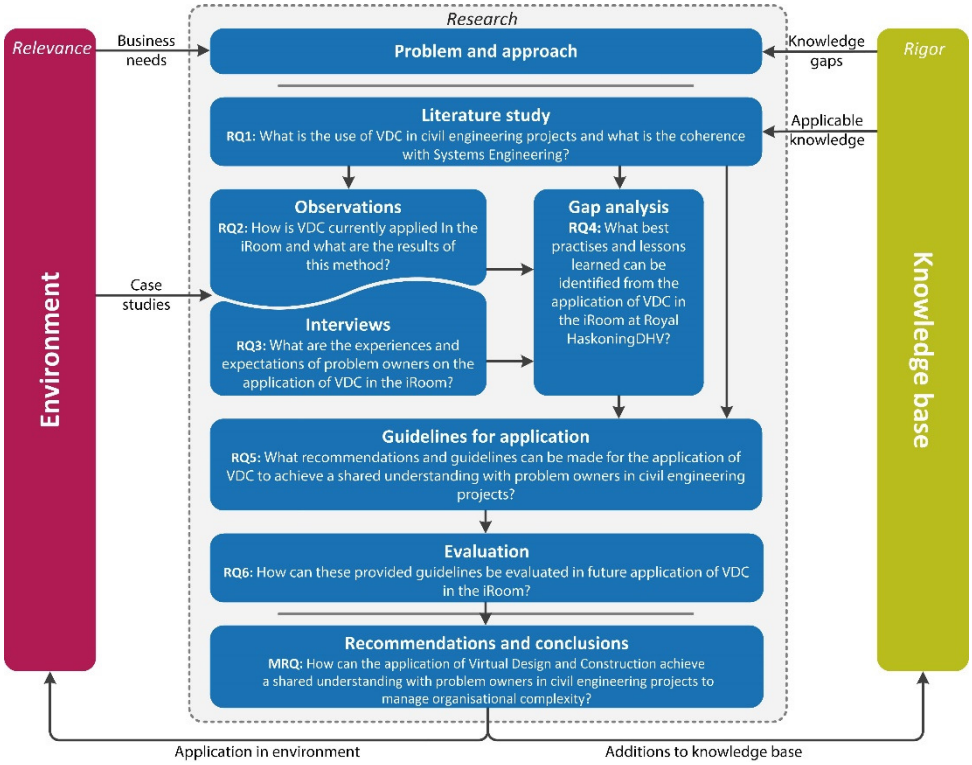


FIGURE 3.1 Research approach

The research approach that is chosen is based upon Design Science Research (DSR) (Hevner, 2007; Hevner, March, Park, & Ram, 2004). This research approach has the objective to develop a general applicable knowledge which can be used by Royal HaskoningDHV in order to give an answer to their specific problem.

From the figure above can be derived that in this research at first the literature is studied in order to create an understanding on the use of VDC and the coherence with SE. This study will provide applicable knowledge that is used throughout this thesis. The next step in this research is to make observations in various iRoom sessions at Royal HaskoningDHV. By this first-order data is collected from the application of VDC. From these sessions the participants were interviewed in order to obtain insight in the expectations and experiences from the perspective of the problem owner. The gained knowledge from the case studies is used to perform a gap analysis. This will conclude on the lessons learned and potentials for improvement in the application of VDC at Royal HaskoningDHV. To enhance the application of VDC the findings of this research are used to design guidelines that can be used develop and prepare iRoom sessions for explicit projects. Following these identified guidelines an evaluation is presented.

The conclusions of this research aim to provide an answer on how the application of VDC can help in achieving a shared understanding with problem owners in civil engineering projects. The outcome of this research can be used for application in the environment and will provide additions to the knowledge base.

3.4 Data collection & analysis methods

This section describes and justifies the applied methods that are used for data collection and analysis as presented in the design approach in more detail.

3.4.1 Literature study

In the first step of this research a literature study is conducted with the aim to provide a knowledge base. With this literature an understanding is provided on the concept of VDC. Then the use of VDC is explained by examining the field of application, the Dutch civil engineering sector. Additional, the coherence with System Engineering is examined by making an comparison between these design methods. This literature study will provide an answer to the first research question:

RQ1: *What is the use of VDC in civil engineering projects and what is the coherence with Systems Engineering?*

Approach of literature study

- *The study of academic literature*
  To gather knowledge on VDC at first academic literature is researched that already is available. This will be used to acquire an understanding of this concept. Also the field of application and the coherence with SE is examined using literature. Sources for this are study thesis projects, scientific articles and books. Literature is acquired through the TU Delft library, Web of Science, Scopus and Google Scholar.
- *The study of documents and guidelines derived from the civil engineering sector*
  Royal HaskoningDHV has knowledge on the use of SE and VDC in the civil engineering sector. In addition, there are many guidelines and documents in the civil engineering sector that are commonly accepted. These will be analysed to provide an answer to the research question. Additionally, general interviews with field experts on Virtual Design and Construction are conducted to acquire this information.

Outcome of literature study

- Knowledge on the theoretical background of VDC;
- Knowledge on the design tasks and complexity in the Dutch civil engineering sector that define the need for VDC;
- Knowledge on the coherence of VDC with Systems Engineering and how this potentially can benefit to the application.

3.4.2 Case analysis

The second step in this research is to gather data to analyse the application of the Virtual Design and Construction in civil engineering projects at Royal HaskoningDHV. This data is gathered by conducting a series of observations and interviews in cases where the iRoom is applied. This analysis will be used to answer the following research questions:

RQ2: *How is the VDC currently applied in the iRoom and what are the results of this method?*

RQ3: *What are the experiences and expectations of problem owners on the application VDC in the iRoom?*

Approach of cases analysis

- *The selection of cases and interviewees*
  For the case studies five projects are selected that included the use of the iRoom. These five cases were selected randomly according to availability and the scope of this research. The selected cases all consist of civil engineering projects from national, regional or local public clients.

- *Observation of iRoom sessions*
  A series of observations in iRoom sessions provide knowledge on how VDC is used in practise at Royal HaskoningDHV. For these observations a framework was developed. This framework observes the conditions of application, the application of VDC and the results of the application. Alternatively, the concerned project leaders or facilitators of iRoom sessions could have been questioned by interview to examine the use of VDC at Royal HaskoningDHV. However, this could have provided prejudiced data on the application and results of the iRoom.
- *Interviews with problem owners*
  After the iRoom sessions the problem owners that participated to the session were interviewed. The interviews are conducted by using a lists of questions that were prepared in advance. These qualitative interviews have the aim to provide knowledge on the experiences and expectations of these clients on the use of VDC.

Outcome of cases analysis

- Knowledge on the application and added value of VDC at Royal HaskoningDHV;
- Knowledge on the experiences and expectations of problem owners on the use of VDC

3.4.3 Gap analysis

From the empirical data of the observations and interviews are gathered a gap analysis is executed. In this step the collected data is examined by making an comparison between theory, observations and interviews to the added value of the iRoom session. From this the best practises and lessons learned are defined that help to create an understanding on the potentials for improvement. This step provides an answer to the following research question:

RQ4: *What best practises and lessons learned can be identified from the application of the iRoom at Royal HaskoningDHV?*

Approach of gap analysis

- *Conditions of application*
  VDC and the iRoom can be applied for divergent objectives and in different project phases. Therefore, on the basis of the case studies, it is examined under which conditions VDC is most useful.
- *Application of iRoom*
  Various trade-offs can be made within the application of VDC. These trade-offs, derived from the case studies, are examined in relation the results of the VDC. From this various hypothesis of these best practises and lessons learned can be defined for the application of VDC in general.

Outcome of gap analysis

- Best practises of the application of VDC at Royal HaskoningDHV;
- Lessons learned from the application of VDC at Royal HaskoningDHV.

3.4.4 Guidelines of application

Based upon the gained knowledge derived from the analysis in this research a guideline for the application of VDC is developed. This guideline can be used by Royal HaskoningDHV to develop and prepare feature iRoom sessions. In these guidelines the preconditions and trade-offs for a successful iRoom session are considered and suggest design for iRoom sessions are given. The identified guidelines need to be proven in practise. Therefore an evaluation is presented for the identified guidelines. This includes an evaluation of the guidelines with VDC experts and an evaluation scheme that can be used for future iRoom sessions. This step has the aim to give an answer to the following research questions:

RQ5: *What guidelines can be made for the application of VDC to achieve a shared understanding with problem owners in civil engineering projects?*

RQ6: *How can the provided guidelines be evaluated in future application of VDC in the iRoom?*

Approach of design

- *Preconditions*
  Based upon the gap analysis preconditions for the application of VDC are recommended. These recommendations are strongly dependent on the outcome of the analysis.
- *Basic program of VDC*
  A general applicable basic program is suggested for the application of the iRoom at Royal HaskoningDHV which can be applied for various objectives.
- *Trade-offs*
  In order to design and prepare iRoom sessions successfully various trade-offs are suggested to align the application to specific projects. These recommendations are derived from the research results.
- *Evaluation of guidelines*
  To justify and further enhance these guidelines an evaluation is presented.

Outcome of design

- Guidelines for the application of VDC to prepare future iRoom sessions at Royal HaskoningDHV.
- Evaluation scheme that can be used to evaluate future application of VDC.

3.5 Research relevance

This thesis project is relevant in several ways and is discussed in this section. The relevance can be explained from both a scientific and social perspective.

Scientific relevance

From a scientific perspective this thesis will provide a contribution to the knowledge of Virtual Design and Construction. First, the research results give understanding on the added value and use of VDC in the civil engineering sector. This achieved with the help of case studies. Secondly, this thesis examines the application of VDC in SE driven projects. This provides an understanding of the use of these methods in coherency.

Societal relevance

Besides the scientific relevance, the results of this research aims to be used by Royal HaskoningDHV. The gained knowledge and reflection on the application of VDC can be used by this company to further improve their design and engineering processes. The provided guidelines for the application of VDC can be seen as the most important contribution. Ultimately, this could lead to a better shared understanding with problem owners and a better project performance. Royal HaskoningDHV therefore benefits most from the results from this thesis project as the recommendations are specific for this company.

Chapter 4 Theoretical framework

This chapter was developed through a review of existing literature with the aim to create an understanding on the use of VDC in theory. This study of literature will provide an answer to the following research question:

RQ1: *What is the use of VDC in civil engineering projects and what is the coherence with Systems Engineering?*

To answer this question first the theory of VDC is introduced and explained *(Section 4.1)*. Then, the field of application is discussed by presenting the shifting roles and responsibilities of engineering firms in the civil engineering sector *(Section 4.2)*. The following section will examine the coherence with Systems Engineering *(Section 4.3)* as applied in the civil engineering sector. The final section will provide a conclusion of the research question *(Section 4.4)*.

4.1 The concept of Virtual Design and Construction

Central in this research is Virtual Design and Construction (VDC). This section will provide an overview of VDC according to the theory. At first the concept is introduced, then the method and components of VDC are further explained. Finally the implementation of VDC is examined.

4.1.1 Introduction to Virtual Design and Construction

Virtual Design and Construction is an design and engineering method that is developed by the Stanford University at the Centre for Integrated Facility Engineering (CIFE) in 2001 (Kunz & Fischer, 2012).

The method was originally intended for the US Architecture, Engineering and Construction industry. However, the method is general and can also be applied to other construction-design process. The method resulted from the fact that necessary alignment between organisations in multi-disciplinary design teams is a difficulty. Design processes are often fragmented and this often created problems that result in long project durations. In addition, they noted that design and construction processes are often experienced as paper based and inflexible (Kunz & Fischer, 2012). Project stakeholders and managers were encountered with complex decision making and felt distance from the actual design and construction process as it was too complicated to understand.

This problem of fragmentation and complexity resulted in the development of Virtual Design and Construction by CIFE. The concept of VDC is defined as the use of multi-disciplinary performance models of design-construction projects, including the Product (i.e., facilities), Work Processes and Organisation of the design - construction - operation team in order to support business objectives (CIFE, 2012; Kunz & Fischer, 2012).

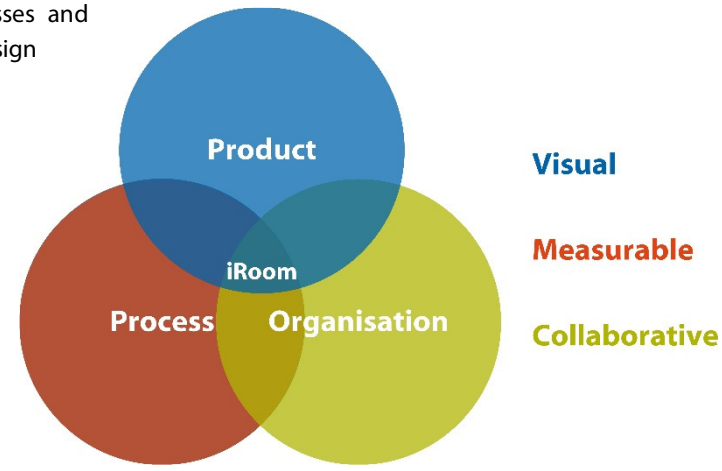


FIGURE 4.1 The concept of Virtual Design and Construction (DHV, 2012b)

VDC focuses of three main components as can be seen in Figure 4.1. These components are present in every design and construction process: product, organisation and process (POP) (Garcia, Kunz, Ekstrom, & Kiviniemi, 2004; Kunz & Fischer, 2012). In VDC these subjects are made visual and measurable with the use models, drawings and simulations.

In VDC a central key role is given to the iRoom. This iRoom facilitates the use of POP visualisations and metrics used in the process of Integrated Concurrent Engineering (ICE). This method uses a singularly rapid combination of expert designers; advanced modelling, visualisation and analysis tools; social processes, and a specialized design facility; to create preliminary designs for complex systems (Chachere, Kunz, & Levitt, 2004).

4.1.2 Theoretical basis of VDC

Virtual Design and Construction consists of several characteristics. The first characteristic is the use VDC models are all *virtual*. This implies that the use of VDC models are flexible, visual and interactive (Kunz & Fischer, 2012). VDC not paper-based, but computer-based so models can easily be presented in the iRoom. The second characteristic is that VDC models are *integrated*. Many design processes are fragmented due to multiple teams. Linking these teams creates a lot of effort and confusion. Therefore VDC has the aim to integrate product, organisation and process tightly (Kunz & Fischer, 2012). By using computer models information can be exchanged and used effectively. An example is the use of Building Information Models (BIM). The method is described as *multidisciplinary* because actors from various disciplines such as architecture, engineering, contracting, as well as the sub-disciplines and the client are involved. Finally, the method is stated to be *performance based.* With this is meant that the project performance is determined in advance and can be measured during the process. The use of metrics and visualisations make it able to examine and measure the performance of the design.

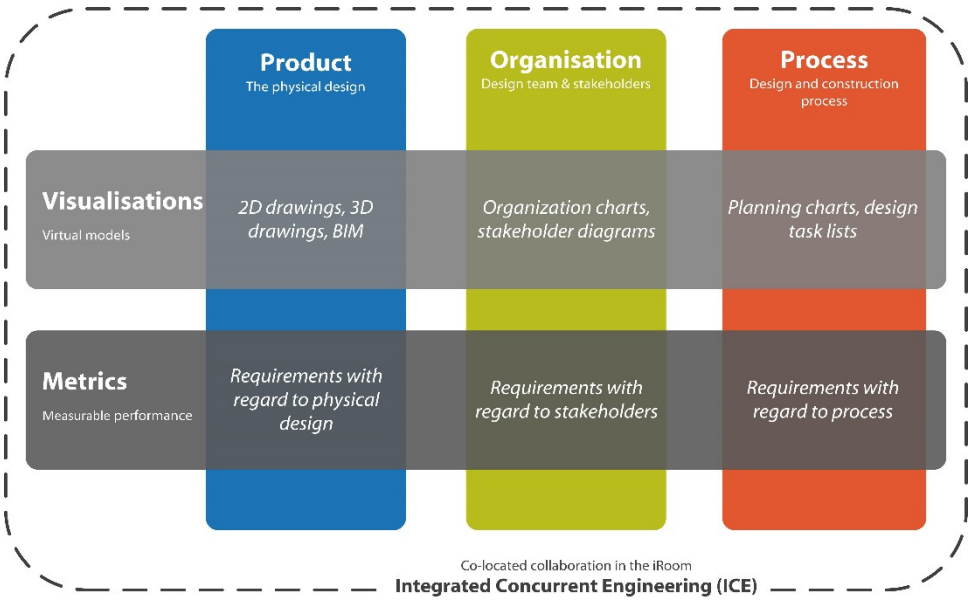


FIGURE 4.2 Components of VDC (Schrama, 2011) - edited

As shown in Figure 4.2 the method consists of POP models that are used in a process of Integrated Concurrent Engineering. To enhance perception to the product, organisation and process visualisation are used. Metrics have the purpose to measure the performance of product, organisation and process. It is expected that VDC improves quality and reduces rework, due the integration of product, organisation and process (Garcia et al., 2004). The following sections will discuss the components of the VDC in more detail.

Virtual Design and Construction cannot be considered as a standardized design method as CIFE does not propose standards for the VDC models and approach. They argue that this probably takes a long time to emerge. CIFE, however, wants to support individual project teams with modest incremental effort (Kunz & Fischer, 2012).

Integrated Concurrent Engineering in iRoom

Important component of VDC is the use of Integrated Concurrent Engineering (ICE) in the iRoom (Garcia et al., 2004). This method is also known as Extreme Collaboration (XC) (Mark, 2002). ICE is not exclusive part of VDC but does form a basic concept of this method.

The idea is to make use of a multiple stakeholders from different disciplines. This is also known as co-location. This means that you make use of professionals from different disciplinary backgrounds that collaborate at the same location (Chachere et al., 2004). This makes the method multidisciplinary as stakeholders from engineering, architecture, contracting and clients are involved in the process. By combining product, organisation and Process in a concurrent environment will trigger all involved stakeholders to think further for than their expertise (Garcia et al., 2004).

Additionally, Integrated Concurrent Engineering makes use several tools such as models and visuals that can be applied to support the collaboration. The tools can help stakeholders to provide an understanding and analyse design alternatives (Garcia et al., 2004). In relation to VDC, Kunz and Fischer describe that the purpose of the application of ICE is to increase the focus of involved stakeholders and make perceptions more explicit and understandable.

FIGURE 4.3 The use of the CIFE iRoom and VDC at Royal HaskoningDHV

The process of Integrated Concurrent Engineering is supported by the use of the iRoom which can be seen in Figure 4.3. This term was introduced by Kunz and Fischer and is defined as an interactive meeting room that has the purpose to facilitate de VDC process. The iRoom is featured with multiple interactive presentation touchscreens. Stakeholders are invited to use the Smartboards to enhance and present the interactive POP models and visualisations.

Traditionally, projects are fragmented and different design disciplines are separated. Also projects are characterized by a vertical organisation as managers have different hierarchy then engineers. The VDC method argues that the organisation should be flat with minimal boundaries and manager involvement. The VDC facilitator manages the design process in the iRoom. This facilitator needs to ensure that all stakeholders are equally included in the process and maintains the overview of the process. The facilitator is needed to have multi-disciplinary capabilities of both social skills and technical knowledge.

POP visualisations

Important component of the VDC theory is the use of visualisations on product, organisation and process. These visualisation are solely virtual and computer based. This makes the visualisations more flexible and interactive to use. For example visualisations can be rotated and components can be switched on or off (Kunz & Fischer, 2012).

Product visualisations

Product visualisations contain a representation of the system or components in a project. The method stimulates to make use of these kind of visualisation. Preferable with the help of 3D drawings as these are more interactive to use. The use of 3D drawings can reduce the amount of rework as these are more easily to understand (Kunz & Fischer, 2012). Also the VDC method argues that the use of visual information can break language barriers.

Organisation visualisations

Organisation visualisations present the visual representations of the involved actors in the design and construction of the building (Kunz & Fischer, 2012)). The organisation consists of actors such as architects, engineers, advisors and contractors. Also, the stakeholders and decision makers such as the client can be part of organisation visualisations. The organisation can be visualised using an charts which shows a network of the actors and stakeholders involved in the project process, as well as the reporting paths (Kunz & Fischer, 2012).

Process visualisations

Process visualisations represent the design and construction process which the organisation follows to develop the building (Kunz & Fischer, 2012). The process consists of tasks, activities or actions which have to be undertaken by the organisation. The process is visualised in a process diagram, ideally in the shape of a network diagram, showing the activities of the design tasks, task interdependencies and deadlines (Kunz & Fischer, 2012).

POP metrics

VDC imposes to measure the performance on product, organisation and process. By determine project objectives in advance the projects performance can be predicted and measured. For this process the VDC method uses POP metrics. These can be seen as requirements and objectives of the performance of product, organisation and process. They are used to measure the progress and manage the project. An example on how to use POP metrics can be seen in the following figure.

Function		*Form/Scope*	*Behaviour*		*Weigthing factors*		*Qualitative threshold values*				
Measurable objective	Objective value		Predicted	Assessed	Weighted assessment	Weighted value	-2	-1	0	1	2
Product											
Parking places	200		?p	1	25	25	185	190	195	200	205
Costs per parking place	20000		?p	1	25	25	26000	24000	22000	20000	18000
Organization											
Actors attending meetings (%)	95		?p	1	10	10	80	85	90	95	100
Actor backlog (days)	<3		?p	1	10	10	5+	4+	3+	<3	<2
Process											
Conformance with schedule (%)	85		?p	1	15	15	70	75	80	85	95
Maximum schedule delay (wks)	0		?p	1	15	15	3	2	1	0	-1
Project evaluated goodness					100	100					

FIGURE 4.4 Example of POP-model (Schrama, 2011)

In this example function, form/scope, behaviours, weighting factors and threshold values are described. The first aspect describes function requirements and objectives for the product, organisation or process and can often be derived from the program of requirements or the stakeholders. The form/scope describe how the function is chosen into a design. The behaviour indicates if the form/scope reaches the objective values. Weighting factors make clear which POP functions are of importance in comparison. Threshold values define how the function should be assessed and can be defined by the involved stakeholders. POP models can be built in different variations to present visualisations and metrics.

POP models consist of different levels of detail. POP level-A describes product, organisation and process on a system level. Lower level POP models describe sub-system and component levels and are more detailed. The use of POP models and visualisations is stated to have the most value in the early phases of design.

4.1.3 VDC implementation

VDC can be seen as a new design method and CIFE does not deliver standardized visualisations, metrics or design steps. The method should be implemented to the needs individual project teams. This makes that the implementation of VDC involves time as POP models need to be developed. This section discusses various implementation levels and the current level of implementation at Royal HaskoningDHV.

VDC maturity model

Based upon the implementation at various users of the method a VDC maturity model was defined (Kunz & Fischer, 2012). This model consist of three different levels of implementation as can be seen Figure 4.5.

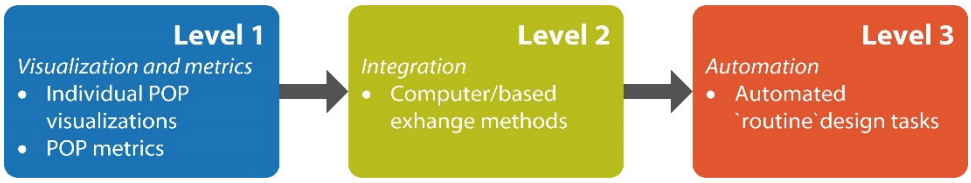


FIGURE 4.5 Schematic representation of the VDC maturity model levels (Schrama, 2011) -edited

The first indicated level is the use and development of individual POP models (Kunz & Fischer, 2012). The design team makes visualisation and metrics of the product, organisation and process. These models are used individually as they do not exchange information with other models.

The next level makes use of integration of the POP models. In the civil engineering sector this integration is also known as Building Information Modelling (BIM). This means that project data and information from one model is exchanged with other models. This phase of integration is more difficult to achieve, however once a standard has been made it is expected that this results in a decrease in effort and time (Kunz & Fischer, 2012).

The final and third level is reached by automation of the design tasks. This automation is about prefabrication of certain design task that can easily be implemented and used in the VDC design process. By this certain design task are standardized and may lead to efficiency.

Implementation at Royal HaskoningDHV

The application of VDC has only been recently implemented at Royal HaskoningDHV and is continuing in development. In the year 2011 the application was introduced at their building departments. Later, the application was introduced throughout the company. With the aim to have real time integrated workshops the iRoom was built at several offices and is used frequently for various objective. The iRoom is mostly used in collaboration with main stakeholders. However, the use of VDC as the main approach in projects is remains limited (Schrama, 2011). Therefore many project managers currently follow courses to become VDC specialists to further implement VDC. The implementation of VDC is continuing in small steps forward. First Royal HaskoningDHV needs to become comfortable with the theory, facilitation and method (Schrama, 2011).

4.2 The evolving civil engineering sector

This research examines the application of VDC in the Dutch civil engineering sector. Therefore, it is of importance to obtain an understanding on this field of application. In this sector VDC may be used for various objectives or in different project phases. In addition, the complexity of the sector may have an impact on the implementation and use of the method. This section therefore describes the civil engineering sector and its complexity. From this the purpose and drivers for the application of VDC are reasoned.

4.2.1 Changed design and engineering challenge

The last decade a couple of market developments have led to a changed design and engineering challenge in the civil engineering sector. These changes are important to consider to place the VDC method in context to the field of application. On the other hand these developments can be seen as possible drivers for the use of VDC.

Reduced involvement of government

The main reason for the changing role of engineering firms is the reduced involvement of governments in design and engineering projects. This change in policy promoted to involve and assign private parties more and earlier in design and engineering processes. As a result the amount of knowledge at public parties is declining due to cuts and dilution at these organisations. Due to this in procurement strategy roles, responsibilities and risks shifted from client to the market (CROW, 2007).

The objective of these changes is to stimulate innovation, increase transparency, and improve the cost-performance ratio (Rijkswaterstaat, 2007). With the use of integrated contracts and Systems Engineering this goal will have to be achieved.

From Traditional to Integrated contracts

In traditional procurements public parties, such as Rijkswaterstaat and ProRail, were given a dominant role in de development and management of civil engineering projects. Market parties were only contracted once the contracting authority has developed a solution to the design problem. In the development of the solution contracting authorities were often assisted by consultancy and engineering firms. This traditional design and engineering process can be seen in Figure 4.6.

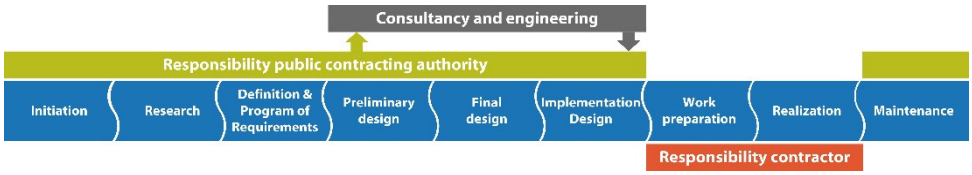


FIGURE 4.6 Role of engineering firms in traditional contracts (Wind, 2006) -edited

As public parties developed their own solution to a problem the importance of functional specifications were of a less importance. The traditional role of consultancy and engineering firms was to help public parties to design and develop the technical specifications. Once this process has been completed the specifications of the solution were contracted out and the contractor had to build what the contracting authority prescribed. However, this traditional process limits the extents of market creativity as contractors are limited to only build the technical specification.

To achieve more creativity in the market to develop better and more cost efficient projects integrated contracts are increasingly used. As a result, part of the design and engineering process that traditionally belonged to the contracting authority has shifted towards the market. In these type of contracts the process of design and construction will be contracted to the market. In some contracts the maintenance part is also assigned towards the market.

The thought in using of integrated contracts is that the integration of design, construction and maintenance enables contractors to be competitive on more than only price. Traditionally prices were the main competitive factor, while these contracts can in theory also be won by proposing more efficient solutions. In practice, however, this seems still difficult to realize (Siebrand, 2010). The design process of integrated contracts is presented in Figure 4.7.

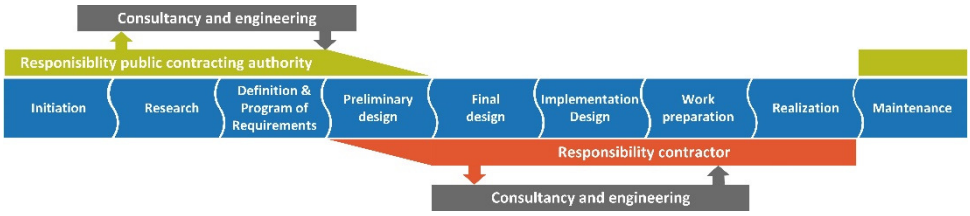


FIGURE 4.7 Role of consultancy and engineering firms in integrated contracts (Wind, 2006) -edited

Due to the fact that contractors shift over the traditional role of consultancy and engineering firms does not means that they are completely driven out of the process. The process from project assignment to tender specification can outsourced to consultancy and engineering firms. The policy of Rijkswaterstaat in is to consult the market unless this leads to major risks (Rijkswaterstaat, 2011).

This means that engineering firms can be consulted by public parties in the exploration phase of civil engineering projects to develop tender specifications. This brings a new design task for Royal consultancy and engineering firms. Additionally, engineering firms can be consulted by the market to develop solutions to their problems. The change of policy results in that consultancy and engineering firms are confronted with different roles and clients. Especially in projects from national public clients, such as Rijkswaterstaat en ProRail, integrated contracts are often used.

In relation to the application of VDC the method can be applied at two different sides in a projects by Royal HaskoningDHV. On one side in collaboration with the contracting authorities such as municipalities and provinces. On the other side with contractors. This research is scoped to apply the method in the early design phases in collaboration with public problem owners. The application of VDC can be seen as an opportunity during these early design phases in market development. In this process the engineering challenge is to specify functional requirements to the actual design question. Other useable application is to explore the project on feasible design alternatives.

4.2.2 Complexity and uncertainty in the civil engineering sector

Civil engineering projects are often seen as a complex undertaking. In addition, the sector has difficulties in responding to the increasing complexity seen in civil engineering projects. This is demonstrated in the large amount of cost overruns, failure cost, late completion dates and technical problems that are substantiated by various studies (Cantarelli et al., 2012). Therefore this section will provide an understanding on complexity and uncertainty often encountered in civil engineering projects. These could be important to consider during the application of VDC.

As a term project complexity is often used. However, there are different interpretations and definitions given by the literature. The term "complexity" argues that these projects can have some degree of difficulty and consists of varied interrelated parts (Baccarini, 1996).

Project complexity can be distinguished between structural and dynamic complexity (Whitty & Maylor, 2009). The large number of interrelated components that a project or systems consist from can be referred as the structural complexity. These components can contain various tasks, technical parts and stakeholders. In relation to VDC this type of structural complexity can be well quantified, measured and prepared for during iRoom sessions. The unpredictable, uncertain and emergent behaviour that are subject of change in projects can be defined as dynamic complexity. These dynamic complexities can result from interaction and can change over time. In contrast to VDC this type of complexity can be considered hard to quantify and measured and can occur during an iRoom session. Another distinction made is between organisational and technical complexity (Rycroft & Kash, 1999).

Civil engineering projects are general unique as projects contain of different organisations and technical systems that can consist of many interrelated components.

Technological complexity

Technology used in civil engineering projects is often proven and robust. The use of state of the art technologies is limited. The technologies used for example, bridges and roads have been used for years and have proven themselves. The complexity is therefore not in the use of state of the art and new technologies. However, civil engineering projects often consist of many interrelated components and this results in many internal interfaces.

On the other hand civil engineering projects are often part of a larger traffic system. This makes that these projects have to be connected to the existing infrastructure. This interaction creates external interfaces to the project and these can be complex to understand. For example, a new road can have an impact on the traffic movements in a larger traffic system. This sort of complexity can be defined as dynamic. Also, existing infrastructure can be outdated or poorly documented and can make the integration a difficulty. Besides, civil engineering projects are often encountered with spatial problems. The projects must often be integrated into the environment and this can be considered a complex spatial task.

Organisational complexity

Besides the technical complexity encountered in the development of civil engineering projects, the organisational complexity can be even more problematic. This type of complexity is best explained with the help of the following figure.

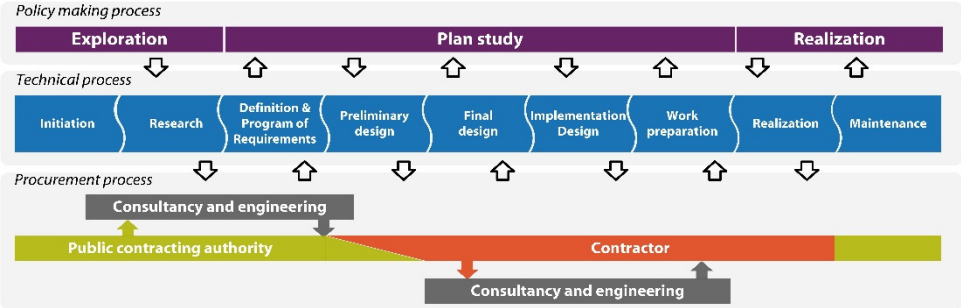


FIGURE 4.8 Influences on technical process in the civil engineering sector (Freerks, 2012) -edited

The technical process itself, as seen in Figure 4.8, may seem structured with stepwise phases from project initiation to realization and maintenance. However, it isn't only in the technical engineering process itself that makes civil engineering processes complex. The influence of the policy making process makes and fragmentation due to a procurement process make the development of civil engineering projects organisational complex.

In the top row of this figure we see a policy making process which has its influence on the technical development of civil engineering projects and are subject of change. This brings a dynamic complexity to these projects as the objectives of different stakeholders can change over time and are often uncertain.

This complexity is strengthened by the thought that the social aspect plays an increasing role in the realisation of civil engineering projects. The presence of a large number of actors with differing and often conflicting interests in these projects can be complex and result in an uncertain outcome. Conflicting interest of different stakeholders increase as civil engineering projects are realised in more urbanised environments. Also, sustainability is higher on the agenda and has become a more dominant criteria in the decision making of civil engineering projects. Finally, these projects are often encountered with long project durations and high investment cost which make these project of greater importance to the

involved stakeholders. Because of this the decision making process becomes a more time-consuming task as the creation of support among stakeholders is more challenging.

In the bottom row of Figure 4.8 the procurement process can be seen which also has its influence on the technical development of civil engineering projects. In this process the contracting authority tenders out a set of specifications to a contractor to be build. This set of specifications are made often in collaboration with consultancy and engineering firms. This results in an organisational fragmentation in the technical development of the project and can be considered as complex. me

This influence gives an organisational complexity due to the fact that the technical process is fragmented due to a this procurement process. This brings organisational interfaces to the projects. A contractor is encountered with the design considerations done by engineering firms. When there is no proper coordination between these parties this could ultimately lead to design failures. To deal with this fragmentation and organisational complexity contracts are used and Systems Engineering is frequently applied. However, the use of VDC is expected to provide added value in achieving a shared understanding between these different organisations. The application could be useful in the areas of the transfer of knowledge, improved communication and verification and validation of the design.

In addition, the client can consist of several organisations. Demands can hereby often become conflicting and the task is given to the engineering firms, as Royal HaskoningDHV, to provide a good solution to uncertain design questions. As a result this brings a complexity to the project. The iRoom can be very suited to develop and mediate on the design question. Especially during the early phases of a projects in the research and examination of design considerations and feasibility.

4.2.3 The demand for Virtual Design and Construction

The previous sections presented various developments and complexities encountered in the civil engineering sector. On one side, within the application of VDC and the iRoom these developments and complexities should be considered. On the other side these developments and complexities can be seen as drivers for the application of VDC by Royal HaskoningDHV. This section will therefore further reason on the need for this design method.

In theory the application of VDC may seem promising. However, it must be considered the application is new, in development and unproven in practise in the civil engineering sector. Additionally, before VDC can truly develop their must be a demand from the market for the implementation of this design method. Royal HaskoningDHV has however chosen to independently push this method into the market. I therefore consider it first of importance to reason the demand for the application of VDC from the market developments and complexities presented in the previous sections. The following figure schematically presents the drivers identified.

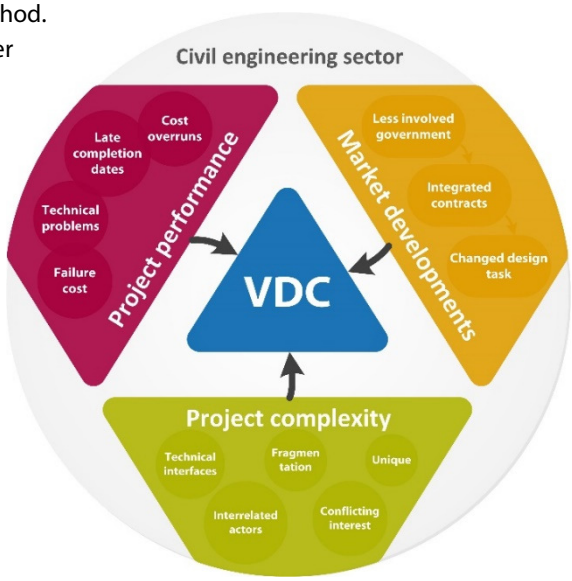


FIGURE 4.9 Drivers for the use of VDC in the civil engineering sector

As can be seen in Figure 4.9 the application of VDC can be reasoned from three different fronts. The first

driver identified is the often poor project performance of civil engineering projects. The second driver is seen the market developments that result in a changed design task for Royal HaskoningDHV. The final driver identified is the project complexity that characterize most civil engineering projects. These front can be seen as main drivers for the application of VDC.

From the market point of view engineering firms are increasingly involved earlier in the development of infrastructure. This brings other design tasks due to a less involved government and integrated contracts. Traditionally the design task of engineering firms was to develop the technical specifications and a design that was tendered to a contractor for establishment. Today engineering firms are increasingly involved in the development of functional specifications and in the exploration phase of projects. On this new design tasks Royal HaskoningDHV can respond with the application of VDC. The method is in theory very suitable to examine the feasibility of projects and to compare and develop design alternatives. In addition, this method also focusses on process.

The complexity encountered in the development of civil engineering projects is in addition to the technical difficulty also organisational. This due to fragmentation and the many interrelated actors involved with often conflicting interest. VDC responds to this by focusing on both the product as well as the organisation and process. With the use of visualisations and metrics the structural complexity can be quantified, measured and prepared during iRoom sessions. Dynamic complexities that result from interaction between stakeholders can occur during iRoom sessions. These type of complexities can be managed with the use of VDC in iRoom sessions.

In respect to the project performance of civil engineering projects, VDC can in theory be used to perform better research and examination in the early project phases. The iRoom can be used as a tool to make cost estimations and examine the projects on feasibility in collaboration with multiple stakeholders. The expectation is that the application of VDC ultimately will result in a reduce of cost overruns and failure cost.

In theory the application of VDC can be of added value reasoned from these drivers. However, its use and expectations are not yet demonstrated and proven in practise. Besides, the client often implies to apply SE in the civil engineering sector. Therefore it is of importance to place VDC in contrast to SE and examine the coherence.

4.3 The application of Systems Engineering in the civil engineering sector

The previous section explained various market developments that can be seen as drivers for the use of VDC. However, these drivers also contributed to the use of Systems Engineering (SE). This design approach was introduced several years ago by Rijkswaterstaat and ProRail, in the Dutch civil engineering sector for integrated contracts. Because SE is increasingly applied in the market, makes it of importance to examine the coherence with this design methodology in regard to VDC. In addition, previous research indicated that the application of VDC at Royal HaskoningDHV can possibly benefit from the design steps of SE and vice versa. Therefore, this section explores how VDC relates to SE and how it possibly could benefit from each other.

4.3.1 Introduction to Systems Engineering

Changes in the market demanded for a structured and explicit design methodology. Systems Engineering was seen as the solution for these developments in the civil engineering sector. However, it is certainly not a new design methodology. The approach originated from the telephony sector. Continuing in the fifties the application and development of SE began to increase due to the aviation and military industry with

companies like Boeing and Lockheed. In these days, SE was taken to the next level to design and engineer complex systems. In the past decades SE received a growing international interest. Its application in combination with the use of integrated contracts is also common in the oil and gas industry. In this industry it is for some time common practise to deposit project risks at contractors.

In the Dutch civil engineering sector SE was first applied in 1999 at several projects. Some early examples are the Northern Betuwe route and the A4 Burgerveen-Leiden. Before this, governments did not prescribe such an explicit way of working. This because the market was only contracted to realize the design and contracting authorities were responsible for the design and engineering by themselves. Since 2007 Systems Engineering is widely applied in the civil engineering sector. Nowadays, SE has become the standard approach for integrated contract for ProRail and Rijkswaterstaat (Leidraad SE, 2009). However, SE can still be seen as a relative new discipline and approach in the sector. So far several successes have been made, but experience has also shown that the application is still in a learning process.

Definition of Systems Engineering

To obtain an understanding of the principles of System Engineering at first the definition is presented. However, within the literature their exists several different definitions. This suggest that there are various forms on use and interpretation. The following definitions on SE are commonly used in the academic field:

- *"The design, development, production, and maintenance of functional, reliable, and trustworthy systems within cost and time restraints." (Sage & Armstrong, 2000)*
- *"Systems Engineering is a robust approach to the design, creation and operation of systems." (NASA, 1995)*
- *"Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems." (INCOSE, 2004)*

The definition of the International Council on Systems Engineering (INCOSE) is most recent. This definition is also included in the Guideline Systems Engineering for Public Works and Water Management in the Netherlands, also known in Dutch as the "Leidraad SE". This guideline is developed by Rijkswaterstaat, ProRail en several market parties.

The guideline is widely accepted throughout the civil engineering sector. In their perspective Systems Engineering can be seen as a multidisciplinary approach with an integrated and structured set of methodologies to design and manage complex engineering projects (Leidraad SE, 2009).

Sage and Armstrong state additionally to their definition that SE is a management technology to assist and support policy making, planning, decision making and associated resource allocation or action deployment (Sage & Armstrong, 2000).

Systems thinking

One of the leading principles in SE is "systems thinking". A system is can be defined as a group of components that work together for a specified propose (Sage & Armstrong, 2000). This suggest that a systems consist of a number of functions which must be implemented to achieve the purpose of the system that supports the entire project life cycle.

Systems Engineering considers to solve complex problems from an holistic perspective. A system is very perceptive-independent as a system can be a combination of multiple sub-systems or components (Sage & Armstrong, 2000). The way this perspective is chosen can be seen as the "system of interest" as can be seen in Figure 4.10.

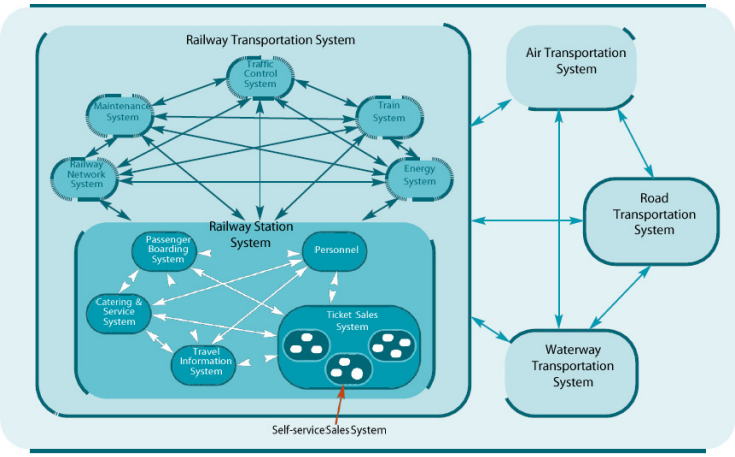


FIGURE 4.10 System and context systems (Leidraad SE, 2009)

The system of interest can be different for each stakeholder that is present in the project. Therefore it can be considered of importance to define a mutual "systems of interest" for the scope of the project. In addition it is of importance to consider the developed project in contrast to the surrounding systems to manage the technological and organisational interfaces.

Separation of specification and design

System Engineering refers back to the original design problem. The problem statement can be seen as the primary requirement and is used as a starting point. From there on the system is further developed in more detail. Out of the defined requirements for the system functions are compiled. Once the system requirements are completed the sub-system requirements will be derived from the system requirements. Once the specification process has been completed the design can be implemented. In the civil engineering sector the V-model is often used. This model, Figure 4.11, shows the separation specification and design and system decomposition.

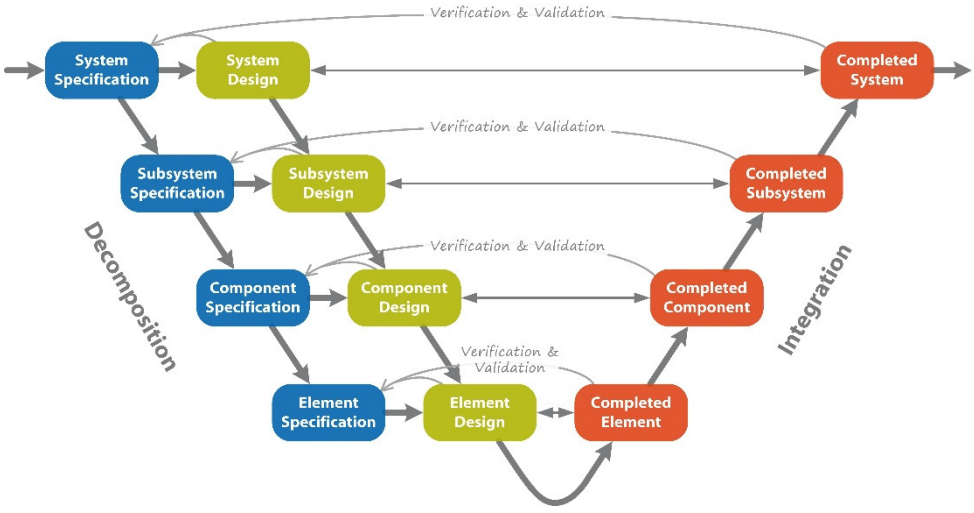


FIGURE 4.11 V-Model (Leidraad SE, 2009) – edited

In this V-Model we see a separation between specification, design and completion. Between each step verification and validation is performed to ensure the systems refers back to the design problem. The V-Model is characterized by its decomposition from a system level to an element level. Once the system is completely specified and designed, the system will be established from the bottom-up.

Verification and validation

Important drivers for use of SE is the transparency and traceability of the approach. With the use of verification and validation this should be achieved. This makes it possible to trace all design choices back to the original design question.

Verification is used to determine whether the design meets to the defined requirements. Validation is used to determine if the design meets to the client's needs. These steps are taken in every step of the systems engineering approach. The process of verification and validation is shown in the Figure 4.11.

Life cycle perspective

Systems Engineering often associated with the use of a life cycle perspective. This means that design consideration of the needed system include not only the user phase but also renewal or even demolition. This life cycle approach from upon concept, development, production, use, operation, maintenance and renewal is shown in the following figure.

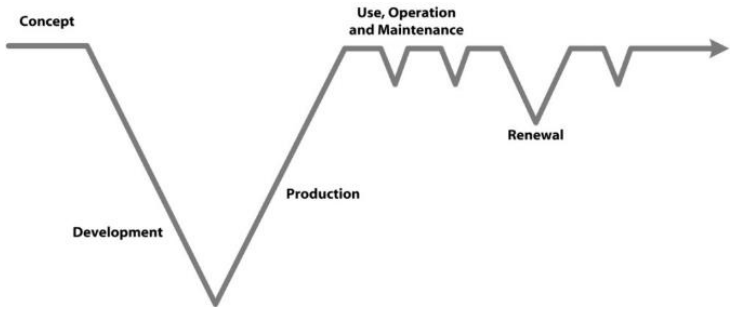


FIGURE 4.12 Systems Engineering V-model and life cycle (Leidraad SE, 2009)

4.3.2 Systems Engineering in the civil engineering sector

Systems Engineering in the civil engineering sector has its own characteristics and meaning. The term System Engineering in the Dutch civil engineering is refers to the approach presented in the Leidraad SE. This approach is narrower than the more broad academic definitions of SE. Therefore this section explains how SE is applied in the civil engineering sector according to the Leidraad SE. Also the result of this application and common seen problems in SE driven projects are discussed.

According to the Leidraad SE provides a coherent set of methodologies to develop and use successful infrastructure. System Engineering is not just about technical systems but also refers to people and procedures (Leidraad SE, 2009)

Systems Engineering is since 2007 widely applied in the civil engineering sector. In the application several successes have been made so far. However, it is also shown that System Engineering is a learning process for both Rijkswaterstaat and market parties. The application of SE is currently often seen as a struggle and the benefits that are expected form this approach are not always fully utilised. The application of SE, especially for larger projects, is increasingly common. For smaller projects, it is expected that more and more is acted in the terms of SE.

Requirements specification

The engineering process in the Dutch civil engineering sector, as mentioned in the previous chapter, is fragmented. This also means that the approach consists of a separation between contracting authority and contractor. This separation of requirements and design is shown in Figure 4.13. This figure shows how the contracting authority is responsible for the requirements of the system and subsystems and the contractor is responsible for the design.

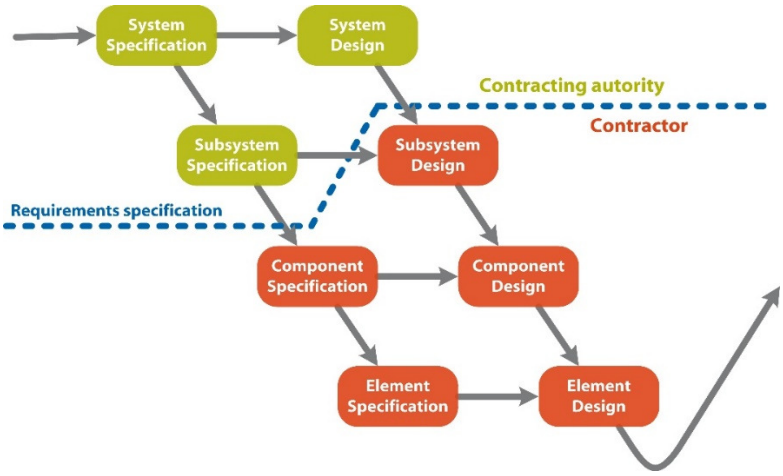


FIGURE 4.13 Requirements specification

Despite this separation brings a difficulty in the application of SE, it also provides the need for an explicit way of working. Public parties increasingly concentrated on the development of a set of functional requirements and the procurement of infrastructure. With this market parties become responsible for the design, realisation and maintenance of infrastructure in conformity with the prescribed requirements.

With this fragmentation of specification and design and engineering SE brings in fact a twofold framework (Goossens, 2007). This is both internally and externally through verification and validation to ensure the traceability of requirements, design and realisation. On one side SE gives contractors an framework to monitor themselves by explicit design steps with the use of the V-model and verification and validation. On the other side SE brings contracting authorities to opportunity evaluate the design to the system requirements. Through system decomposition in theory SE will make the design and development of large infrastructure systems manageable.

Results of the application of Systems Engineering

In practice both public parties and contractors have the difficulty to implement SE effectively (Goossens, 2007). The past years the civil engineering sector gained experience in the use of systems engineering. The approach is certainly being used, however, a standard approach is not developed. In general SE theory suggest that engineering projects will be more maintainable on cost, risks and time. Additionally, SE should enhance the amount of innovative solutions.

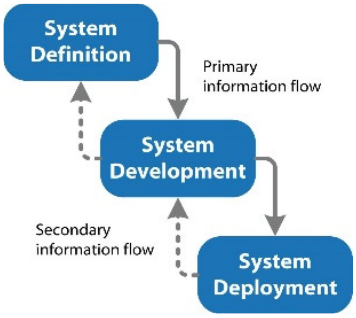
Research has been conducted to the results of the application of SE in the civil engineering sector. This research concludes that in the civil engineering sector SE provides not (yet) a decrease of cost and project duration (Vink, 2008). Also SE does not reduce project risks but rather introduces more risks to projects. Vink gives several reasons why SE in the civil engineering sector does not comply to this expectation:

- Every civil engineering project is unique;
- Large amount of stakeholder involvement and environmental factors;
- Fragmentation between design, construction and maintenance;
- SE needs to be further developed before it can achieve results

These conclusions does not imposes that the SE can be seen as a useless approach. SE provides manageability of time and money, under the condition that the project team is experienced in the discipline (Vink, 2008).

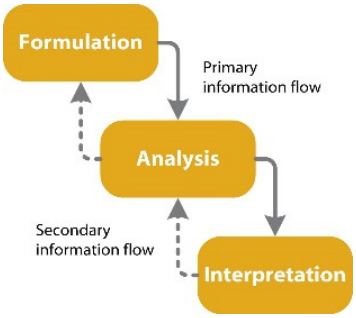
4.3.3 Systems Engineering processes and logical steps

Previous research at Royal HaskoningDHV indicated that VDC could potentially benefit from the design steps of SE (Freerks, 2011). Therefore this section will further examine SE processes and logical design steps derived from the literature of Sage and Armstrong.



Sage and Armstrong present an hierarchy for systems engineering phases as can be shown in Figure 4.14. They state that all systems consist of a minimum of three phases: definition, development and deployment (Sage & Armstrong, 2000). In the civil engineering sector, seen in Figure 4.7, the life-cycle consist of more project phases.

FIGURE 4.14 Three primary systems engineering phases (Sage & Armstrong, 2000) –edited



Within each of these phases they argue that from a formal perceptive systems engineering activity consist of a minimum of three fundamental steps in each design phase: issue formulation, issue analysis and issue interpretation (Sage & Armstrong, 2000). Regardless to the life-cycle, phase, product, system or service to be designed.

FIGURE 4.15 Three primary systems engineering steps (Sage & Armstrong, 2000) –edited

In the formulation steps the needs, objectives and design options are identified. In the step of analysis the impacts of identified design options are examined and researched. In the final interpretation step the design options are considered, evaluated and compared. The most acceptable alternative is selected for further plan of action (Sage & Armstrong, 2000). When the phases of Systems Engineering are combined with the steps the following activities are illustrated as can be seen in Figure 4.16.

		Steps		
		Formulation	Analysis	Interpretation
Phases	Definition	Activity 1	Activity 2	Activity 3
	Development	..	..	..
	Deployment	..	..	Activity 9

FIGURE 4.16 Two-dimensional framework of systems engineering phases and steps (Sage & Armstrong, 2000)

In relation to VDC, iRoom session can be used in for various objectives and can be applied in different project phases in a Systems Engineering process. For example, this can be for analysis in the project definition phase or to conclude on the final design. In other words iRoom sessions can be applied in either of the activities presented in Figure 4.16. However, certain activities are probably more suitable for iRoom sessions then others.

VDC can be applied in different project phases and system levels. However, it can be argued that VDC will at least have to involve the three systems engineering steps presented in Figure 4.15. These steps, that are present in each and every phase in SE, could in theory benefit the further structure the application of VDC.

The interpretation of these steps can vary in many different forms. Therefore Sage and Armstrong further expend these three fundamental steps into seven most useful steps of systems engineering (Hall, 1969; Sage & Armstrong, 2000). These seven steps are presented in Figure 4.17.

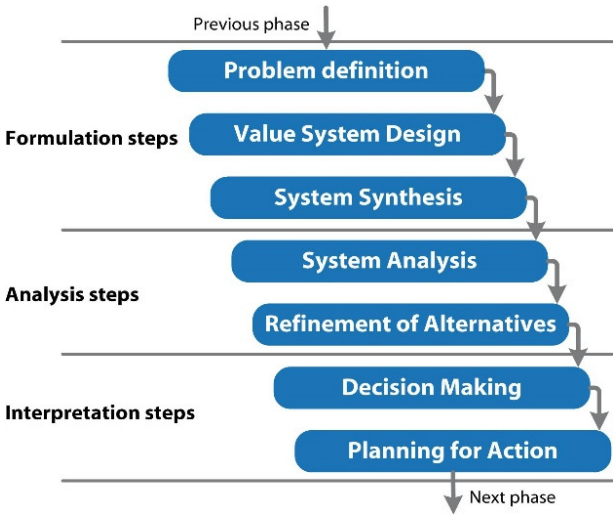


FIGURE 4.17 Seven steps of the logic dimension of systems engineering (Hall, 1969; Sage & Armstrong, 2000)

The activities these seven logical steps of Systems Engineering involve can be explained as follows.

- *Problem Definition*
  Identifying, quantifying, and clarifying a set of needs, alterables and constraints associated with the issue formulation of the problem;
- *Value System Design*
  The selection of the set of objectives and measures that enables determination of decision criteria for selecting the most appropriate system;
- *Synthesis of Alternatives*
  Identification of a number of potential alternatives and associated alternatives measures;
- *System Modelling and Analysis*
  Examination of the performance of the identified alternatives relative to the decision criteria with the use of simulation and modelling methods;
- *Refinement of Alternatives*
  The attempt to optimize alternatives system variables in order to meet the system objects and constraints best;
- *Decision Making*
  Evaluation of the impacts and consequences of alternatives and selection for advancing to the next step;
- *Planning for action*
  Communication of the results and allocating resources to accomplish further plan of action.

These seven logical steps of systems engineering can be used to further structure the application of VDC and can be important to consider in the design of iRoom sessions. However, the specific tools and methods used in iRoom sessions can differ in different project phases to accomplish these seven steps.

4.3.4 The coherence between VDC and SE

From the previous sections it already becomes clear that VDC will interfere with SE when applied in civil engineering projects. Therefore in this section examines the coherence between VDC and SE.

Differences and similarities between VDC and SE

From the gained knowledge from the literature an attempt is made to compare both these methodologies on structure, information and decision making and evaluation. From this the following table is developed.

	Virtual Design and Construction	Systems Engineering
	Design method with the use of the iRoom, POP models and ICE	*Design approach with distinct steps and phases*
Structure		
	POP levels	*System levels*
	System integration	*System decomposition*
	Collaboration	*Fragmentation*
Information		
	Solely virtual and computer-based	*Often document-based*
	Product, organisation and process visualisations and metrics	*System specification, development and deployment*
Decision making and evaluation		
	Performance based models	*Formulation, analysis and interpretation methods*
	Integrated Concurrent Engineering	*Validation and Verification*

TABLE 4.1 VDC and SE comparison

From this table, it can be concluded that VDC and SE on one side are very similar to each other. On the other side, there are some considerable differences. The most drastic difference is that VDC can be considered as a design method and SE as a design approach. In other words, SE is an stepwise design path with clear and distinct phases and steps which build a number of activities to develop successful systems. To conduct these activities in SE various methods and tools are consulted. VDC can be considered as one of these methods or tools to perform activities defined in the process of SE.

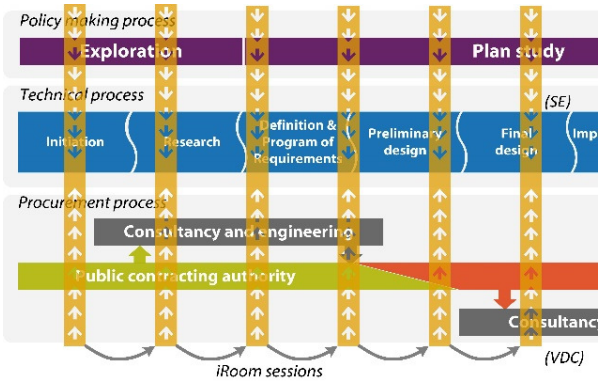
When considering the structure it can be stated that VDC with the use of POP levels is very similar to the system levels in SE. However, there is a substantial difference in the structuring of the design task. In SE the focus is the for the system to breakdown the system in manageable components. In VDC the focus is more on the integration of Product, Organization and Process in order to manage technical and organisational interfaces. In practise it can be reasoned that both a focus on integration and decomposition is needed to develop large-scale systems. Finally, it can be state in practise that system engineering in the civil engineering sector is often considered fragmented as system concept, development, implementation and use is performed by different parties. VDC, however, is aimed on collaboration and involvement of different stakeholders using ICE in the iRoom.

The information developed during the application of VDC and SE also differs. In VDC information is solely virtual and computer based, were in SE it often consist of large and long paged documents. In addition, the information developed in VDC consist of mainly visualisations and metrics on product, organisation and process that are developed through iterative design. Whereas the information in SE is developed sequential in the phases system specification, development and deployment using various tools and analysing methods.

The decision making on the design in VDC is made with performance based models in a process of ICE. As multiple actors are involved in iRoom sessions the design choices are made on a basis of consensus with the aid of visualisations and metrics. In SE design choices follow from the steps of issue formulation, issue analysis and issue interpretation. To ensure the design is in conformance with the client's needs validation and verification steps are performed. Whereas in VDC the design is developed in collaboration.

Integration of VDC and SE

The previous section showed that SE can be mentioned as a design approach and VDC can be considered as a design method. Currently VDC and SE are considered as two separated processes at Royal HaskoningDHV. However, it is expected that these two processes can enhance each other (Freerks, 2011). The integration between, and with it the coherence of, VDC and SE in civil engineering projects is conceptualised in Figure 4.18.



In this figure the process of System Engineering is represented in the technical process from project phases of initiation until the final design. Within each of this phases steps of formulation, analysis and interpretation are performed. With its application SE engineering brings an horizontal guidance in the development of civil engineering projects.

FIGURE 4.18 VDC and iRoom sessions in civil engineering projects

VDC is represented in this figure by the yellow bars and forms a vertical integration of the technical development of the system with the policy making process and fragmentation that results from the procurement processes. The iRoom can be applied when considered needed in each and every phase and step of the SE process. However, certain activities are probably more suitable for iRoom sessions then others. From the concept of VDC can be reasoned that the iRoom is more suitable in activities when:

- the design task can be visualised;
- the design task can be measured;
- the design task contains multi-actor involvement.

The added value of VDC in a process of SE can be reasoned from two sides. On one side the application of VDC will actively involve stakeholders into the SE process in the development of tender specifications. It can be expected that among the involved stakeholders the perception on the design task is enlarged and the creation of a shared understanding and consensus can be accelerated. This involvement will help in managing organisational complexity often confronted in civil engineering projects.

On the other side VDC could theoretically benefit to SE by making the approach more visual and understandable to the involved stakeholders with the help of the iRoom. With this VDC provides SE with a tool for validation and verification of the design.

4.4 Conclusion of theoretical framework

Through a review of existing literature this theoretical framework provides an understanding on the use of VDC. This design method focusses on three main components that are present in every design and construction process: product, organisation and process (POP) (Garcia et al., 2004; Kunz & Fischer, 2012). These components are made visual and measurable with the use models, drawings and simulations. With the involvement of multiple stakeholders from different disciplines, the iRoom is used in VDC to collaboratively develop preliminary designs for complex systems (Chachere, Kunz, & Levitt, 2003; Garcia et al., 2004; Kunz & Fischer, 2012).

To define the use of VDC in civil engineering projects three main drivers are identified. Civil engineering projects are often confronted with cost overruns, failure cost, late completion dates and technical problems (Cantarelli et al., 2012). This can be considered as a first driver of the use of VDC. The iRoom can respond to this by using it as a tool to examine and estimate projects risks and cost in the development of civil engineering projects. The second driver identified is derived from the market developments in the civil engineering sector. Royal HaskoningDHV is increasingly involved in the development of functional specifications in the exploration phase of projects. On this new design tasks Royal HaskoningDHV can respond with VDC. The method is in theory very suitable to examine the feasibility of projects and to compare and develop design alternatives in consultation by problem owners for preliminary designs. The final driver is the project complexity that characterize civil engineering projects. Due to the many interrelated stakeholders that are often involved, these projects are not only a technical difficulty but also organisational complex. VDC responds to this by focusing on both product, organisation and process and examine these with the use of visualisations and metrics in the iRoom. However, it must be considered that the expectations are not yet proven in practise.

In the civil engineering sector Systems Engineering is increasingly considered as the preferred way of working and is often obligated by clients. Therefore it is of importance to examine the coherence of VDC and SE. When making an comparison it can be argued that VDC can be seen as a design method and SE as an design approach. SE brings projects clear design phases and steps which build various activities to develop successful systems. With the use of several methods and tools these activities can be performed. VDC can be considered as a method to perform activities defined in the SE process. Whereas SE provides an horizontal guidance in the development of systems, for VDC can be argued to aim for a vertical integration between technical development, decision making and organisations. In addition, VDC is expected to benefit by actively involve stakeholders into the SE process that could enlarge perception, shared understanding and consensus on the design task. This makes the SE process more understandable and helps in managing organisational complexity often confronted in civil engineering projects.

Chapter 5

Observations: current application of VDC in the iRoom

This chapter has the aim to examine the current application of the VDC in practise at Royal HaskoningDHV. By observing various iRoom sessions the following research question is answered in this chapter:

RQ2: *How is the VDC currently applied in the iRoom and what are the results of this method?*

The selected cases and the observation framework used is introduced at first *(Section 5.1)*. The following section presents the results of the observations *(Section 5.2)*. Finally this chapter will conclude by providing an answer to the research question *(Section 5.3)*.

5.1 Research method

The application of the iRoom at Royal HaskoningDHV has been research through a series of observations by physically attending to five iRoom sessions. These observations are used to develop an overview on the application of the VDC in civil engineering projects at Royal HaskoningDHV.

It is chosen to make observations in the iRoom to obtain first order information on the application of VDC. To objectify the observations a framework for observation was developed to ensure that each session is observed on the same manner. The framework can be consulted in Annex I.

For each observed iRoom session an individual observation report was made. These reports were all verified with the involved project leaders or facilitators to prevent misunderstandings and to further enhance the objectivity of the observations. The complete observations reports can be found in Annex II.

5.1.1 Introduction of cases

A total of five projects were selected for observation. These cases were selected randomly on availability and based on the scope of this research. In all these projects the iRoom was used together with problem owners from national, regional or local public parties. The following five iRoom sessions have been selected for this research:

- *Border ditch Blaricummermeent (BCM)*
  The municipality of Blaricum expands with a new residential area: the Blaricummermeent. Royal HaskoningDHV has been assigned for the civil engineering in this project. Part of this residential area is a ditch which is exactly located on the border of the municipalities Huizen and Blaricum. The iRoom is used to achieve an agreement with the municipalities and Waternet on the maintenance and design of this border ditch.

- *Renewal St. Sebastiaansbrug Delft (SSB)*
  The St. Sebastiaansbrug at the municipality of Delft will be replaced because it no longer meets to the current and future requirements. In this project is Royal HaskoningDHV is responsible for the technical design of the bridge. The iRoom is used frequently in this project to discuss the project to discuss the process and design considerations in collaboration with the client and main stakeholders.

- *Traffic measures renewal Zaanbrug (TZB)*
  The Zaanbrug will be renewed because it currently constitutes a constraint for shipping traffic on the Zaan. As the bridge will be temporary closed when renewed, traffic measures are needed in the surrounding community. These measures should be established before the construction of the bridge. In addition, there is a temporary bridge required for cyclists and pedestrians. A feasible design for these measures are needed that has a joint agreement of all stakeholders. The iRoom is used twice to facilitate this process.

- *Tunnelling rail crossings Ermelo (TRE)*
  Within the municipality Ermelo there are three railway crossings. These crossings are problematic as it results in more dangerous situations due to increasing railway traffic. Both cars and bicycles are faced with longer waiting times. The situation is currently is anything but optimal. Therefore the municipality of Ermelo and ProRail are examining a solution for this problem. Royal HaskoningDHV has been assigned to study possible alternatives for tunnelling the crossings. In this project the iRoom is used to facilitate this progress in close collaboration with the client.

- *Western ring road Alkmaar (WRA)*
  In earlier research it was concluded that the Western Ring Road in Alkmaar will be faced with major congestions in the near future. Royal HaskoningDHV was consulted to develop possible alternatives to this upcoming problem. The iRoom was used to actively involve the project group in a process where possible alternatives for the are developed and examined on feasibility.

5.1.2 Observation framework

In order to examine all observed iRoom sessions in the same manner and make results comparable a framework for observation is developed. Three areas of observation are defined for the iRoom sessions. The framework is presented in the following figure.

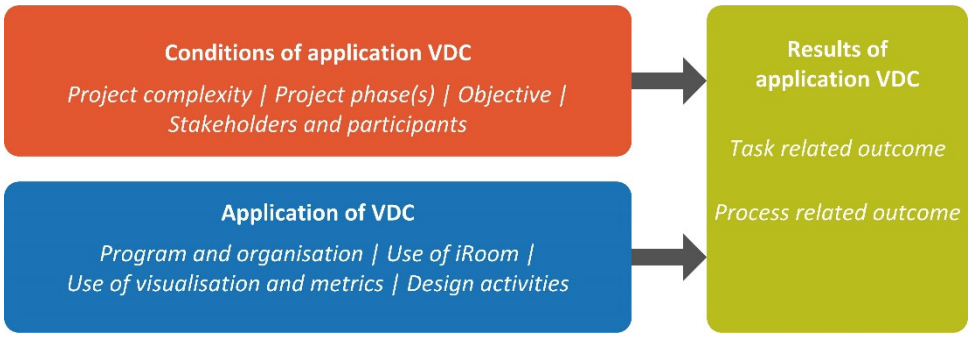


FIGURE 5.1 Observation framework iRoom sessions

It can be stated that both the condition of application and the application itself have influence on the results that derive from the application of the VDC. Therefore these three areas are examined distinctively.

For the conditions of application the complexities of the project and the phase in which the project is located are considered. Also, the objective of each session is stated and the participants of the sessions are listed. Then the application of the VDC is analysed. This includes the program and organisation, use of the iRoom, visualisations and metrics and the design activities of the session. The results derived from the VDC sessions are divided in a task related outcome relative to the design objective and a process related outcome for the project. The complete framework is presented in Annex I.

5.2 Research results

This sections presents the results of the observations to the iRoom session. The complete observation reports of each project can be found in Annex I.

To present observations organized, the results are combined in several tables. The following icons are often used the present whether various aspects were observed or not during the iRoom sessions.

Legend
✓ = Fully observed
~ = Limited observed
× = Not observed

5.2.1 Conditions of application VDC

This section presents the conditions of application of the observed iRoom sessions. It must be mentioned that the selection on criteria and scope of this research affects the outcome of these results. The research covers only projects with public clients, therefore no conclusions can be made on the application of the iRoom consulted by private clients (i.e. contractors).

Project complexity

During the sessions, for each case the complexities are examined that were considered most dominant. These complexities are divided in technical and organisational complexities. The following table shows these complexities per case.

	Technological complexity:	Organisational complexity:
BCM	*Spatial limitations*	*Conflicting stakeholder interest*
SSB	*Spatial limitations, Technical interfaces*	*Conflicting stakeholder interest*
TZB	*Spatial limitations, Traffic implications*	*Conflicting stakeholder interest*
TRE	*Spatial limitations*	*Conflicting stakeholder interest*
WRA	*Spatial limitations, Traffic implications*	*Conflicting stakeholder interest*

TABLE 5.1 Project complexities per case

Characteristic of all the projects observed in the iRoom is the presence of multiple stakeholders with conflicting interest. For example, in the SSB project the organisational complexity was derived from the fact the municipality was the owner of the bridge ramps, the province of the bridge and the region of the rail tracks. These components had all tight interfaces within the project. In all the observed sessions some sort of organisational complexity was identified. This created an urgency to achieve a mutual agreement on the design between these stakeholders. The expectation is that the iRoom can be used to accelerated this process through involving problems owners in the design and providing everyone with the same information.

It was also observed that the iRoom was used in order to deal with different technical complexities. Most notable were the spatial limitations encountered in these projects. The integration of civil engineering projects in the surrounding community was often observed as problematic. By using visualisations in the iRoom the stakeholders were able to examine and develop solutions accordingly.

In the SSB case there were many technical interfaces on the bridge. In the iRoom the stakeholders were able to examine and integrate these visually. The iRoom sessions observed in the TZB and WRA cases involved traffic. The implications of the design had its influence on the traffic system and could be considered complex to understand. The iRoom was used to examine the traffic system in the new situation with the use of visualisations. From this the stakeholders derived an understanding on the effectiveness of the design in regard to the traffic system.

Project phase(s)

The following figure shows the application of the observed sessions in comparison to the phases in which the project is situated.

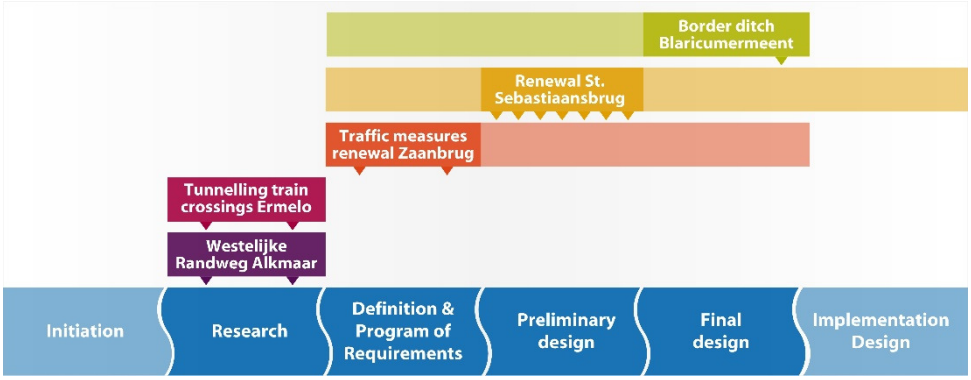


FIGURE 5.2 Project phases and iRoom sessions per case

The observed iRoom sessions ranged from upon the research phase until the final design phase. For example in one project VDC was used in the research phase to examine the feasibility of the project. In another case to conclude on final design considerations in collaboration with the problem owners.

The triangles in the figure show the individual sessions relative to the point of application in the project phase. From this can be derived that in three cases the iRoom was used in the initiation and finalisation of a project phase. At the initiation the iRoom was applied for issue formulation to clarify the interest of different stakeholders and to achieve an agreement on the design principles. In the meantime the project is developed by Royal HaskoningDHV in response to the iRoom session. Near the end of the phase the iRoom is used again for interpretation to validate the design with the stakeholders or make decisions on design alternatives.

In one case the iRoom was applied more frequently during the project. For the renewal of the St. Sebastiaansbrug the iRoom was used for the facilitation of progress meeting together with the problem owners and other main stakeholders. The strength of the iRoom was seen as a possibility to quickly discuss a variety of project documents and drawings in a collaborative manner.

In the Blaricummermeent project the iRoom was applied at the in final stages of the design phase. In this project most engineering was completed but there were some remaining interrelated issues on a detailed level. For this the problem owners were involved in the iRoom to make a definitive decision.

Objective of iRoom session

VDC can be applied in the iRoom for various objectives in a project. Therefore the following table provides an overview of the objectives from the observed sessions:

	Objective of iRoom session
BCM	*Make all choices that are needed to complete the final design.*
SSB	*Discuss the progress and bottlenecks of the project.*
TZB	*Definition of the program of requirements engineering.*
TRE	*Definition of tree alternatives for rail tunnelling rail crossings per location.*
WRA	*Definition of tree alternatives for the western ring road.*

TABLE 5.2 Objectives of iRoom session per case

From the table can be derived that VDC is used for different objectives. In two of the projects VDC was used to define alternatives in the project in collaboration with the problem owners. For this objective, VDC was observed to be very suitable due to the extensive use of visualisations.

In the BCM session VDC was used to conclude on the final design. This objective was also observed as suited for a iRoom sessions. The remaining bottlenecks were shown visually and the problem owners collaboratively developed a solution. With the use of the iRoom a contribution was made to this objective.

In the TRE session, the problem owners were particularly asked to define the requirements for the project. However, it was observed that task was more difficult as requirements were long listed. This made it harder for the iRoom to contribute to this specific objective.

In contrast to the other sessions, one session did not have a very clear objective. This was observed in the SSB project. VDC was used here to discuss the project progress and bottlenecks in collaboration with the problem owners. The expected outcome of the session was not formulated clearly. A majority of the sessions, however, did have a clear and scoped objective. The objective was often discussed with the participants at the start of each session.

Stakeholders and participants

The iRoom sessions that have been observed in this research were all in collaboration with public clients. The following table presents an impression of the type and composition of the participants during the observed sessions.

	BCM	SSB	TZB	TRE	WRA
Organisations					
• Local public (municipalities)	2	-	2	2	3
• Regional public (provinces, hoog-heemraadschap)	1	2	1	-	1
• National public (ProRail, Rijkswaterstaat)	-	-	-	1	-
• Market (architects, contractors)	-	1	1	-	-
Total organisations:	3	3	4	3	4
Participants					
• Participants of stakeholders	*7*	*6*	*12*	*7*	*8*
• Participants of Royal HaskoningDHV	*5*	*3*	*3*	*4*	*3*
Total participants:	12	9	15	11	11

TABLE 5.3 Participants of iRoom session per case

In all observed sessions, three to four organisations participated in the iRoom. In most cases this consisted of a combination of a number of municipalities and a province. The market was not often invited in the iRoom. However, in one case there was an architect consulted to present his design ideas. In another session an engineering firm was invited to explain a previous traffic research.

In each of the sessions there were nine to fifteen participants. With this amount of participants the iRoom was almost observed as full. From most stakeholders organisations two or three persons attended in the iRoom sessions. Often in a combination of a project leader and a more technical orientated expert.

In most sessions there was only a limited amount of absent participants. From this can be suggested that the problem owners give importance to the participation. From Royal HaskoningDHV designers, experts and project managers were also present. These participated in these sessions to explain design choices and examine the feasibility of design.

5.2.2 Application of VDC

This section presents the results of the observations regarding the application of VDC in the iRoom. This was observed by examining the program, use of the iRoom, use of visualisations and metrics and design activities that were performed.

Program of iRoom session

The observed iRoom sessions were all notably different on approach. This is most likely due to a lack of guidance for the application of VDC. For each project iRoom sessions are prepared and designed individually. This made all VDC experiences observed notably different as each individual has its own way of working. It was not observed that there was a clear exchange on methods, steps or facilitation between the different projects. As a result the sessions differentiated on quality. The programs of each of the sessions was also hardly comparable. The programs of the observed iRoom session can be found in Annex II.

Remarkable of some of the sessions was that participant quickly were invited to discuss many technical in-depth issues and develop solutions accordingly. This without first obtaining a shared understanding on the needs, principles and the design on a system level. For example in two cases, BCM and SSB, the discussion was almost immediately on in-depth technical project bottlenecks. The question remains whether the participants really needed this in-depth information. Other sessions, TRE and WRA, were more structured and logical design steps were taken.

	BCM	SSB	TZB	TRE	WRA
Program					
• Duration	*. +/- 4 hours*	*+/- 4 hours*	*+/- 4 hours*	*+/- 5 hours*	*+/- 4 hours*

TABLE 5.4 Program of iRoom session per case

The duration of each of the observed iRoom sessions took between four and five hours. This made that all session lasted a half day, often planned in the morning or afternoon. In two cases stakeholders mentioned at the end the sessions lasted long. It was observed important that the momentum remained during the iRoom session. In some cases this was observed problematic as presentations lasted long. This resulted in that participants became less involved as attention declined. Also breaks were often long delayed and were observed necessary earlier.

Organisation of iRoom session

The way in which the iRoom sessions were organized by Royal HaskoningDHV is shown in the following table.

	BCM	SSB	TZB	TRE	WRA
Organisation					
• Session moderator	*Facilitator*	*Experts / Client*	*Project leader / Experts*	*Project leader / Facilitator*	*Project leader*
• Facilitator	✓	×	×	✓	×
• iRoom Controller	✓	✓	✓	✓	✓
• Experts	✓	✓	✓	✓	✓

TABLE 5.5 Organisation of iRoom session case

For the organisation of the iRoom sessions by Royal HaskoningDHV some variations were observed. Most considerable difference was on the discussion leader or moderator of the session. In the BCM case an independent facilitator was given this role. He was unfamiliar with the project and had the lead during the complete iRoom session. This particular facilitator was experienced with the use of the VDC and the iRoom. However, his unfamiliarity to the project gave him a neutral position. This was observed as positive as he was unprejudiced towards stakeholders and vice versa. In the WRA case the project leader of was the session moderator. This had the benefit that he was well informed on the project. A combination of these approaches was seen in de TRE session. In this case the project leader was given the role for moderation on the substance and the facilitator on the process. In the SSB case the client had the lead in the discussion.

In all cases there was a controller present who was managed the use of the Smartboards. This was often a project engineer who was familiar with the designs and operating the applied software. Additionally, there experts present in the iRoom. These experts had knowledge on the design details of the project. Also they were able to examine feasibility of suggestions by experience. Their role was often combined with the role of the controller.

Use of iRoom

The iRoom is an important component of VDC. It was observed that the iRoom was applied differently in each session. Therefore this section discusses the use of the iRoom.

Use of Smartboards

The Smartboards often were used to provide an understanding on the problem to the participants. For example the left screen was used to visualise the surrounding, the middle screen for sketches and the third screen to present some technical drawings. This showed the clear added value of using the iRoom as stakeholders were able to receive an complete and concise picture of the project. In general the Smartboards present the following during the observed iRoom session.

	Left Smartboard	Middle Smartboard	Right Smartboard
BCM	*Aerial photos, reference work, street level photos*	*Presentation, working document, drawings.*	*CAD-drawings, Planning*
SSB	*Presentation*	*CAD-drawings*	*Aerial photos*
TZB	*Aerial photos, Street level photos*	*Simulations, Presentation*	*Documents (Program of Requirement)*
TRE	*3D Models, Aerial photos*	*Aerial photos, Multi Criteria Decision Analysis*	*Presentation, Whiteboard*
WRA	*3D Models, Aerial photos*	*Simulations*	*Presentation, Multi Criteria Decision Analysis*

TABLE 5.6 Smartboard content per case

It was observations that the use of Smartboards can be distinguished into two different approaches. In the first approach the participants are invited to come in front of the Smartboards and sketch their ideas using whiteboard functionalities. This approach is observed as participant-driven. In the second method the facilitator is the only user of the Smartboards and translates the ideas from the participants with sketches on the Smartboards. This approach was observed as facilitator-driven.

	BCM	SSB	TZB	TRE	WRA
Smartboards					
• Input	*Facilitator-driven*	*Participant-driven*	*Facilitator-driven*	*Participant-driven*	*Participant-driven*
• Interactive use	✓	~	~	✓	✓

TABLE 5.7 Smartboard use per case

The facilitator-driven approach suggested to be the most efficient. This as it was observed that participants were often not familiar with the use of the Smartboards and this brought the momentum out of the session. However, in this approach the facilitator does mediate in the suggestions of the participants. This makes the role of the facilitator in this approach more imported.

Seating configuration

In the all sessions the tables were configured differently. It was observed that not much thought was taken in advance on this configuration. Also problem owners were in none of the sessions allocated to a seat. During the observed sessions the tables were configured in a number of rows, U-shape or a single row, as can be seen in the following table.

	BCM	SSB	TZB	TRE	WRA
Configuration					
• Seating	 *V-shape*	 *U-shape*	 *Two rows of three tables*	 *U-shape*	*Side-by-side*
• Suitability discussion	✓	✓	×	✓	~
• Suitability inter-action Smartboards	~	×	✓	×	×

TABLE 5.8 Seating configurations in iRoom per case

In most cases the seating was observed as decent. However, when the tables were positioned next to each other participants were not able to easily walk in front of the Smartboards. This was seen as a hindrance for interaction with the Smartboards. Two other configuration, TZB and WRA, had the problem that the stakeholders could not see each other directly. This does not ease the discussion as stakeholders have to turn around completely to have a discussion with each other.

Visualisations and metrics

Visualisations and metrics are two important components of VDC. During the sessions it was observed how metrics and visualisations were used to present and measure product, organisation and process.

VDC characteristics

VDC models are stated to consists of several characterises. The following table shows if the models meet to the characteristics of VDC.

	BCM	SSB	TZB	TRE	WRA
VDC characteristics					
• Virtual models	✓	✓	✓	✓	✓
• Integrated models	×	×	×	✓	×
• Multidisciplinary	✓	✓	✓	✓	✓
• Performance based	×	×	~	~	✓

TABLE 5.9 VDC characteristics per case

The level of integration between the models in general was limited. However, in one of the cases a VDC model was made that was integrated. In this session participants could sketch their ideas for a new train tunnel on the Smartboards. In advance an adaptable 3d model was prepared for the session. By quickly changing the parameters the designer could instantly create a 3D representation of the sketched alternatives. With this 3D model stakeholders were able to examine their own developed alternative from different perspectives.

Some of the sessions were not observed as performance based. In other words, no models were used to measure or predict the performance of the project. In the WRA project traffic implications were visualised and measured with the use of simulations. In these session the problem owners were able to examine the alternatives on the performance relative to the requirements that were chosen in advance.

POP-visualisations

In VDC visualisations are used in the iRoom to examine the project on product organisation and process. These visualisations strive to enhance the perception of the involved participants. The following table shows what type POP visualisations were observed during each of the sessions.

	BCM	SSB	TZB	TRE	WRA
POP-visualisations					
• Product	✓	✓	✓	✓	✓
• Organisation	×	×	×	×	×
• Process	✓	×	~	×	×

TABLE 5.10 Use of POP-visualisations per case

Product visualisation were used in all of the observed sessions. Visualisation were often used to help in the formulation of the issue with the help of 3D models, street level and aerial photos. For example in the WRA and TZB projects the use of simulations helped the problem owners in obtaining a perception of the problem. These visualisations illustrated were major traffic issues would appear in a new situation. In other projects often with the help of visualisations possible solution were generated and evaluated. This gave the participants an overall view of the problems that had to be tackled. In the TRE project a dynamic 3D visualisation was used that participants could adjust during the session to quickly examine various possible alternatives.

Organisational visualisations were not observed during either of the iRoom session. Possibly it was not considered as important or already known. However, in the SSB session it was observed that the stakeholders had considerable conflicting interests. This did have an influence in the development of the solution as stakeholders did not agree on basic principles. From this could be argued that it could have been relevant to first map out the organisation and interests using visualisations.

During the iRoom session process visualisations were also not used by default. However, in the BCM case the planning was discussed at the end of the session. Additional tasks that resulted from the iRoom session were written down in a working document on a Smartboard. At the end of the session all these tasks were collected from the working document and were compared to the product planning. The project planning was a visualisation using MS Project.

POP-metrics

The VDC method describes to measure performance on product, organisation and process using metrics. The following table presents the use of POP metrics in the observed iRoom sessions.

	BCM	SSB	TZB	TRE	WRA
POP-metrics					
• Product	×	×	~	~	✓
• Organisation	×	×	×	×	×
• Process	×	×	×	×	×

TABLE 5.11 Use of POP-metrics per case

In most of the sessions the use of metrics was not or only limited observed. Metrics aim to provide a contribution to the decision making as the understanding of product, organisation and process is enlarged.

During the sessions decisions were often made on the basis of consensus between stakeholder with the help of visualisations. Aspects such as costs, risks and planning were only included on a conceptual level in most of the decision making. However, these aspects were often considered in collaboration with the designers which could made rough estimates. For some stakeholders this approach was not sufficient as they did ask to work out these decisions in terms of cost and planning subsequently to the iRoom sessions. This argues that there is a request on using these kind of metrics. Only in the sessions, WRA, product metrics were observed and were limited in the TZB and TRE sessions.

VDC maturity level

For the implementation of VDC different maturity levels are defined in the literature. Level one is the use of metrics and visualisations, level two the integration of metrics and visualisations and level three is reached when there is automation in design tasks. According to these levels the sessions were observed. The results are presented in the following table.

	BCM	SSB	TZB	TRE	WRA
VDC maturity					
• Level	*1*	*1*	*1*	*1*	*1*

TABLE 5.12 VDC maturity level per case

During all the session visualisations and metrics were used individually. Integration of models and metrics was not observed in either of the session. From this was concluded that all observed iRoom sessions could be defined as level one VDC sessions.

Design activities

In the problem exploration of this research it was stated that the VDC method can possibly benefit from the structure of SE. In the previous chapter is was showed that a logic structure for design phases are the seven steps of Systems Engineering. The sessions were analysed to examine if and how these steps were taken in the iRoom.

	BCM	SSB	TZB	TRE	WRA
Logical steps of SE					
• Problem Definition	✓	~	✓	~ *(1st session)*	✓ *(1st session)*
• Value System Design	~	×	×	~ *(1st session)*	✓ *(1st session)*
• Synthesis of Alternatives	✓	~	~	✓ *(1st session)*	✓ *(1st session)*
• System Modelling and Analysis	×	×	×	~ *(Between)*	✓ *(Between)*
• Refinement of Alternatives	×	×	×	× *(2nd iRoom)*	✓ *(2nd iRoom)*
• Decision Making	✓	×	×	✓ *(2nd iRoom)*	✓ *(2nd iRoom)*
• Planning for action	✓	×	×	~ *(2nd iRoom)*	✓ *(2nd iRoom)*

TABLE 5.13 Use of SE steps per case

As can be shown in the table only one session, WRA, was able to perform all seven logical systems engineering steps. In this project iRoom was used in a first session to define the problem and formulate the objectives and measures for the to be developed solution. Then some possible alternatives were generated during this session. In the meantime between the

two sessions these alternatives were modelled and analysed by Royal HaskoningDHV. In the second session the results of the analysis were presented. In the following step the alternatives were refined on the basis of analysis in collaboration with the stakeholders. As a final step the alternatives were ranked on the basis of performance and three alternatives were chosen for further study. A similar approach was seen in the TRE session.

Other sessions did not cover these steps very clearly. In the steps of issue formulation the problem was often well defined and introduced. However, the objectives and constraints where not often well considered during these sessions. These sessions then continued in presenting the project bottlenecks and generating solutions accordingly. The steps value systems design and system modelling and analysis were in these session not covered extensively.

5.2.3 Results of application VDC

This section describes the result of the application of the VDC as was analysed by the iRoom observations. It must be considered that these result were stated from the perspective of the observant and can be seen as subjective.

The result of the session are distinguished in a tasks related outcome relative to the design objective and a process related outcome to the project.

Task related outcome

For the task related outcome observations were made on whether the objective of the sessions was achieved and if any new solutions for the design task were developed. The following table present these results.

	BCM	SSB	TZB	TRE	WRA
Task related outcome					
• Objective achieved	✓	~	~	✓	✓
• New solutions	~	×	~	✓	✓

TABLE 5.14 Task related outcome per case

It was observed in all the sessions that the objective was more or less achieved. None of the sessions were completely useless relative to the design task. In two of the sessions, TRE and WRA, it was seen that the iRoom clearly contributed to the development of new solutions for the project. In the SSB case the task related outcome was observed lowest. However, the session defined various bottlenecks that after the session were followed up.

Process related outcome

Beside that the iRoom contributes to the development of the technical solutions there are other more process related outcomes. These outcomes can enhance the decision making in the projects and the relation between stakeholders. The following table presents observation results on the process related outcome of the sessions.

	BCM	SSB	TZB	TRE	WRA
Social outcome					
• Involvement	✓	~	~	✓	✓
• Perception	✓	✓	✓	✓	✓
• Shared understanding	✓	×	~	✓	✓
• Consensus	✓	×	~	✓	✓

TABLE 5.15 Social outcome iRoom per case

It was evident that participants were enthusiastic on the application of VDC in these projects. This as it was observed that most participants were actively involved in the discussion. In two cases the involvement was observed as limited. In the SSB case the session mostly consisted of a long presentation and little possibility was available for discussion and design activities. During the session the involvement of participants inclined. In the TZB case stakeholders were actively involved in the first part of the session. In this part the result of a traffic research was presented using visualisations. This resulted in much debate between the stakeholders. In the second part of the session the participants were much less involved. This part was about the requirements for a new temporary bridge. As this activity was harder to visualise it was observed the stakeholders were less involved in the discussion.

The iRoom was observed to contribute in all observed sessions to the perception of the problem owners. The use of visualisations clearly contributed in most cases in an understanding of the problems and proposed solutions. For example in the TRE case there was debate on the social safety of different proposed alternatives. By using 3D models stakeholders were able to walk virtually through the tunnels and examine the safety level. From this they could examine various alternative in a very conceptual stage.

In three session the iRoom contributed to a shared understanding and consensus in the design task. In the SSB case, however, the iRoom session resulted in more debate on the project as many questions were left unanswered. This made that a shared understanding or consensus between the problems owners was not achieved. In the TZB case it was unsure if the application of VDC resulted in a shared understanding. This as the design space was very limited and stakeholder did not agree on the traffic research.

5.3 Conclusion on observation results

This chapter presents the results of observations on the application of VDC that were performed in five different iRoom sessions. It can be concluded that the application of VDC differs considerably at Royal HaskoningDHV between projects. As a result the quality and experience of each iRoom session varies. This conclusion could have been expected as there are no clear guidelines for the application of VDC and the only recent introduction of the method at Royal HaskoningDHV.

VDC and the iRoom are used for various objectives in civil engineering projects. For the conceptualization and examination of design alternatives in collaboration with the problem owner the iRoom was observed as most useful. In particular, by using visualisations for integration issues the iRoom was observed to provide an added value.

Within the application of VDC, the use of metrics and visualisations for organisation and process remains limited. However, visualisations were often used for the product by presenting 3D models, simulations, aerial and street level photos. These provided a clear contribution to the design task. When considering the design activities not always logical steps were taken as the steps value systems design and system modelling and analysis were not always performed.

In general all session managed to provide an contribution relative to the objective of the project. The iRoom resulted most in an enlarged perception at problem owners. In addition, it contributed to the involvement and shared understanding.

Chapter 6

Interviews: iRoom experiences and expectations of problem owners

The previous chapter presented the observations of five iRoom sessions in various civil engineering projects at Royal HaskoningDHV. After these observations the participants of the iRoom sessions were interviewed on their expectations and experiences. This chapter will present the results of these interviews and provides an answer to the following research question:

RQ3: *What are the experiences and expectations of problem owners on the application of VDC in the iRoom?*

This chapter starts with an explanation of the research method *(Section 6.1)*. This contains an introduction of the interviewees and questionnaire. In the following section the interview results are presented *(Section 6.2)*. The interviewees were questioned on their expectations, experiences and recommendations to the iRoom sessions. In the final section a conclusion is made for the research question *(Section 6.3)*.

6.1 Research method

The experiences and expectations of the iRoom at Royal HaskoningDHV have been research through a series of interviews with the problem owners of the observed iRoom sessions. This has not only the purpose to make conclusions on the observed iRoom sessions but also for the application of VDC in general. From this analysis the effectiveness and usefulness of VDC could be examined from the perspectives of the participants. On the basis of these interview results possible recommendations for further improvement of the application of VDC could be derived.

There is chosen to make use of qualitative interviews, preferably face-to-face with the problem owners. Alternative method could be to make use of quantitative surveys. This method may have been less time consuming and easier to execute. However, interviews were considered more useful to determine the expectations and experiences of participants from their perspectives. This can be difficult to obtain using quantitative surveys. With the use of open questions it is more convenient to acquire the opinion and experience of the participants. In addition, the interviewer can question on at the subjects in which the interviewee is more restrained or obscure.

A questionnaire was prepared for the interviews in advance. Once the interviews were conducted an report was made. These reports were verified by the interviewees in order to avoid misinterpretation. The research questionnaire can be found in Annex III and interview reports can be found in Annex IV.

6.1.1 Introduction of interviewees

A total of nine interviews were executed for this research from four of the five observed iRoom session. This means that from one of the cases none of the participant were interviewed. In this case the participants were unavailable for interview.

The selection of interviewees from the iRoom sessions have been made according to relevance and availability of the participants. It was attempted to interview the main client in each project. Additionally, important problem owners have been interviewed to complete the picture.

The interviewees were selected and approached in accordance with the corresponding project leaders of Royal HaskoningDHV. The following problem owners were interviewed from the observed cases:

	Organisation	Function
BCM	*Municipality of Blaricum*	*Project manager Blaricummermeent*
	Municipality of Huizen	*Head of department Public Roads*
SSB	*Province Zuid-Holland*	*Project manager St. Sebastiaansbrug*
	Region Haaglanden	*Project manager Tramline 19*
	Municipality of Delft	*Project coordinator St. Sebastiaansbrug*
TZB	*Province Noord - Holland*	*Project manager traffic measures Zaanbrug*
	Municipality of Wormerveer	*Project manager Zaanbrug*
TRE	*ProRail*	*Project manager*
	Municipality of Ermelo	*Project manager*

TABLE 6.1 Interviewees

6.1.2 Research questionnaire

The questionnaire is used to acquire data of the iRoom sessions from perspective of the problem owners. The questionnaire starts with an introduction to obtain an understanding of the role and position of the interviewees in the concerned projects. Then, the interview focusses on to the application of the iRoom. First, the expectations are questioned followed by the experiences. The questionnaire concludes on recommendations of the interviewees. The following questionnaire was prepared:

- *Introduction*
  - What is the scope of this project?
  - What is your role and responsibility in this project?
  - What are the main stakeholders in this project?
- *Expectation of application iRoom*
  - What was the motivation to apply the iRoom in this project?
  - What was the objective to apply the iRoom in this project?
  - What were the expectations on the application of the iRoom?
- *Experiences of application iRoom*
  - How did you experience the iRoom session in this project?
  - What task related added value did you experience using the iRoom?
  - What process related added value did you experience using the iRoom?
  - How did you experience the organisation and facilities of the iRoom session?
  - How did you experience the design approach in the iRoom?
- *Recommendations of application iRoom*
  - What conditions are in your opinion suitable for an iRoom session?
  - What are the factors of success for using the iRoom?
  - What role is suited for Systems Engineering in the iRoom?
  - Are there any other recommendations on the iRoom?

6.2 Interview results

This sections presents the results of the interviews that were taken from the participants of the observed iRoom sessions. The complete reports of these interviews are presented in Annex IV.

Legend
✓ = Fully experienced
~ = Limited experienced
× = Not experienced
+ = Positive experienced
± = Neutral experienced
− = Negative experienced

In order to display the results of the interviews summarized they have been in several tables. In these tables the icons from the legend above are used to present the experience of the interviewees on the questioned subjects.

6.2.1 Expectations of application iRoom

Problem owners can apply VDC for several reasons. Probably most have some expectations on the method. This section presents the interview results on the motivation, objective and expectations to apply the iRoom according the problem owners.

Motivation

Most projects are faced with some events prior to the iRoom session. These occurring's can result in an motivation to apply the iRoom into a project. The following table presents why the iRoom was used according to the problem owners.

		Motivation of iRoom session:
BCM	*Municipality of Blaricum*	*We had a spatial design problem around the border ditch. At official level we had a mutual need to achieve agreement on this problem. Politically, there is great tension around this ditch. Therefore we decided to collaboratively solve this problem in the iRoom.*
	Municipality of Huizen	*A number of design meetings proved that it was difficult to get agreement on some related design elements. That was the reason to conduct a design session, with all parties and a collaboration design on the spot.*
SSB	*Province Zuid-Holland*	*RHDHV suggested to apply the iRoom in this project to involve important stakeholders more closely in the project. Together with the municipality of Delft and region Haaglanden we must design a supported solution for the St. Sebastiaansbrug. The iRoom is used to facilitate this process.*
	Region Haaglanden	*I was invited into the iRoom by RHDHV and the province of Zuid-Holland to reach agreement on the preliminary design for the St. Sebastiaansbrug.*
	Municipality of Delft	*We were invited by RHDHV in the iRoom to discuss the principles for the preliminary design. We had a wide range of requirements established for the St. Sebastiaansbrug. It was necessary to get an agreement between the parties on this.*
TZB	*Province Noord - Holland*	*The idea the use the iRoom in this project came from RHDHV. Between the involved stakeholders, there is much debate about the location of the new bridge. In the iRoom we can jointly solve this problem.*
	Municipality of Wormerveer	*Prior to the iRoom session the impact on the traffic has been researched. The reason to use the iRoom was to closer involve the main stakeholders and to collaboratively discuss issues and develop possible solutions.*
TRE	*ProRail*	*RHDHV indicated that they would like to apply the iRoom in one of our projects. This project seemed suited for treatment in the iRoom. Particular, because three different locations need to be analyzed. In the design various issues such as the housing and traffic flows must be considered. With the iRoom we are able to involve the municipality in this process.*
	Municipality of Ermelo	*Applying the iRoom was proposed by ProRail and RHDHV. This was positively received by us.*

TABLE 6.2 Motivation of iRoom session per interviewee

The table shows that the motivation to apply the iRoom has various reasons. Main motivation seen is that an agreement on the design is often needed between the stakeholders. In some cases interviewees argue that the design task is surrounded by political

sensitive tensions. For example, in the BCM case the project was in a deadlock and earlier meetings proved to be difficult. The motivation to use the iRoom was to move this project over this deadlock.

Second motivation to apply the iRoom is the need to collaboratively examine and develop possible solutions to the design task. Closely related design elements or spatial design problems are considered difficult to examine in normal meetings. Therefore the iRoom is consulted to research and develop solutions for these type of problems in a collaborative and visual method.

Objective

The iRoom was applied in most cases with a certain objective and an expected outcome to the project. The following table presents these objectives of the iRoom session according to the problem owners.

		Objective of iRoom session:
BCM	*Municipality of Blaricum*	*To collaboratively establish a supported design for the redevelopment of the boundary ditch, this then can be presented back to the various policy makers for further decision.*
	Municipality of Huizen	*The aim of this session is to bring parties together and to show direct results. The outcome is a joint design accepted.*
SSB	*Province Zuid-Holland*	*The iRoom is used in this project for the progress meetings. For this objective the iRoom may not necessarily. However, the iRoom can be seen as a nice space to facilitate these meetings as drawings and other project document scan be retrieved and presented easily.*
	Region Haaglanden	*I was involved when the iRoom was used when creating the preliminary design. The objective was to come on an agreement on the design principles and requirements.*
	Municipality of Delft	*Objective of the meeting was to make suggestions for the primarily design. For this RHDHV featured some bottlenecks in the design that were discussed.*
TZB	*Province Noord - Holland*	*The iRoom session was used clarify the requirements and demands of stakeholders. In addition the potential traffic measures were discussed in response to the traffic simulations. Also, we wanted to define the requirements for functional procurement of the temporary bridge.*
	Municipality of Wormerveer	*The objective of the session was to get a good estimation on the bottlenecks in this project and to develop possible solutions accordingly. This concerns to visualise the impact of closing the Zaanbrug for traffic. Without the iRoom this will be more difficult to estimate.*
TRE	*ProRail*	*Through the use of the iRoom we can consider the importance of the tunneling. By utilizing the iRoom the municipality can decide for a continuation of this project.*
	Municipality of Ermelo	*The iRoom is used for the purpose in a very fast and clear manner the implications of the suggestions for this project visible.*

TABLE 6.3 Objective of iRoom session per interviewee

From these results can be derived that the iRoom is used for various objectives according to the problem owners. In a majority of cases the objective of the session was to achieve a jointly supported agreement on the design task. This is expected to be achieved by involving multiple stakeholders in the iRoom and present immediate results of possible alternatives.

From this also can be concluded that according the problem owners the iRoom can be used in different abstraction levels and project phases. For example the iRoom is stated to be used to find an requirements, preliminarily, and detailed designs.

In addition, some interviewees mentioned the iRoom session had the objective to examine the projects. For example on effectiveness, cost, feasibility, risks or possible alternatives. The results are often used to help policy makers in the further decision making. As problem owners are present in the in the iRoom and involved in the design makes it more easy to clarify certain design consideration to their officials.

Expectation

Prior to the iRoom sessions each participant would have created its own expectations on the facilitation, method and/or the results. The problem owners have been questioned to their expectations they had prior to the sessions. The following table presents these results.

		Expectations iRoom session:
BCM	*Municipality of Blaricum*	*To solve with the aid of the available techniques of the iRoom in a "pressure cooker environment" the spatial bottlenecks regarding the design effectively.*
	Municipality of Huizen	*I expected the iRoom would contribute to an interactive session were all employees have an eye on each other and focus on a common accepted design.*
SSB	*Province Zuid-Holland*	*Expectation was that the iRoom will easier the perception. I also had the idea that information could easily be exchanged in the iRoom.*
	Region Haaglanden	*Collaboration is very important, individually it is impossible to complete the design task. Due to the help of the visual aids I was very excited about this concept in advanced.*
	Municipality of Delft	*I was unfamiliar with the iRoom and did not know exactly what it was. I expected an interactive environment with the added value of live designing and show instant results. That could have accelerated the decision making process.*
TZB	*Province Noord - Holland*	*In the iRoom I expect that with good interaction you can get view on the bottlenecks of the project. Then I expected that with an interactive design process you can achieve a supported design solution. This means that an iRoom session requires a good collaboration.*
	Municipality of Wormerveer	*I had the expectation that the iRoom would contribute to broadly achieve insight into what exactly we are going to make. The techniques used with the video screens was as I expected. This is needed to analyse traffic and it worked very instructive.*
TRE	*ProRail*	*Previously I attended a demonstration session. I was not directly excited because the applications did not yet matched the expectations. However, I get the impression that the approach has been developed. The expectation was that RHDHV could take both ProRail and the municipality in the design process and be able quickly and visualize different design alternatives.*
	Municipality of Ermelo	*With the deployment of the iRoom, we expect a reduction of the project duration. In addition, we also have the expectation that non-technically can be well included in the design process.*

TABLE 6.4 Expectations of iRoom session per interviewee

The results show that all interviewees had positive expectations prior to the iRoom sessions. Some even stated that they were very excited in advance. Most expected an interactive sessions that will contribute to the perception, information exchange and/or decisions making. The available techniques in the iRoom are needed to help to achieve these results. One of the interviewees stated he saw the iRoom as an “pressure cooker environment”, meaning that the iRoom can accelerate the project.

Additional, a couple of interviewees respond that there is a major expectation and role to the collaboration. Interviewees said that collaboration is considered essential in civil engineering projects. Using the iRoom individually will not provide an added value to the project. In addition, the response was made that commitment and mandate from the participants is a requirement for successful iRoom sessions.

Others indicated that they had the expectation that it would be possible to design real-time in the iRoom. In other words, the problem owners would have liked to see the possibility to adjust designs immediately with the use of the Smartboards and present direct results. Only in the TRE session it was possible to design real-time with the help of 3D visualisations. In the other sessions the possibilities were often constrained by technical limitations of simulation or visualisation software.

6.2.2 Experiences of application iRoom

This section presents how the problem owners of the observed cases experienced the iRoom sessions. They have been questioned on the experiences on added value, organisation, facilities and the design approach.

General experience

The interviewees were at first confronted with an open question about their general experience of the iRoom. The following table presents the results of this question.

		General experience iRoom session:
BCM	*Municipality of Blaricum*	*The iRoom is very suitable to work in a constructive setting on a spatial (3D) bottleneck between different stakeholders. The iRoom has served its purpose. At the official level we achieved a consensus.*
	Municipality of Huizen	*Good, this was a significant step in the design process and has contributed to help us over a dead lock.*
SSB	*Province Zuid-Holland*	*I see iRoom as a convenient instrument. Major advantage of its use is the allowance of sharing easily digital project information. Perception I see as the greatest added value.*
	Region Haaglanden	*Royal HaskoningDHV could have more prepared this session. There should have been thought on what people to invite and what to achieve during this session. As a result participants were unprepared and both the province and municipality had different intensions.*
	Municipality of Delft	*The composition of participants was incorrect. There were several design choices to make. We couldn´t make this cause of the political difficulty. The three Smartboards allowed us to visualise discussion points. That was nice, despite the start-up problems.*
TZB	*Province Noord - Holland*	*This setting could also have taken place with a simple beamer setting. This could have provided the same result. Good thing is that you are somewhere else out of your "comfort zone". I wonder if this session was really successful and if we achieve the result we had in mind.*
	Municipality of Wormerveer	*As a presentation format I experienced the iRoom as very positive. It's a proper way to get insight in to the project. This is something else then a discussion with traditional drawings. The project bottlenecks were different than expected on paper. Difficulty was the large size of the group.*
TRE	*ProRail*	*I found the use of the iRoom positive. It's different when you have three large screens at your disposal where you actively design on. I also experienced that using this approach allows to actively involve stakeholders in the design process and the end result. This I see as the greatest strength.*
	Municipality of Ermelo	*The iRoom satisfied well to my expectations prior to the sessions*

TABLE 6.5 General experience iRoom session per interviewee

The general experience of the problem owners differs per project. The experiences range from very positive to the level that participants had higher expectations from the session.

In the BCM project the experience was very successful according to the two interviewed problem owners. One stated the iRoom as suitable and a constructive settings. The other problem owner stated the iRoom was a significant step and helped to get over a deadlock.

The interviewees from the SSB project were more critical on their experiences. They all saw the iRoom as an convenient instrument. However, there was an lack of preparation to the session. By this the objective was unclear and the composition of participants was incorrect. Despite this, the iRoom gave some contribution their perception to the project.

In the TZB project both stakeholder indicated a different experience. This as both had different interest during the iRoom session. For the municipality main concerns were on the expected traffic congestion. The province had more interest in making progress on the requirements for the temporary bridge. Because the focus of the iRoom session was mostly on the traffic simulations a more positive experience was given to the municipality. However,

it was indicated that the size of the group was probably too large. The province stated that the session also could have taken place with an simple beamer and more progress was expected.

The iRoom was also considered positive in the TRE session and satisfied to the expectations. the use of Smartboards made the problem owners actively involved in the design process and the end result.

Overall was experienced that the iRoom has great potential. However, these expectations are not always achieved. The following sections will present experiences more in-depth.

Task related added value

The problem owners were questioned on the added value of the iRoom session relative to the design task. To provide an answer to this the problem owners were first questioned on whether the objective for the iRoom was achieved. Then they were asked if the application of the iRoom has led to any new insights and/or solutions for the project. Finally they were asked on if the productivity in achieving the design task was accelerated. The following table presents the results.

	BCM		SSB			TZB		TRE	
	Municipality of Blaricum	*Municipality of Huizen*	*Province Zuid-Holland*	*Region Haaglanden*	*Municipality of Delft*	*Province Noord-Holland*	*Municipality of Wormerveer*	*ProRail*	*Municipality of Ermelo*
Task related outcome									
• Objective achieved	✓	✓	~	×	×	~	✓	✓	✓
• New insights	✓	✓	✓	×	×	✓	✓	✓	✓
• New solutions	✓	×	×	×	×	×	✓	✓	✓
• Productivity	✓	✓	~	~	×	~	✓	✓	✓

TABLE 6.6 Task related outcome of iRoom session per interviewee

In two of the three projects the objective of the iRoom sessions was more or less achieved according to the interviewed owners problem owners. This was the case in the BCM en TZB sessions. In the SSB case the interviewees stated that the objective was not achieved. Mostly because the problem owners stated that a more explicit objective was needed for the iRoom session. For this project the iRoom was used to facilitate the regular meetings.

Furthermore, it can be expected that the application of the iRoom could results in new insights and solutions to the project. Most of the problem owners responded that the application of the iRoom resulted in new insight to the design task. However, the application has not always resulted directly into new solutions. Some problem owners said that new gained knowledge were not developed immediately into new solutions. This was often experienced as a missed opportunity. For two of the problem owners the iRoom also did not result new insights. This as they argued that a normal presentation would also have delivered the same insights in the projects. One of the problem owners indicated the iRoom did not result in new solution but rather helped in developing a supported solution.

Finally the interviewees were questioned on whether the use of the iRoom enhanced the productivity during the iRoom session. According to most interviewees this was more or less the case. This as all stakeholders were involved in the iRoom and the project was be discussed integral and more efficient. In one of the projects, the communication was previously mostly written. This was considered less efficient and gave an inferior picture compared to what was achieved in the iRoom. In the SSB sessions two of the problem owners stated that the would have want to see more progress from the iRoom sessions.

Process related added value

Besides the task related added value the iRoom could also provide a more process related added value to the problem owners. To examine this the problem owners were questioned of whether the application of the iRoom enhanced their involvement into the project or contribute to their perceptions. Also the application if the application of the iRoom contributed to a shared understanding or consensus among the involved stakeholders. The following table shows the social added value experienced by the interviewees.

	BCM		SSB			TZB		TRE	
	Municipality of Blaricum	*Municipality of Huizen*	*Province Zuid-Holland*	*Region Haaglanden*	*Municipality of Delft*	*Province Noord-Holland*	*Municipality of Wormerveer*	*ProRail*	*Municipality of Ermelo*
Process related outcome									
• Involvement	✓	✓	×	~	~	✓	✓	✓	~
• Perception	✓	✓	✓	~	~	✓	✓	✓	✓
• Shared understanding	✓	✓	~	×	×	✓	✓	✓	✓
• Consensus	✓	✓	~	×	×	~	~	✓	✓

TABLE 6.7 Process related outcome of iRoom session per interviewee

This table shows that a social added value is experienced in most cases on several aspects. In the SSB project, however, the social added value remained limited.

Most notable is the added value to the perception of the problem owners. One of the problem owners stated that "spatial bottlenecks often are hard to visualize, but with the use of the iRoom these bottlenecks were made clear". The iRoom is seen as an instrument that contributes to the perception. Apparently visualisations are considered an important feature of the iRoom. Two of the interviewees mentioned that the iRoom could have contributed to their perception, but was not fully utilized towards the capabilities.

In addition, the results show that the iRoom contributes to the involvement of the problem owners. The interviewees point that participating in the iRoom is fun and makes the stakeholders more enthusiastic. Also makes participating in the iRoom the involvement mandatory and more direct. One of the interviewees mentioned this as one of the important strengths of the iRoom. Yet the SSB project shows that not always an added value is experienced by the problem owners on their involvement. However, they mention that the iRoom can be used to enhance the involvement of other stakeholders.

Finally, it can be expected that the iRoom contributes to a shared understanding and consensus among the participants. Both these aspects were experienced by a majority of the interviewees. It shows that everyone can easily exchange his thoughts and ideas by presenting these with the use of the Smartboards. The iRoom is therefore seen as a good instrument to exchange information. In the SSB project the use of the iRoom resulted in misunderstandings. The presented information was found difficult to interpret by the interviewees. In the majority of cases, the iRoom also led to a consensus. In the BCM case the interviewees mentioned that due to the application of the iRoom an consensus was finally achieved, and was far more efficient than previous meetings. In the SSB project was mentioned that the same result could have been achieved in another meeting. This was mostly accused on the preparation of the session and the position of the stakeholders. The problem owners from the TZB session mentioned that the session was exploratory of nature. However, it was stated that they would have like to see the session to have taken this extra step.

Organisation and facilities

The participants were questioned on their experiences on the organisation and facilities of the iRoom session. Hereby was considered how the stakeholders have experienced the facilitation, the used tools and the configuration. The results are shown in the following table.

	BCM		SSB			TZB		TRE	
	Municipality of Blaricum	*Municipality of Huizen*	*Province Zuid-Holland*	*Region Haaglanden*	*Municipality of Delft*	*Province Noord-Holland*	*Municipality of Wormerveer*	*ProRail*	*Municipality of Ermelo*
Organisation and facilities									
• Facilitation	+	+	±	–	±	+	+	+	+
• Tools	+	+	±	±	±	+	+	+	+
• Configuration	+	+	+	+	+	–	–	+	+

TABLE 6.8 Experience organisation and facilities of iRoom session per interviewee

In two of the project the problems owners have a positive experience on the facilitation. In the BCM session there was explicitly chosen for an independent facilitator who had no connection with the project. This was a seen as positive because he was unprejudiced and neutral towards the stakeholders. One of these problem owners indicated however that the amount of support staff was large and costly. In the SSB session the participants had limited positive experience on the facilitation. They found that more preparation and attention could have been given on how to facilitate the session.

On the available tools used in the iRoom most interviewees responded positive. The iRoom is seen as a suitable space for these types of sessions. Due the use of the multiple screens a more complete picture is given according to one of the interviewees. In the SSB session it was suggested that the tools in the iRoom have potential but were not completely utilized. Potential was seen in the possibility to design during a meeting, but this was not possible. This criticism was not on the tools themselves, but rather on its use.

The configuration of seating was, as mentioned in the previous chapter, quite different per session. In two projects there were no significant comments on the configuration however, in the TZB case there was. In this session the problem owners mention that the configuration was not a suitable for the discussion. They stated that it was more preferred to use a U-shape. Additionally, it was suggested that there were too many stakeholders present. The question remained at the interviewee how much value this large group gave to the session. With a smaller group probably more could have been achieved. Also was mentioned that the session would be more interactive if everyone was directly in front of the Smartboards by one of the interviewees.

Design approach

From the above sections it appears that the iRoom as an instrument has great potential. This section presents how the interviewed problem owners have experienced the design method. For this are the problem owners were interviewed on their experiences with the visualisations, metrics and design steps taken.

	BCM		SSB			TZB		TRE	
	Municipality of Blaricum	*Municipality of Huizen*	*Province Zuid-Holland*	*Region Haaglanden*	*Municipality of Delft*	*Province Noord-Holland*	*Municipality of Wormerveer*	*ProRail*	*Municipality of Ermelo*
Design approach									
• Visualisation	+	+	±	±	+	±	+	+	+
• Metrics	±	–	–	–	–	±	±	±	+
• Design steps	+	+	–	–	–	±	+	±	+

TABLE 6.9 Experience design approach of iRoom session per interviewee

The overall experience on the use of visualisations was positive. By making use of visualisation, the design task was considered more efficient and understandable to examine. Simple 2D sketches, aerial photos and various cad drawings were used in most cases. Some interviewees suggested that 3D models could enhance the perception even more. In the SSB case the problem owners mentioned that the visualisation could be used more convincing and more should be possible. In another case was mentioned that de used visualisations were not adequate. However, used in combination with the local knowledge that was present in the iRoom still provided a complete picture.

The use of metrics was not or only limited experienced by the problem owners. This means that the outcomes of the design task was not always fully measurable. One of the stakeholders from the BCM session explained that during the session there is designed on outlines and on an abstract level. This made it difficult to fully estimate the investment and maintenance cost. The level on which the considerations were based were seen as sufficient for the moment. However, after the session a number of these considerations turned out differently. This experience is shared by a couple of the other participants and indicates that there is a need to substantiate design considerations with the use of metrics. In the TZB session the use of simulation models made the design task more measurable. The participants, however, would have liked to see a simulation model that is directly adaptable during the session. Generally considered the participants found that the use of metrics could enhance the iRoom session, but they understand the technical limitations.

In two sessions, the participants were satisfied with the design steps. The problem owners of the BCM and TZB sessions indicated that the structure of these sessions were good. In the SSB session the stakeholders were less satisfied on the design approach. According to one of the problem owners this was mainly because the session only consisted of a presentation of technical bottlenecks and actual design steps were not taken subsequently. As a result this session was experiences no different from any other meeting.

6.2.3 Recommendations on application iRoom

Besides that the interviewees have gained a certain experience in the iRoom they may also have developed some recommendations themselves. Therefore, the problem owners were questioned on whether under which conditions they consider the iRoom as useful. In addition, they were questioned on what factors they consider as essential for successful iRoom sessions. Finally, they were questioned on any other recommendations they have for the application of the iRoom.

Conditions of application

The following table shows what the interviewed problem owners find useful conditions for an application of the iRoom.

		Conditions of application iRoom session:
BCM	*Municipality of Blaricum*	*In particular spatial bottlenecks where stakeholders with different opinions are involved, but which intention to solve these together.*
	Municipality of Huizen	*The application of the iRoom can always be useful, but especially if there is a motivation to speed up the process or to break a deadlock in the project. Often this involves complex tasks.*
SSB	*Province Zuid-Holland*	*The iRoom can be used throughout the entire process. Integration issues in the spatial surrounding are very suitable for an iRoom session. It is of more importance to consider the objective of the iRoom and what people then have to participate.*
	Region Haaglanden	*The iRoom can always be used as long as there is a clear objective for it.*
	Municipality of Delft	*The iRoom can be used in different phases of the project. It is important that there is a clear goal for which the iRoom will be deployed. The iRoom is not an objective on its own.*
TZB	*Province Noord - Holland*	*The iRoom can be used in different project phase.*
	Municipality of Wormerveer	*The application is most suited at the early phases of the project. For example, to define the problem as we have done. With images, the discussion is easier. Problems that are able to visualise are more suitable to treat in the iRoom.*
TRE	*ProRail*	*The iRoom is especially useful in the early stages of a project. In particular when several alternatives have to be developed and when no clear vision on the end result. With the iRoom you are able to jointly address an issue in a relatively short time.*
	Municipality of Ermelo	*Especially suited for more complex designs. In addition, it seems sensible to deploy the iRoom in (larger) projects to present plans to residents or to the council committee.*

TABLE 6.10 Recommendations conditions of application of iRoom session per interviewee

Problem owners have various views on the application of the iRoom. This result can be due own experiences to the problem owners have on the application of the iRoom.

A majority stated that the iRoom can always be applied in civil engineering project. This can be throughout the entire process and with various objectives. Precondition is that there is a clear objective assigned for the iRoom and the right people participate.

However, some of the problem owners gave suggestions under which conditions they see iRoom is most valuable. Summarized they stated that the iRoom is most suitable in one or more of the following conditions:

- Spatial bottlenecks which allow visualisation;
- Integration issues in the spatial surrounding;
- Early design phases of the project;
- Conflicting stakeholders interest;
- Shared motivation to accelerate the process;
- Shared intention to solve the design task;
- Deadlock in a project.

Most suggested that the iRoom is considered suited to solve spatial design problems. Apparently the iRoom is most impressive in this function according to the problem owners.

Factors of success

Then asked to issue owners what are the factors for success in the iRoom. The following table presents these results.

		Factors of success:
BCM	*Municipality of Blaricum*	*With the use of professional tools and a good process design difficult design tasks can be made transparent for the stakeholders. This makes it able to define solutions in a constructive environment.*
	Municipality of Huizen	*Visualisation of solutions with all designers in one room with one objective. Condition is that everyone is committed to this in advance.*
SSB	*Province Zuid-Holland*	*Clear objective, preparation and the right people.*
	Region Haaglanden	*Good preparation and the right people on the table.*
	Municipality of Delft	*Proper preparation, right people and setting and an clear objective.*
TZB	*Province Noord - Holland*	*Clear principles and objective to the session and the right participants.*
	Municipality of Wormerveer	*Joining each other in such a session combined with the facilities of the iRoom is interesting in the basis. However, if the solution is successful can only be determined in afterwards.*
TRE	*ProRail*	*It is especially important that the process is managed tightly. It must remain within the boundaries of the project. This requires that the principles and the scope of the project are clearly defined and the session cannot include anything. This is also a pitfall because I can also imagine that a iRoom session can turn out wrong. Expectation management is very important*
	Municipality of Ermelo	-

TABLE 6.11 Recommendations factors of success of iRoom session per interviewee

As can be derived from the table the problem owners are on the success factors more unanimous. Summarized can be seen that according to the interviewees the following factors for a successful iRoom session are considered:

- Good process design and facilitation;
- Clear objective;
- Good preparation;
- Right participants;
- Right setting and principles.

This result may seem very trivial and applicable for every design session. It shows however what is lacking in some of the cases and what is considered as essential for an iRoom session.

Other recommendations

Finally, the interviewees were questioned on whether they have any other recommendations on the application of the iRoom. This gave limited response as many was already discussed in the previous sections. The following other recommendations were given:

- Professionalise the application of the iRoom;
- Management of expectations;
- An overview of the results in costs for applying the iRoom;
- Present the capabilities of the iRoom more explicit to the market.

6.3 Conclusion on interview results

This chapter presents the results of nine interviews derived from four different iRoom sessions. In general can be concluded that the experiences of problem owners on the application of VDC in the iRoom differentiates per project. This indicates that some iRoom sessions were considered more useful than others. The experiences range from very positive to the level that participants had higher expectations from the session.

All problems owners had positive expectations prior to the iRoom sessions. A contribution of the perception, information exchange and/or decisions making was expected. The iRoom was often motivated to collaboratively examine and develop possible solutions for the design task. In addition, an mutual agreement on the design task was often needed. Most had the expectation that it would be possible to design real-time with stakeholders collaborative and show directly the design results during the iRoom session.

From the iRoom sessions the problem owners experienced in most sessions both an task related outcome and a social outcome. Task related the iRoom was useful considered to develop a supported design and to examine project limitations. Social related the iRoom contributed most to the perception of the participants. The use of visualisations was thereby considered as added value, especially for special bottlenecks and technical interfaces. However, the use of metrics was experienced as limited during the sessions. With this cost estimates and analysis were often seen as very abstract and conceptual.

Not in all sessions the iRoom was considered as completely utilized in contrast to the expected capabilities. In some of the cases it was argued to professionalise the application. According to the problem owners good process design, facilitation and objective are seen as essential for successful iRoom sessions. In addition, it is must be considered that the participants with mandate are invited for the sessions. For spatial bottlenecks, technical interfaces and conceptualisation in early design phases the iRoom was recommended by the problem owners.

Chapter 7 Gap analysis

The previous two chapters revealed the results of a series of observations and interviews on the application of VDC in the iRoom. This chapter compares these results against each other and to the theory. From this, different hypothesis are developed for the application of the iRoom in general. This results in several potentials for improvement. This chapter will provide an answer to the following the following research question:

RQ5: *What best practises and lessons learned can be identified from the application of VDC in the iRoom at Royal HaskoningDHV?*

In Figure 5.1 it was considered that there were two main influences on the results of the iRoom, the conditions of application and the application itself. Therefore this chapter is separated in two sections. The first contains an analysis of the conditions of application of the iRoom *(Section 7.1)*. In this analysis is discussed on the basis of the observations and interviews when and under which conditions the iRoom has most potential. In the following section the application of the VDC is analysed *(Section 7.2)*. This section presents various gaps and potentials for improvement for the application of VDC at Royal HaskoningDHV in general.

7.1 Conditions of application

In this section an analysis is made on the conditions of application of VDC in the iRoom. The central question, is under which conditions is VDC most valuable in civil engineering projects. In this section various hypothesis are derived from the knowledge gained from the interviews and observations. For this the complexity, project phase, objective and participants of the iRoom sessions are considered. In addition it is showed in which of these conditions the iRoom can be developed further.

7.1.1 Project complexity

As argued in the theoretical framework civil engineering projects are both considered technical and organisational complex. These complexities may, on one side, be seen as a drivers for the application of VDC. On the other hand, they can make application of VDC a difficulty.

Technical complexities

During the observations different complexities were observed during the iRoom sessions. Technical complexities were observed as suited to examine and managed during iRoom sessions. The use of visualisations, metrics and simulations helped in gaining in providing an understanding. It was in particular seen in the interviews and observations that the iRoom was suited to examine and manage:

- Spatial limitations
- Design implications
- Technical interfaces

Especially the use of visualisations provided added value in creating an understanding on these complexities. By enlarging the perception, participants were able to collaboratively examine these difficulties and develop solutions accordingly. However, it can be stated that the application of the iRoom can be further developed with the use of metrics to examine these complexities. In particular to quantify the implications of various design choices.

Organisational complexities

Besides the technical complexities, civil engineering projects are often confronted with organisational complexities. In all the observed iRoom sessions the involved stakeholders had some degree of conflicting interest. This complexity is considered dynamical as the decision making in projects can be subject of change and cannot be predicted. However, the iRoom can be seen as a tool to achieve a mutual agreement with the problem owners. This was often achieved during the observed iRoom sessions. From this it can be argued that the iRoom provides handles and grip to manage this dynamical organisational type of complexity. This is done by involving stakeholders actively into the projects.

7.1.2 Project phase(s)

VDC can be applied throughout different project phases in civil engineering projects. The observed iRoom sessions ranged from upon the research till the final design phase as can be seen in Figure 7.1.

From the theory the assumption was made that iRoom sessions would be more beneficial during the early phases of a project. This assumption was supported by the observation and interviews as several problem owners mentioned that the iRoom would be most useful in the early project phases.

FIGURE 7.1 Project phases for iRoom application

It also can be stated that the application of VDC can provide added value in each of this phases. Therefore the lessons learned and potentials for improvement for each phase are considered in the following sections.

Research phase

In the research phase VDC was considered very suitable and the two iRoom sessions that were observed during this research phase provided most notable results. The iRoom is useful to explore and conceptualize projects in early phases. In addition, this phase is for Royal HaskoningDHV considered important for acquisition for further development of these projects.

In this phase the application of VDC is clearly most developed. However, a standardised design approach can be developed for this phase. The steps taken in the sessions from the case analysis were very similar and can be used in other projects as well. The use of a standardized approach for this phase can guarantee quality on the application of VDC throughout different projects. In addition, it can ease the preparations of iRoom sessions.

The application of VDC could be further developed in this phase with the use of metrics. In this phase the design task is already on a highly abstraction level. This creates the risk that too many assumptions are made due to a lack of knowledge. Also group thinking initiates a risk of optimistic behaviour. The observed cases showed that it regular occurred that after sessions results turned out different than expected in the iRoom. By making design considerations more measurable could provide more substance and quality to the session.

Also more attention could be given in this phase to the more soft engineering discipline (Checkland, 2000). In this phase objectives of problem owners are often unclear or undeveloped. Now much attention was given to the technical development and feasibility of the project. However, the needs of the involved stakeholders were often not fully considered.

Definition & Program of Requirement phase

The application of VDC for the definition and development of requirements was analysed to perform more difficult in the iRoom. This as requirements are harder to visualize and are long listed. It can be considered hard to compare requirements and examine these collaboratively. However, actively involving stakeholders in this phase was seen as positive as traditionally documents are exchanged and with the use of the iRoom everyone is actively involved.

To successfully apply the iRoom during this phase the appropriate tools and approaches have to be developed. During this phase the requirements and functions of the system have to be defined. Therefore it can be considered that tools for collaborative issue formulation are essential. The use of objective trees or score cards can be used to enhance the discussion. These were now rarely used in the iRoom at Royal HaskoningDHV in all of the sessions. In addition, it was not observed that there was any linkage with the application of SE in these cases.

In this phase visualisations can be used in this phase to identify the problem, system of interest, interrelated systems or scope of the project. Metrics can thereby be developed in order to examine the design.

Preliminary design phase

In the preliminary design phase the iRoom is used to discuss the design on a more detailed level. In this phase VDC must be used with caution in collaboration with the problem owners.

The risk in this phase lies, namely, in overwhelming the problem owners with all kind of technical issues in the project. The case analysis showed that problem owners were not always interested in these in depth technical issues. This as they were not always familiar with the technical knowhow. In addition, this task is in fact dedicated to the engineering firm.

However, the iRoom can be beneficial when it is clear that the design does interfere directly with the requirements of the problem owners. If requirements are considered conflicting the iRoom can be used to enhance an understanding at the problem owners of certain design issues. VDC can then convince certain stakeholders to adopt another standpoint on the design. By using metrics and visualisations the impact on specific design requirement can be made understandable.

Furthermore VDC can be enhanced in this phase especially with the use of Building Information Models (BIM) as project data grows. The use of these type of models was not observed during the iRoom sessions. It is expected that BIM is increasingly applied in civil engineering projects. The use of BIM models can be visualised in the iRoom and can be used to manage technical interfaces.

Final design phase

In the final design phase the iRoom the iRoom was observed used to conclude on some remaining interrelated issues on a detailed level. The iRoom was used very successfully and held to solve a solution that was a long lasted deadlock in the project.

The iRoom can also be considered useful in this phase to validate the design to the problem owners. Problem owners can in the iRoom get acquainted with the final design. By using visualisations they can virtually examine the final design from all angles. With the aid of metrics the project performance can be presented relative to the requirements. The use of the iRoom in such a way was not observed during the iRoom sessions of Royal HaskoningDHV. However it can be reasoned to develop such iRoom sessions.

7.1.3 Objective

The application of VDC was expected to be useful for various objectives to the project. This expectation is supported by the case studies. The following lessons can be learned from the case studies.

- *Define a clear objective to the application of VDC for the project*
  From the analysis can be learned that VDC is most valuable when there is a clear objective defined for the iRoom sessions to the project. In one of the cases the iRoom was an objective on its own to discuss the project process. As there wasn't a common objective for the participants the session was observed less constructive. Many identified issues were left unanswered. This also had a reflect on the experiences of the problem owners. This resulted in less notable for results and outcomes of this particular session. From the analysis the hypothesis can be made that the application of VDC can be more focused and constructive when there is a clear objective to the project.

- *Communicate the objective of the iRoom session in advance*
  It is consider important to communicate on the objective of VDC to the project prior to the sessions. This to prevent that the wrong people are invited to the iRoom sessions. With this also expectation of participants can be managed. In one of the sessions it turned out that the problem owners in advance where unaware what was going to happen during the iRoom session. This resulted that the participants had false expectations to the sessions and the composition of the participants was incorrect. From this the can be stated that objective of iRoom sessions should be communicated in advance to manage expectations.

- *Focus and reflect on the objective during the iRoom sessions*
  In most of the cases the objective of the session was collaboratively discussed at the start. With this participants were given the opportunity respond and to become aware of the sessions objective. However, in one of the sessions the objective was not considered fully achieved. This because the session got stuck as there was much debate on a certain aspect of the project. No response was made by the facilitator adequately to focus on the objective of the iRoom session. As a result use of VDC turned out less constructive then was expected by the client.

It can be concluded that VDC can be applied for various objectives to the project. However, from the cases became clear that the iRoom was particularity useful for the following objectives.

- *Development of alternatives*
  The application of VDC is particularly suited to develop various conceptual alternatives for the project. By facilitating problem owners to develop collaboratively possible alternatives for the project was analysed as efficient. Traditionally engineering firms developed solutions for the project. In the iRoom the problem owners are given this task and the engineering firm supports them with the use visualisations and metrics. This approach is considerably different but is was often experienced as an acceleration.

- *Break a deadlock in a project*
  In one of the sessions the project was in a deadlock for some interrelated remaining design issues. The problem was that different stakeholders had conflicting viewpoints in relation to these issue. The objective for the iRoom was made to deal with these remaining bottlenecks collaboratively in the iRoom. Previous traditional meetings proved not sufficient as their spatial design problem was seen complex to solve. The use of the iRoom proved successful as multiple stakeholders were facilitated to collaboratively solve these issues with the help of visualisations.

7.1.4 Participants

In all of the projects there were multiple stakeholders involved in the iRoom sessions. Often the participants involved a composition of national, regional and local public parties. However, no conclusions could be derived from the analysis on whether the application of VDC was more suited in collaboration with one of parties. Yet, the following lesson could be learned from the case studies.

- *Large amount of participant can slow down the process*
  In one of the sessions the group consisted of fifteen participants. This size was considered large as the iRoom was observed crowded. One of the interviewees stated that the large group size was experienced as a difficulty. On one side because it the relations and opinions of individuals become more obscure and on the other side because more time was needed. It can be suggested that larger group sizes slow down the process in the iRoom and this should be taken into account

- *Composition of participants should be considered*
  From the analysis it became clear that in several cases some problem owners did not understand certain design activities. As a result the involvement of these problem owners declined during the sessions. It was mentioned that the sessions was not aligned to the composition of the participants. It occurred that more process orientated people were confronted with in depth technical data. This caused much confusion and was seen as useless. Therefore thought should be gone on what people to invite to the sessions and how align the session to their knowhow.

7.2 Application of VDC

Within the application of VDC various variations exist. In this section these are considered relative to the results of the iRoom sessions. From this various gaps and potentials for improvement of the iRoom are derived.

7.2.1 Program of iRoom session

From the case studies it was concluded that there are no guidelines for the application of VDC. Programs therefore varied and were hardly comparable. This resulted in a variation of quality experienced in the iRoom sessions. From this the following lessons and gaps were identified.

- *Develop standardised programs and guidelines to guaranty quality*
  Despite the iRoom can be applied for various activities, more guidance is needed for the application of VDC. Now in each project iRoom sessions are prepared individually as there is a lack of exchange in design steps, methods and tools. By providing guidance with more standardised programs for the VDC in projects can guaranty the quality of this design method. This can ensure that essential steps are taken in each and every iRoom session.

- *More focus on the process perspective*
  Considering the programs of the sessions turned out that the participants were quickly invited to examine many technical in-depth issues. However, the process perspective was often forgotten. A view on needs, requirements and criteria of the stakeholders can be considered needed. Especially considered when in most sessions the objective was to achieve a mutual agreement for the design task. Therefore the focus should be more on the process perspective and not solely on the engineering perspective.

- *Plan breaks and spare time in programs*
  All sessions lasted between four and five hours. It cannot be expected from the participants to continuously pay attention and breaks are needed. However, breaks were often postponed as design tasks were underestimated. As a result participants quit the sessions by themselves and became also less involved. Therefore it can be reasoned to be important to plan enough breaks and spare time in the sessions.

- *Keep participants actively involved*
  In several cases projects or issues were presented to the stakeholders. These presentations often lasted too long. From the interviews it appeared that the problem owners did not want to see a long presentations. As a result the attention of the participant declined. This argues that a balance must be find between presentation and active participation.

7.2.2 Organisation of iRoom session

For the organisation of the iRoom session in the case studies different were observed. Most notable was the variation on the session leader. The following lessons can be identified from the case studies.

- *Consider the session leader in the application of the iRoom*
  During the sessions variations were seen in leader or moderator of the iRoom session. From the case analysis the hypothesis can be made that this role differs too the type of session. The distinction can be made between project leaders and facilitators that can perform this role, or a combination of both. It can be concluded that facilitators are suited in the more process oriented iRoom sessions. The facilitator is unfamiliar with the substance of the project but skilled in mediation and process management. The project leader on the other hand was observed more suited in more technical orientated iRoom sessions. In this sessions technical knowhow of the iRoom is considered important for the development of the project.

- *Consult and use iRoom experts and facilitators*
  In some of the cases project leaders individually initiated, prepared and executed iRoom sessions, often with good results. However, the application of VDC can be further develop if the application is performed in collaboration with iRoom experts and facilitators. These are familiar with the use of the iRoom and can share knowledge on its application along projects. This can be stated as a gap in the current application of VDC at Royal HaskoningDHV

- *Make project managers familiar with VDC and the iRoom*
  This though of making project manager more familiar with VDC brings two advantages. First advantage is that project managers can apply VDC more efficient in their projects. The second advantage is that as project managers become are aware of the use and added value, it can be expected that VDC is increasingly applied.

7.2.3 Use of iRoom facilities

Within the application of the iRoom variations were observed on the use of the Smartboards and the configuration of the seating. From the cases the following lessons can be learned.

- *Consider the use of the Smartboards*
  Within the cases analysis two approaches of the use of Smartboards were observed. A participant and a facilitator driven approach. Dependent on the activities in the session

one of these approaches can be favourable. The facilitator-driven approach is less time consuming, but is less interactive and gives more importance to the role of facilitator.

- *Preparation of seating configuration*
  In the observed cases different seating configurations were seen. However, it was observed that little thought went to the configuration and allocation of seats. From the analysis it became clear that the participants need to have sight on each other and can easily reach the Smartboards.

7.2.4 Visualisations and metrics

Visualisations and metrics are two major components in the application of VDC. From the case analysis the conclusion can be made that these component can be further developed. The following gaps were identified.

- *Limited use of metrics*
  The most notable gap within the application of VDC is the limited use of metrics. Currently the application at Royal HaskoningDHV relies mostly one the use of visualisations. However, metrics were considered needed by the problem owners to quantify results. Analysis methods, such as multi criteria decision analyses, should be developed and standardized for the application of VDC to fill this gap.

- *Limited use of visualisations on organisation and process*
  Currently mostly product visualisations are consulted in the iRoom. The use of visualisations on process and organisation however remains limited. The application of VDC can benefit from the development of organisations and process visualisations that can be used throughout various iRoom sessions. These for example can contain visualisations of the planning with the use of interactive Gantt charts. Or they can visualise the needs of involved organisations with the help of an interactive stakeholder analysis.

- *Integration of metrics and visualisations*
  The implementation of VDC at Royal HaskoningDHV currently finds itself in the first maturity level of the application. To reach the next level of VDC integrated POP models should be used. The use of Building Information Models can help to achieve this in the iRoom.

7.2.5 Design activities

The steps and activities taken in the iRoom did not always cover the steps of issue formulation, analysis and interpretation fully as concluded in the case analysis. From the analysis the following lessons were learned.

- *Steps of issue formulation are undeveloped*
  The formulation of objectives and constraints for the design are undeveloped in the iRoom. Often these activities were forgotten and the participants were invited to immediately consider the alternatives of the design. The steps of issue formulation should be anchored in the application of VDC.

- *System analysis and modelling limited*
  Within the iRoom the activities of system analysis and modelling remains limited. Mostly due to technical difficulties of software which don't allow to quickly adjust for example simulation models. However, problems owners currently expect to design in the iRoom and see immediate the results and performance. Therefore modelling and analysis tools should be developed for application in the iRoom.

7.3 Conclusion on gap analysis

This chapter presents various gaps and recommendations in the application of VDC in the iRoom at Royal HaskoningDHV. It can be concluded that VDC has most potential in the early project phases. In particular for the conceptualisation of various design alternatives. The iRoom contributes to this by using visualisations and metrics to examine projects quickly and on level that is understandable for problem owners. In addition, projects are often the confronted with organisational complexities and mutual agreement between problem owners is often needed. With the application of VDC these complexities can be managed and can even help to break a deadlock within a project. VDC also shows also that the technical integration of projects in the environment can be examined and developed in iRoom sessions.

Within the application of VDC various approaches exists at Royal HaskoningDHV. A lack of exchange in design methods, tools and approach was observed and this results in a variation of quality in the application. To guaranty this, guidelines and tools for the application of VDC should be developed to prepare future iRoom sessions. Most notable gap is the limited use of metrics within the application of VDC at Royal HaskoningDHV. Also the steps of issue formulation and system analysis and modelling are undeveloped and considered limited.

Chapter 8 Guideline for the application of VDC

The previous chapter concluded on a lack of structure within the application of VDC at Royal HaskoningDHV. Therefore this chapter presents a guideline to prepare and develop future iRoom sessions. This guideline will provide an answer to the following research questions.

RQ5: *What guidelines can be made for the application of VDC to achieve a shared understanding with problem owners in civil engineering projects?*

RQ6: *How can the provided guidelines be evaluated in future application of VDC in the iRoom?*

First this guideline presents several precondition where civil engineering project must meet to for the application of VDC *(Section 8.1)*. For the application of VDC no one size fits all program could be developed as the method can be applied in different phases and for various objectives. However, a basic program which is considered essential for each type of iRoom session is developed *(Section 8.2)*. Within this basic program various trade-offs can be made to align the iRoom to specific project needs *(Section 8.3)*. Then to justify and further enhance these guidelines an evaluation is presented *(Section 8.4)*.

8.1 Preconditions

With VDC, Royal HaskoningDHV has a valuable method in possession to actively involve problem owners and clients into their design and engineering process. However, its application may not always be useful in each situation. This section defines when to consider the application of VDC by discussing objective, design task and the participants.

Objective

The application of VDC cannot be considered an objective on its own in a project. In order to make optimal use of the iRoom there must be a clear objective defined for the project. The objectives for the application of VDC and the iRoom can be different. Examples of possible objectives for an iRoom session are the development of possible alternatives or a mutual agreement on design principles. Collectively discussing the project with the use of visualization is not considered a clear objective to the project.

Design task

The design task must be suited for treatment in the iRoom. The iRoom is considered most useful when the design task satisfies to two condition. At first the design task contains some sort of organisational complexity. This demands for alignment between different stakeholders in engineering projects. The iRoom can contribute to this by involving stakeholders actively in the design and engineering process. On the other hand the design task must contain some sort of technical complexity. In particular integration issues which can be visualised in the iRoom are considered suited. If the design task does not meet to one of these conditions other methods may be considered more efficient.

Participants

To successfully apply the iRoom in civil engineering projects some conditions consists to the participants. First, it is required that the involved participants have mandate. In the iRoom often crucial design choices are taken. iRoom sessions can become a difficulty if participants do not have the freedom to act their own. It is also important that the involved stakeholders have the intention to develop a solution for the design.

To the knowledge of participants no preconditions are given as VDC is considered very accessible. However, it is important to keep the level of the session in line with the know-how of the participants.

8.2 Basic program of VDC

This section presents a suggested basic program to for the application of VDC. This program is general and can be used for iRoom sessions with different objectives. This application consists of three phases: preparation of VDC, application of VDC and the evaluation of VDC. These phases are considered to be present in every VDC application. Within these phases various steps are performed which consist of several activities. The basic program is shown in Figure 8.1.

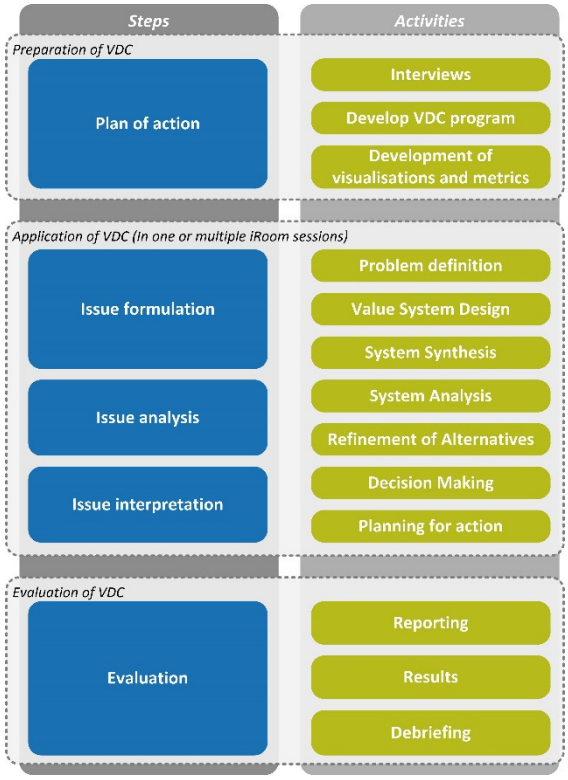


FIGURE 8.1 Basic program for the application of VDC

8.2.1 Preparation of VDC

Prior the application of VDC a plan of action should be developed. The plan of action is developed in cooperation with iRoom experts or facilitators. The development of the plan of action and consists of several steps namely: interviews, VDC program and the development of visualizations and metrics.

In de first activity interviews are used to examine the needs and expectations of the problem owners. From the interviews the objective of the session can be derived. In addition the interviews can be used to explore the needs of the problem owners on the design.

Then the program of VDC should developed be developed for the project. This by concerning the objective, complexity, design task and amount of stakeholders. The amount of sessions and a script of each of these sessions should completed during this step. This results in a detailed script that defines each of the activities, time and the used tools.

On the basis of the program of the iRoom sessions required data must be collected. This can consist of reports, drawings, photos, models and simulations. These are needed to develop visualisations and metrics for product, organisation and process.

The plan of action is discussed and evaluated with the client and clearly defines the outcome of the VDC sessions.

8.2.2 Application of VDC

The application of VDC is suggested to consist of a minimum of three steps namely issue formulation, analysis and interpretation. This as from a formal systems engineering activity consist of a minimum of three fundamental steps in each design phase (Sage & Armstrong, 2000). These steps can be taken in one or multiple iRoom sessions.

The following sections present how to apply these steps in the iRoom using the Smartboards.

Issue formulation

- *Problem Definition*
  Identifying, quantifying, and clarifying a set of needs, alterables and constraints associated with the issue formulation of the problem;
- *Value System Design*
  The selection of the set of objectives and measures that enables determination of decision criteria for selecting the most appropriate system;
- *Synthesis of Alternatives*
  Identification of a number of potential alternatives and associated alternatives measures;

Issue analysis

- *System Modelling and Analysis*
  Examination of the performance of the identified alternatives relative to the decision criteria with the use of simulation and modelling methods;
- *Refinement of Alternatives*
  The attempt to optimize alternatives system variables in order to meet the system objects and constraints best;

Issue Interpretation

- *Decision Making*
  Evaluation of the impacts and consequences of alternatives and selection for advancing to the next step;
- *Planning for action*
  Communication of the results and allocating resources to accomplish further plan of action.

8.2.3 Evaluation of VDC

After the application of iRoom an evaluation step should always be taken. This evaluation is suggested to consists of several steps namely reporting, results and debriefing.

During the session, it is advisable to make notes in the presentation slides. Once the session is completed the slides can be used as a summary and report to the problem owners. The slides and notes will include the session report. This can be sent to the problem owns almost instantly. This make the participants able to consult directly after the session the main results. Subsequently, the results of the iRoom session will be further processed in the design task of Royal HaskoningDHV.

Finally the application of VDC is evaluated with the problem owners. In this evaluation it is considered whether the application of VDC meets to the expectations of the problem owners. The evaluation scheme presented in .

8.3 Trade-offs in application VDC

Within the application of VDC various trade-offs exist. These can be made to adapt the session to the individual needs of a project. This section considers trade-offs on the number of sessions, design activities, use of the iRoom and the facilitation.

8.3.1 Number of iRoom sessions

On the basis of the objective for the application of VDC there must considered how many iRoom session will be performed for the project. The number of iRoom session is strongly dependent upon:

- The complexity of the design task;
  - Amount of technical interfaces;
  - Amount of involved stakeholders;
- The scope of the project;
- Commitment of the stakeholders;
- The experience of the design team with the iRoom;

Especially the scope and size projects have influence on the amount of sessions to be scheduled. The following table provides some guidance in the amount of sessions to apply within a project phase.

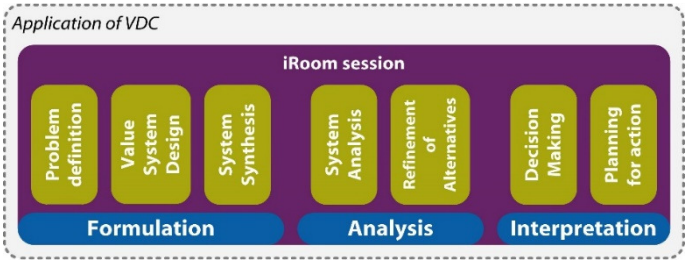
Amount of iRoom sessions	Project scale	Technical complexity	Number of stakeholders
1 session	*Small*	*Low*	*1 - 2*
2 - 3 sessions	*Medium*	*Normal*	*2 - 3*
4 - 5 sessions	*Large*	*High*	*4 -5*

TABLE 8.1 Number of iRoom sessions to apply

This table is derived from the observed practise and lessons learned from previous iRoom sessions. In this table the largest value is decisive for the amount of sessions. This as most likely large projects involves higher complexity and more involved stakeholders.

8.3.2 Design activities per iRoom sessions

The design activates per iRoom session can differentiate. Therefore, this section suggest a subdivision in the design activities to perform in individual iRoom sessions.



Small scale design task with modest complexity that only allow visualisations able to withstand with one iRoom session as can be seen in Figure 8.2

FIGURE 8.2 One iRoom session configuration

Sessions which are considered more complex and need to be substantiated with metrics are hard to perform in one iRoom session. The step of system analysis is observed as a difficulty to perform within the iRoom as this is generally a time consuming task. Also this activity requires little input from the problem owners. Therefore it is suggested to split a configuration with two iRoom sessions between the systems synthesis and the system analysis. This configuration can be seen in Figure 8.3.

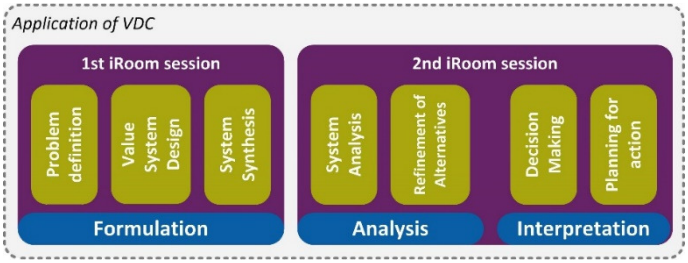


FIGURE 8.3 Two iRoom session configuration

In a VDC approach that consist out of three sessions variations are possible. This is depended to the objective of the session. A distinction is suggested between more system oriented objectives and process oriented objectives.

In sessions that involve more complexity with regard to the technical systems it is suggested to invest more effort in the steps of system analysis and interpretation. This can be for example when traffic needs to be considered. Such a task requires more effort in the steps of system analysis and refinement of alternatives.

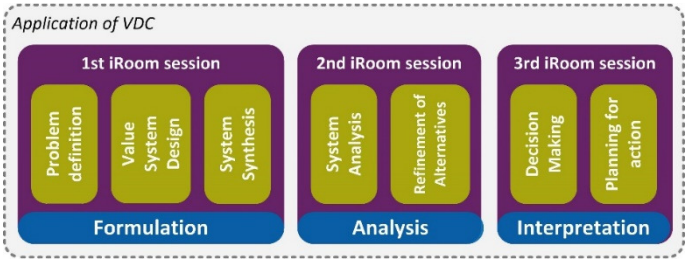


FIGURE 8.4 Three iRoom session configuration in system oriented objectives

In projects were achieving a mutual agreement between stakeholders is problematic and considered complex, more effort should be given to the step of issue formulation. This approach is presented in Figure 8.5. Large scale projects that are both organisational and technical highly complex are suggested to use four or five iRoom sessions in the form of a combination of these approaches.

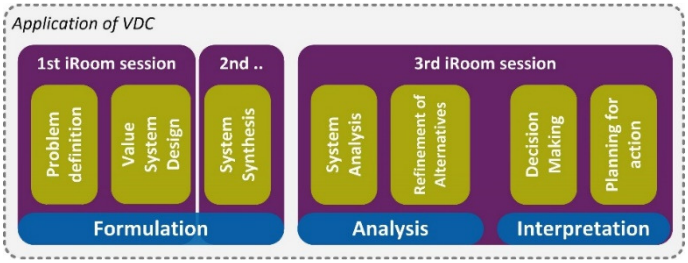


FIGURE 8.5 Three iRoom session configuration in process oriented objectives

8.3.3 Use of the iRoom

In order to make optimal use of the iRoom it is essential that participants are able to communicate with each other and the Smartboards. Therefor it is suggested that participants are seated in a semicircle in fort of the Smartboards. This configuration can be seen in Figure 8.6

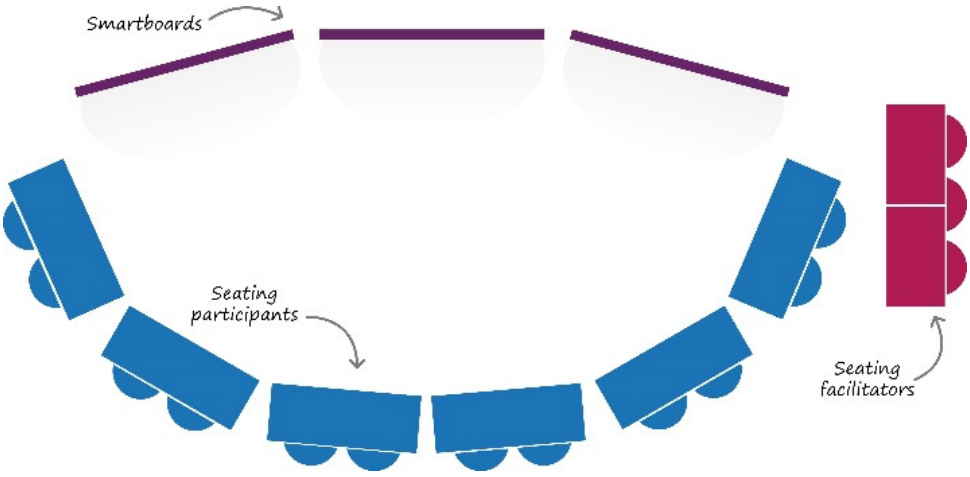


FIGURE 8.6 Preferred iRoom configuration

8.4 Evaluation of guidelines

Despite of the above guidelines are derived from the practise and lessons learned from previous application of VDC, it is important to consider that these guidelines are not yet proven in practise.

Therefore these guidelines should be evaluated in future application of the iRoom. In addition, the presented guidelines should be evaluated by the VDC experts at Royal HaskoningDHV. This section presents an evaluation scheme for these purpose.

	Not utilized	Limited utilized	Fully utilized
POP-visualisations			
• Product	..	..	..
• Organisation	..	..	..
• Process	..	..	..
POP-metrics			
• Product	..	..	..
• Organisation	..	..	..
• Process	..	..	..
Logical steps of SE			
• Problem Definition	..	..	..
• Value System Design	..	..	..
• Synthesis of Alternatives	..	..	..
• System Modelling and Analysis	..	..	..
• Refinement of Alternatives	..	..	..
• Decision Making	..	..	..
• Problem Definition	..	..	..
Task related outcome			
• Objective achieved	..	..	..
• New insights	..	..	..
• New solutions	..	..	..
• Productivity	..	..	..
Process related outcome			
• Objective achieved	..	..	..
• New insights	..	..	..
• New solutions	..	..	..
• Productivity	..	..	..

TABLE 8.2 Program of iRoom session per case

Evaluation should be performed after each iRoom session. The results of the evaluation of future application using the proposed guidelines can be compared to the case studies that are provided by this research. This evaluation scheme can help to obtain further improvements in the iRoom.

Chapter 9 Conclusion and recommendations

This final chapter presents the conclusions of this thesis project. In addition, it provides recommendations for the application and development of VDC with the iRoom by Royal HaskoningDHV. Finally, this chapter provides a discussion on the approach, methods and results of research.

9.1 Conclusion

This thesis strives to improve shared understanding in civil engineering projects with the use of VDC to manage organisational complexity. This because objectives of problem owners are often not entirely clear and are subject of change, especially in the early project phases (Leidraad SE, 2009). VDC can be seen as a collaborative design method which makes use of the multi-screen iRoom that allows different stakeholders to simultaneously describe, present and evaluate a project on product, organisation and process perspectives (Kunz & Fischer, 2012). Ensuring shared understanding in collaborative design is considered challenging (Piirainen et al., 2012).

The findings in this report show that the application of VDC provides a clear added value in the development of civil engineering projects. Through actively involving problem owners in the iRoom the understanding and perception on the design task is enlarged. It appears that with the application of VDC contributes to the management of both technical and organisational complexities. The iRoom is in particular useful in design tasks were a mutual agreement between problem owners is needed on spatial design issues. The extensive use of visualisations and metrics on product, organisation and process in the iRoom contribute to this.

The case analysis from this research makes clear that problem owners have positive expectations to the application of VDC in their projects. In this they consider the possibility to collaboratively examine and develop possible solutions for the design task as the most important added value. However, the application of VDC can be further developed as experiences range from very positive to the level that participants had higher expectations. The possibility to design real-time and show directly the results of the design could be further improved. This makes the development of appropriate tools and methods of importance. In particular the use of metrics remains limited within the application of VDC at Royal HaskoningDHV. Also visualizations for organization and process are not used. In addition, it can be concluded that VDC currently contains a lack of structure and a more standardized approach should be used to enhance the outcomes of its application. Currently the quality of iRoom sessions varies because there is limited exchange in methods and approach. The guidelines, presented in Chapter 8, provide a first step in this development.

From a scientific standpoint, the conclusion can be made that the application of VDC contributes to a shared understanding with problems owners to manage organisational complexity. The case studies provided in this thesis demonstrated this expectation. However, from the perspective of the project manager the application of VDC is observed challenging. This because no clear design steps and tools are provided by the method. The guidelines in this research combine the application of VDC with the seven logical steps of SE by Sage and Armstrong (2000). These should help individual design teams in their application of VDC.

The application of VDC brings also different approach in the development of engineering projects for Royal HaskoningDHV. Through the application of VDC a shift is made from pure engineering to the facilitation of design and decision making processes. As a result Royal HaskoningDHV has to focus more on the process perspective discipline.

9.2 Recommendations

With this conclusion recommendations are given on the application of VDC. These recommendations should be considered by Royal HaskoningDHV to further enhance the application of the iRoom. In addition, recommendations are given for further research and development.

9.2.1 Application of VDC

The following recommendations are considered short term as these can be made instantly within future application of VDC.

- *Define clear objectives to iRoom sessions*
  The application of VDC cannot be considered an objective on its own. It is shown that the use of the iRoom is most valuable if there is a clear objective defined to the project. The objective of VDC should be discussed with the problem owners prior to the session. After of each session a reflection should be made to the defined objective.

- *Manage expectations of problem owners*
  The management of expectations is important to prevent wrong intentions by problem owners. Therefore it is recommend to interview the involved problem owners prior to the sessions in order to obtain their interest to the project. This can ensure that all problem owners act on the same objective and prevents false expectations and disappointment.

- *More focus on the process perspective in application of VDC*
  Currently the application is mostly focussed on the development of the product. Participants are mostly invited to develop technical solutions. Needs, requirement and criteria of stakeholders are often not fully considered during iRoom sessions. This means that the process perspective is often forgotten. Therefore more focus should be given to organisation and process within POP models and not solely on the engineering perspective.

- *Make use of logical design steps*
  In current application of VDC at Royal HaskoningDHV not always logical design steps are taken. Therefore it is recommend to make use of the seven logical steps of SE by Sage and Armstrong (2000). The VDC program presented in this thesis can help in making more logical design steps for individual project teams.

- *Consult and use iRoom experts and facilitators*
  Currently iRoom application is mostly performed by individual project leaders, often with good results. However, to further professionalise the application of VDC the recommendation is made to solely develop and perform iRoom sessions in collaboration with iRoom experts and facilitators. Experts are familiar with the use of VDC and can be given the role to share knowledge and develop POP models and iRoom sessions.

- *Make use of metrics*
  Most notable gap is the limited use of metrics. However, metrics are considered needed by the problem owners to interpret design results. Therefore the recommendation is made to achieve to make design choses measurable with the use of metrics. Low effort example is the use of multi criteria decision analyses.

9.2.2 Further research and development

The following recommendations are given for further research and development. These recommendations are considered long term. The recommendations are presented in a chronological order.

- *Development of standardised adaptable POP models*
  The application of VDC proves to provide already an added value in civil engineering projects. However, visualisations and metrics can be further developed. In addition, a lack of exchange is observed in the used tools, methods and approach. Therefore the recommendation is made to standardise the POP models for the iRoom that can be adapted for different projects.

- *Development of explicit design activities*
  This research examines the use of VDC from a broad perspective applied by civil engineering firms. Further research and development efforts should be given to the development of explicit design activities. Examples are the definition of the value system design or the development of alternatives. For these explicit design activities tools and methods should be developed that can be used in the application of VDC in various projects.

- *Integration of POP models*
  The implementation of VDC at Royal HaskoningDHV currently finds itself in the first maturity level of the application of VDC. To obtain the next maturity level of VDC integrated POP models should be developed. The use of Building Information Models can help to achieve this in the iRoom.

9.3 Discussion

This thesis provides an answer how VDC can be used to improve shared understanding between problem owners to manage organisational complexity. To achieve this result, certain choices were made during the execution of this research. This section gives a reflection on the approach and methods that were used. Also the results that derive from this research are discussed.

9.3.1 Research approach

The guidelines provided by this research are the result of a study of literature, observations, interviews and a gap analysis. The research approach that is chosen is based upon Design Science Research (DSR) (Hevner, 2007; Hevner et al., 2004). The execution of the design approach was performed as planned. However, with regard to DSR an evaluation step of the provided guidelines should be made in the application of VDC. Therefore an evaluation scheme is presented to reflect on these guidelines that are suggested to be used by the early adaptors.

In addition, I have chosen to examine the application of VDC in the iRoom from the perspective of the problem owners. This provided a clear result on the added value of VDC in civil engineering projects. However, the project leaders were only included in this research limited. From their perspective possibly other recommendations could be derived as the challenges they experienced in execution of VDC were not included. Therefore in further research it is recommend to also include the experiences of the project leaders.

9.3.2 Research results

This research was strongly dependent on the available cases that were used for iRoom observations and interviews. This gave a limitation to the results derived to from this research. It was observed that the cases did not all fully utilise the characteristics of VDC. Mainly due to the limited use of metrics in the iRoom. From this the discussion can be made whether the application of VDC was examined or the implementation of the iRoom by Royal HaskoningDHV and the capability of individual project teams.

This thesis shows that the application of VDC provides added value in the development of civil engineering projects. However, no concern has gone to the perspective of costs. Some problem owners indicated in this research that the iRoom was seen as a costly undertaking. The resources and efforts that are reserved for the application of VDC should be balanced to the provided added value derived from this method. This may help individual project teams to decide on the application. Therefore further research should be given to the perspective of costs.

References

Aanbestedingsinstituut Bouw & Infra. (2010). Laagste prijs demotiveert markt en staat innovativiteit in de weg. *PPS Netwerk*.

Agentschap NL. (2011). Werk mee aan duurzaam GWW.

AIA. (2007). Integrated Project Delivery: A Guide. *American Institute of Architects*.

Baccarini, D. (1996). The concept of project complexity—a review. *International Journal of Project Management, 14*(4), 201-204.

Busker, Henri. (2011). Faalkosten in de GWW sector dalen licht. *USP Marketing Consultancy*.

Cantarelli, C. C., Molin, E. J. E., van Wee, B., & Flyvbjerg, B. (2012). Characteristics of cost overruns for Dutch transport infrastructure projects and the importance of the decision to build and project phases. *Transport Policy, 22*, 49-56.

Chachere, J., Kunz, J., & Levitt, R. (2003). Can you accelerate your project using extreme collaboration? a model based analysis. *Center for Integrated Facility Engineering (CIFE), Stanford University, CIFE Technical Report*(154).

Chachere, J., Kunz, J., & Levitt, R. (2004). Observation, theory, and simulation of integrated concurrent engineering: Grounded theoretical factors that enable radical project acceleration. *CIFE WP, 87*.

Checkland, P. (2000). Soft systems methodology: a thirty year retrospective. *Systems Research and Behavioral Science, 17*, 11-58.

CIFE. (2012). CIFE Mission. from http://cife.stanford.edu/mission

CROW. (2007). Handboek Oplossingsvrij specificeren.

De Bruijn, H., & Herder, P.M. (2009). System and actor perspectives on sociotechnical systems. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on, 39*(5), 981-992.

DHV. (2010). The roud to the future: Business plan Infrastructuur 2010-2015.

DHV. (2012a). System Engineering. from www.dhv.nl/markten/mobiliteit/integraal-projectmanagement/systems-Engineering

DHV. (2012b). Virtual Engineering.

Freerks, M. (2011). *From interoperability till integrality: Improving design and engineering based on Building Information Modeling.* Hogeschool Utrecht.

Freerks, M. (2012). De koppeling BIM en SE: Integraal werken in Virtual Engineering. *DHV*.

Garcia, A., Kunz, J., Ekstrom, M., & Kiviniemi, A. (2004). Building a project ontology with extreme collaboration and virtual design and construction. *Advanced Engineering Informatics, 18*(2), 71-83.

Goossens, A.M.A. (2007). Geïntegreerde contracten - de scheiding der markten. *GHC International,*.

Hall, A.D. (1969). Three-dimensional morphology of systems engineering. *Systems Science and Cybernetics, IEEE Transactions on, 5*(2), 156-160.

Hevner, A.R. (2007). The three cycle view of design science research. *Scandinavian Journal of Information Systems, 19*(2), 87.

Hevner, A.R., March, S.T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS quarterly, 28*(1), 75-105.

Hutchinson, R., & Wabeke, H. (2006). Opportunity and Project Management Guide. *Shell International Exploration and Production B.V.*

INCOSE. (2004). INCOSE Systems Engineering Handbook.

Kunz, J., & Fischer, M. (2012). Virtual design and construction: themes, case studies and implementation suggestions. *CIFE, Stanford University, Stanford, CA, CIFE Working Paper, Version 14*.

Leidraad SE. (2009). Leidraad voor Systems Engineering binnen de GWW-sector.

Mark, G. (2002). Extreme collaboration. *Communications of the ACM, 45*(6), 89-93.

NASA. (1995). NASA Systems Engineering Handbook.

Piirainen, K.A., Kolfschoten, G.L., & Lukosch, S. (2012). The Joint Struggle Of Complex Engineering: A Study Of The Challenges Of Collaborative Design. *International Journal of Information Technology & Decision Making, 11*(06), 1087-1125.

Rijkswaterstaat. (2007). Handreiking Systeemgerichte contractbeheersing.

Rijkswaterstaat. (2008). Visie toonaangevend opdrachtgever.

Rijkswaterstaat. (2011). Stappenplan van projectopdracht tot Vraagspecificatie.

Royal HaskoningDHV. (2012). Profile. from http://royalhaskoningdhv.com/About

Rycroft, R.W., & Kash, D.E. (1999). *The complexity challenge: Technological innovation for the 21st century*: Thomson Learning.

Sage, A., & Armstrong, J. (2000). *Introduction to systems engineering*: John Wiley & Sons, Inc.

Schrama, Paul. (2011). *Implementing Virtual Design and Construction: Evaluation and improvement of the VDC implementation in the design phase of AEC projects.* (Master), Delft University of Technology.

Siebrand, Ronald. (2010). Prijs voorlopig nog doorslaggevend? *Cobouw*.

Vink, Eline. (2008). *Systems Engineering in de praktijk.* Technische Universiteit Delft.

Whitty, S.J., & Maylor, H. (2009). And then came complex project management (revised). *International Journal of Project Management, 27*(3), 304-310.

Wind, H. (2006). *Wat vraagt de markt? Een onderzoek naar de veranderende vraag aan het advies- en ingenieursbureau door de veranderende infrastructurele markt.* Universiteit Twente.

Annex I

Observation framework

1. Conditions of application VDC

A. Necessity of VDC
- *Why is VDC used in this project?*
- *Which project complexity has contributed to the use of VDC?*

B. Project phase(s)
- *In which project phase(s) VDC is applied?*

C. Objective
- *What is the objective to be achieved from the iRoom session?*

D. Stakeholder and participants
- *Which stakeholders are present and why are these involved in the iRoom session*?

2. Application of VDC

A. Program & organisation
- *What is the scope of the iRoom session?*
- *What issues are addressed in the iRoom session?*
- *What was the program of the iRoom session?*
- *How was the session organised?*

B. Use of iRoom
- *How are the stakeholders positioned in the iRoom?*
- *How were the Smartboards used during the iRoom session?*

C. Use of visualisations and metrics
- *How are product, organisation and process visualisations used?*
- *How are product, organisation and process metrics used?*
- *What was the VDC maturity level of the session?*

D. Design activities
- *Which design steps are taken in the iRoom and how are they applied?*
  - *Problem Definition*
  - *Value System Design*
  - *Synthesis of Alternatives*
  - *System Modelling and Analysis*
  - *Refinement of Alternatives*
  - *Decision Making*
  - *Planning for action*

3. Results of application VDC

A. Task related outcome
- *Was the objective of the iRoom achieved?*
- *Did the use of the iRoom result in new insights and solutions?*

B. Process related outcome
- *Did the iRoom contribute to the involvement of stakeholders?*
- *Did the iRoom contribute to the perception of stakeholders?*
- *Did the iRoom contribute to a shared understanding among stakeholders?*
- *Did the iRoom contribute in creating a consensus between stakeholders?*

Annex II

iRoom observations

The section presents the reports of the observations made in the iRoom in the following projects:

- Border ditch Blaricummermeent
- Renewal St. Sebastiaansbrug
- Traffic measures renewal Zaanbrug
- Tunnelling rail crossings train Ermelo
- Western Ring Road Alkmaar

These observation reports have been validated by the specific project leaders and/or facilitators of the iRoom sessions.

II.A Border ditch Blaricummermeent

Time: 14:00 – 17:00 op 7 june 2012
Location: iRoom Amersfoort

1. Conditions of application VDC

A. Necessity of VDC

- *Why is VDC used in this project?*
  The municipality of Blaricum expands with a new residential area: the Blaricummermeent. Royal HaskoningDHV is responsible for the civil engineering in this project. Part of this residential area is a ditch which is exactly located on the border of the municipalities Huizen and Blaricum. VDC is used in the iRoom to achieve an agreement between the municipalities and maintainer on the design of this border ditch.

- *Which project complexity has contributed to the use of VDC?*
  Despite the border ditch only a few hundred meters long, stakeholders have conflicting interest. The ditch lies on the middle of a border so both municipalities have to agree on the design. Additionally, the maintenance is carried out by a third party who has the interest of maintaining the ditch at low cost. Besides these conflicting interests the ditch has interfaces with the project Blaricummermeent and surrounding yet to be constructed roundabouts. This makes the design space of this problem limited. VDC is used to facilitate the solution for this problem.

A. Project phase(s)

- *In which project phase(s) VDC is applied?*
  The iRoom was used in the final design phase. The design for the complete project was almost finished. However the border ditch remained an unsolved problem. The session was used to solve remaining design issues of the border ditch together with the stakeholders.

B. Objective

- *What is the objective to be achieved from the iRoom session?*
  The objective of the iRoom session was to: "Make all choices that are needed to complete the final design". These design choices had to ready be submitted to the municipal councils. The objective was introduced to the participants at the introduction of the iRoom session. All participants agreed to this objective with the addition that "at least the principles will have to be completed".

C. Stakeholder and participants

- *Which stakeholders are present and why are these involved in the iRoom session*?

  There was a large delegation in the iRoom session as all important stakeholders were present. This gave an indication of the importance of the iRoom session and interest from the stakeholders. The participants were from: Project Blaricummermeent, Waternet, municipality Blaricum and Huizen. The participants were project managers, process managers or designers.

2. Application of VDC

A. Program & organisation

- *What is the scope of the iRoom session?*

  The scope of the iRoom session was defined together with the participants. They formulated the scope of the session as: "agreement between stakeholders on arrangement, maintenance and design of the border ditch". The session was tightly scope to the ditch and other aspects of the project Blaricummermeent were not discussed.

- *What issues are addressed in the iRoom session?*

  The iRoom facilitator presented six issues for the border ditch to the stakeholders for discussion in the iRoom session (rotation curves, boat ramps, trees and interfaces bus stop and roundabouts). The stakeholders had the possibility to add additional issues (pumping station and position of cranes). These issues were discussed sequentially. The idea was that the principles of the first solution will ease the discussion on the second.

- *What was the program of the iRoom session?*

  The program with a time schedule was immediately presented at the start of the session. The program was to start with an introduction of participants, scope and objective of the session. The following steps in the session were to debate on the substantive discussion points. For this a total of two hours including a break was reserved. At the end of the session the planning and tasks were discussed. The total session lasted four and a half hours.

13:30 – 13:45	1. Opening & introduction
13:45 – 14:00	2. Report previous meeting
14:00 – 14:05	3. Objective iRoom session
14:05 – 16:00	4. Discussion points
15:00	- Break -
16:00 – 16:15	5. Additional points
16:15 – 16:30	6. Planning and tasks
16:30 – 17:00	7. Clossing

- *How was the session organised?*

  An independent facilitator had the lead during the complete iRoom session. The facilitator was experienced with the use of VDC and the iRoom. However, he was unfamiliar with the substance of the project and that gave him a neutral position. This had a positive effect as he was unprejudiced towards stakeholders and vice versa. The project leader of Royal HaskoningDHV was also present as a participant of the iRoom session. The Smartboards were operated by two designers that were familiar with the drawings, and intervened when technical feasibility was needed to be discussed. This organisation set-up proceeded well during the session.

B. Use of iRoom

- *How are the stakeholders positioned in the iRoom?*
  The tables were positioned in a large V. Participants seated therefore both in front of the Smartboards and to each other. The seating worked well as the participants were able to discuss without having to turn around and were able to observe each other. Also they were in front of the Smartboards. However, there was a restriction in walking to the Smartboard as participant had to walk all around to tables to make sketches on the Smartboards.

- *How were the Smartboards used during the iRoom session?*
  Three Smartboards were used in the iRoom session. In general the Smartboards present the following during the iRoom session:

  Left Smartboard: Aerial photos, reference work, street level photos
  Centre Smartboard: Presentation, working document, drawings
  Right Smartboard: CAD-drawings, Planning

  The facilitator of the iRoom session was the main user of the Smartboards. He had the lead and was capable of translating the ideas of the participants on to the Smartboards. This resulted in that the participants barely have touched or used the Smartboards. This approach worked very well as most participants are not experienced in using these technologies. By sketching and writing down the ideas of the participants the facilitator was able to keep momentum in the session and no time was lost. All sketches were made in one single working document that was presented on the centre screen. This working document was well prepared and all discussion points were shown with technical drawings in this presentation. The facilitator could simply add the decisions made in to this document. At the end of the session this document was used as a report of the session that was emailed to the participants almost instantly.

  The Smartboards often were used to give an overall picture to the problem to the stakeholders. For example the left screen was used to show the surrounding, the middle screen for sketches and the third screen to show some technical drawings. This showed a clear added value for discussing this problem in the iRoom.

C. Visualisations and metrics

- *How are product, organisation and process visualisations used?*
  Product visualisation were used frequently during this iRoom session, especially during the discussion of the issues. Various top-views from the final design were presented. They were used to visualise the new situation and how the border ditch was able to fit in the surrounding. The use of 2D visualisations was probably sufficient in this iRoom session regarding the objective. 3D visualisation were only used one time during this session. The CAD model on the third screen was used to clarify certain dimensions and technical interfaces with between the ditch and the bus stop on the roundabout.

Organisational visualisations were not used during the iRoom session. Properly because during this phase and the objective of the iRoom session. However, it could have been relevant to first map the interest of the stakeholders on the border ditch. The present stakeholders were only presented at the first slides.

During the iRoom session additional tasks were written down on the working document. By this everyone had clear who has to do what. At the end all these tasks were picked from the document and were compared to the product planning. The project planning was a visualisation using MS Project. However they were not able to adjust the planning quickly rather than writing over it.

- *How are product, organisation and process metrics used?*
  The VDC method describes to measure performance on product, organisation and process using metrics. The decision making in the session was not made on the basis of metrics but on consensus among stakeholders. Aspects such as costs, risks and planning were not included detailed in the decision. However, these aspects were often during the discussion considered with the designers. For some stakeholders this approach was not sufficient as they did ask to work out these decisions in terms of cost and planning subsequently to the iRoom session. This argues that there is a request to use these kind of metrics during the iRoom session. The use of visualisations was not enough to convince the municipality councils by the participants. The use of metrics can provide more value to the iRoom.

- *What was the VDC maturity level of the session?*
  During the session visualisations and metrics were used individually. Integration of models and metrics with each other was not observed during this session. This indicates that the iRoom session can be typed as the first maturity level according to the VDC theory. Some integration however was reached during the session. For example all drawings and sketches were made in one single working document. This gave in the end the stakeholders an overview of all the decisions that were made during the sessions.

D. Design activities

- *Which design steps are taken in the iRoom and how are they applied?*
  The application of the SE theory during the session was limited as it was not very explicit. However, the steps were present but not always as a clear sequence.

  - *Problem Definition*
    The problem definition step was presented during the start of the iRoom session. The objective, scope and program of the iRoom session were discussed together with the participants. Breaking down the problem in a set of issues made clear to everyone what had to be addressed. However, the session lacked on an identification of needs, alterables and constraints of the project by all the stakeholders. Waternet initiated to start off with a simple presentation. He anticipated that his interest was often seen as difficult and conflicting to other stakeholders. Therefore in his presentation he clarified what he needed to maintain the ditch and showed visually the different types of equipment he used.

This created instantly awareness among the other stakeholders. During the session other stakeholders were constantly considering the demands of Waternet. Although the presentation of this stakeholder was not planned by the facilitator, it was of benefit during the rest of the session and the selection of alternatives.

- *Value System Design*
  During the session this step was very limited. Objectives were not made very explicit for the border ditch. Therefore also no thought has gone on how the participants evaluate alternatives other than considering the presentation of Waternet. On the other hand all stakeholders were present and could immediately criticize mentioned alternatives.

- *Synthesis of Alternatives*
  This step was clearly taken in the session. Alternatives were collectively generated. The feasibility of this alternatives could immediate be evaluated by the attending designers and experts. This showed the added value of the iRoom as all stakeholders and experts were present in one single room. The idea was to discuss the issues one by one. However there were many interfaces between these issues that later alternatives per location were discussed in a more incremental approach.

- *System Modelling and Analysis*
  The alternatives were not modelled and analysed relative to the objectives. They were analysed and discussed with experts in the room but not using a quantitative method. Aspects as cost, planning and quality were not made explicit for the alternatives but considered using the expertise of the designers.

- *Refinement of Alternatives*
  Optimization of the generated alternatives on the basis of analyses was not executed during the iRoom session as the alternatives were not analysed.

- *Decision Making*
  The decision making in the session was made on the basis of consensus. The facilitator suggested some design that could be made. Stakeholders discussed the alternatives together and did chose a solution to the problem together if everyone agreed. A ranking of alternatives by analysing or modelling was not performed. As this was a rather simple problem the question remains if this would be really necessary.

- *Planning for action*
  During the final step of the iRoom session a plan was made for continuation. This included all the steps that have to be taken to conclude the final design phase. With the help of MS Project these were discussed.

3. Results of application VDC

A. Task related outcome

- *Was the objective of the iRoom achieved?*
  The objective to make all the choices that are needed to complete the final design was achieved. All substantive open discussion points were completed during this session. This indicated that the use of the iRoom contributed to the objective.

- *Did the use of the iRoom result in new insights and solutions?*
  It is hard to define whether the use of the iRoom was essential to the developed new solutions. However new solutions were developed and as all stakeholders were present, it gave everyone the same insight to the problem and possible alternatives. This session was clearly insightful for the participants that were present.

D. Process related outcome

- *Did the iRoom contribute to the involvement of stakeholders?*
  Most participants were observed involved during the iRoom session. However some stakeholders were more involved than others. At the start of the session the participants were introduced to the iRoom and the functionality of the Smartboards. The participants were invited to use these Smartboards and debate on possible solutions for the design issues. During the session participants sometimes used the Smartboards. Stakeholders actively debated how to solve the design problem. By this all stakeholders were involved in this process, possibly resulting in greater support for the solution.

- *Does the iRoom contribute to the perception of stakeholders?*
  The iRoom contributed to the perception of stakeholders by using visualisations in the discussion. For example on one discussion the perception of stakeholders changed by the use of the iRoom. The debate was on if the height of the ditch would interfere with the slope to the bus stations. Some argued that the slope of the ditch would be too steep. However, by quickly looking into 3D CAD models during the discussion everyone could argue with the same perceptions.

- *Does the iRoom contribute to a shared understanding among stakeholders?*
  The iRoom helped in creating a shared understanding among stakeholders. This was most visible by the presentation of Waternet. He presented clearly what his objective was. By presenting his equipment using visuals and specifications every stakeholder understand he was needed to maintain the ditch. This clearly created a shared understanding. The use of the iRoom therefore resulted in a shared understanding among the present stakeholders.

- *Does the iRoom contribute to the decision making process?*
  All decisions that were have to be made were taken during the iRoom session. The iRoom facilitated in this decision making process. By presenting visualisations that helped during discussion. During the process different alternatives were sketched on the drawings. By this the Smartboards helped in clarifying arguments of stakeholders in the decision making process. However, not all stakeholders were able to make decisions completely as visualisations alone were not sufficient. In the end municipality councillors will have to make the definitive decision and these were not present during this session.

II.B Renewal St. Sebastiaansbrug

Time: 14:00 – 16:30 op 26 April 2012
Location: iRoom The Hague

1. Conditions of application VDC

A. Necessity of VDC

- *Why is VDC used in this project?*
  The St. Sebastiaansbrug at the municipality of Delft must be replaced. Royal HaskoningDHV is responsible for the technical development and supervision during the construction of this bridge. The iRoom is used frequently in this project to discuss the project process and design considerations with the client and main stakeholders. During the observations, the iRoom was used to define principles of architectural design and to identify possible interfaces with the technical design. Earlier the iRoom was used to clarify the interest of the main stakeholders.

- *Which project complexity has contributed to the use of VDC?*
  The bridge is located in the middle of the municipality of Delft. Designing this bridge is complex due to the integration with the surrounding. Additionally, many stakeholders are directly responsible for the bridge. The province the owner of the moving part of the bridge and the municipality owner ramps of the bridge. Finally the region Haaglanden is owner of the tramline that will run over the bridge. This means that the alignment of these stakeholders interests are complex. This need for alignment between stakeholders results in the use of the iRoom in this project.

B. Project phase(s)

- *In which project phase(s) VDC is applied?*
  The observed iRoom was used at the start of the preliminary design. However the iRoom is planned to be used throughout the complete project.

C. Objective

- *What is the objective to be achieved from the iRoom session?*
  The objective of the iRoom session was to discuss the progress of the project. In this particular session the design space for the architectural design was discussed. During the session no clear objective was stated for the iRoom session. The idea was to discuss and identify the interfaces between the technical and architectural design.

D. Stakeholders and participants

- *Which stakeholders are present and why are these involved in the iRoom session*?
  During this session not all main stakeholders were in the iRoom. The province of Zuid-Holland together with their operation and maintenance department and the architect Zwarts & Jansma participated in this iRoom session. Not present were the municipality of Delft and the region Haaglanden, but these were also not invited. These stakeholders are involved in later iRoom sessions.

2. Application of VDC

A. Program & organisation

- *What is the scope of the iRoom session?*
  The scope of the iRoom session was not very clear and not explicitly stated during the start of the session. This was noticeable during the iRoom session as the discussion was on many diverging issues. For instance at one point the discussion

was on a detailed component level on the traffic barriers of the bridge and later the discussion was more on a system level on the type of bridge. The session focused on the interface between the technical and the architectural design. This was very broad approached by the participants.

- *What issues are addressed in the iRoom session?*
  There were many issues addressed as bottlenecks in the design for Royal HaskoningDHV. These were bottlenecks on installations on the bridge, tramline design and road design that were presented to and discussed with the participants.

- *What was the program of the iRoom session?*
  The program started with a simple introduction. This was followed by a presentation on the progress and bottlenecks in the design. A simple program and time schedule was presented at the start of the session.

1. Opening & introduction
2. Report previous meeting
3. Information exchange
4. Progression activities

- *How was the session organised?*
  The session was leaded by the client. He started the iRoom session and welcomed everybody to the iRoom. After this he gave the word to the designers of Royal HaskoningDHV but he remained the leader throughout the whole session. The Smartboards were controlled by operators.

B. Use of iRoom

- *How are the stakeholders positioned in the iRoom?*
  The tables were positioned in a u-shape configuration in front of the Smartboards. The seating was well arranged and had no negative influence on the discussion. Reaching the Smartboards was a bit problematic as participants have to completely walk around everyone to get in front of the Smartboards.

- *How were the Smartboards used during the iRoom session?*
  All three Smartboards were used in the iRoom session. In general the Smartboards present the following during the iRoom session:

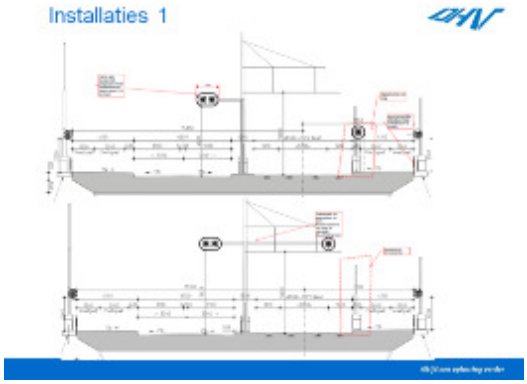
Left Smartboard:	PowerPoint
Centre Smartboard:	CAD-drawing
Right Smartboard:	Google earth

  The Smartboards were mainly used for presentation purposes. The drawing functionalities on the Smartboards were barely used. Only the architect did make some sketches on the board to clarify his ideas to the participants. The Smartboards were used to give an overall picture of bottlenecks by presenting different drawings side by side.

C. Visualisations and metrics

- *How are product, organisation and process visualisations used?*
  Only product visualisations were used during this iRoom session. Many 2D design drawings were presented to the client and architect to clarify current design bottlenecks that had to be tackled. In one case a 3D model of the bridge was presented to show the integration of the bridge in the environment. The example shows two alternatives compared that was discussed during the iRoom session.

- *How are product, organisation and process metrics used?*
  Metrics were not used during the iRoom session. Probably because bottlenecks were only identified and presented to participants.



- *What was the VDC maturity level of the session?*
  Only some individual visualisations were used and there was no integration between models. By this it can be stated that this session had VDC maturity level 1.

D. Design activities

- *Which design steps are taken in the iRoom and how are they applied?*
  No clear steps were taken, other than identifying problems in the current design. In some cases there was discussion on how these bottlenecks could be tackled or some alternatives were given. However no decisions were made accordingly as the session was more exploratory of nature.

3. Results of application VDC

A. Task related outcome

- *Was the objective of the iRoom achieved?*
  There was no clear objective to this iRoom session other than discussing the project progress. From that point of view the iRoom was successful as all stakeholders had in the end clear what the technical bottlenecks are at the moment. However the iRoom could have been used to solve some of these bottlenecks together with the participants. Now many problems were identified but no solutions have been developed. From this last perspective the iRoom session was less successful as it raised more questions in some cases than were actually solved.

- *Did the use of the iRoom result in new insights and solutions?*
  The use of the iRoom gave insights to all participators into the project process and current bottlenecks to the stakeholders. However, the application of VDC did not clearly resulted in new solutions.

B. Process related outcome

- *Did the iRoom contribute to the involvement of stakeholders?*
  It is hard to define whether the iRoom resulted in more involvement from the stakeholders. The iRoom had more an informative character. Besides two main stakeholders were not present during this iRoom session. However, during the iRoom session the participants actively debated on the issues of this project. This made them involved in the design process of Royal HaskoningDHV.

- *Does the iRoom contribute to the perception of stakeholders?*
  The iRoom helped stakeholders to give insight in the progress and the technical issues in the project. For example, one drawing showed the slope of the ramps to the bridge. These intervened with the requirements that are used for bicycles, resulting that there would be a gap for a meter in height at the start of the bridge. For this a

suitable solution has the be created. The use of this visualisation made clear to all stakeholders what the problem is.

- *Does the iRoom contribute to a shared understanding among stakeholders?*
  This is not observed during the iRoom session. At one particular point in the session the architect did argued that the type of bridge is excessive for what was really necessary. He insisted that the bridge only had to lift for a few meters as other fixed bridges on the river already gave a limitations to ships. However, he wasn't able to use the iRoom to come to a shared understanding among the stakeholders. Mostly because this session was not arranged to solve certain design alternatives but rather to identify and discuss bottlenecks.

- *Does the iRoom contribute to the decision making process?*
  The objective of the iRoom session had a more informative character instead of making decisions on the project. Therefore the iRoom session did not contributed directly to the decision making process as only issues were presented to the stakeholders. However it did help Royal HaskoningDHV by validation of certain design choices with the stakeholders.

II.C Traffic measures renewal Zaanbrug

Time: 10:00 – 14:00 on 15 May 2012
Location: iRoom Amersfoort

1. Conditions of application VDC

A. Necessity of VDC

- *Why is VDC used in this project?*
  The Zaanbrug will be renewed. During this renewal the bridge will be closed for traffic for a time. This means that traffic measures are needed in the surrounding community. These measures should be defined and established for the start of the construction of the bridge. In addition, there is a temporary bridge required for cyclists and pedestrians. A feasible design is needed that has a joint agreement of all stakeholders. The iRoom is used twice in this project to facilitate this process.

- *Which project complexity has contributed to the use of VDC?*
  The bridge facilitates a large flow of traffic in the region. As a result, the consequences are considerably when this bridge is closed. It is complex to understand what traffic measures work and which do not on a network level. The temporary will be located in the city centre. As for this project limited space is available make the integration with the surrounding difficult. The iRoom is used to provide insight into these effects.

B. Project phase(s)

- *In which project phase(s) VDC is applied?*
  The session was held to conclude on the research phase and to initiate the definition and program of requirement phase. In a later phase the iRoom will be used again to with the stakeholders.

C. Objective

- *What is the objective to be achieved from the iRoom session?*
  The iRoom session had the following objective: "Defining program of requirements engineering". This program is needed to develop a design which is suitable for permits. An agreement on this objective was to be achieved by the stakeholders.

D. Stakeholder and participants

- *Which stakeholders are present and why are these involved in the iRoom session?*
  There were 15 participants present in the iRoom session from different stakeholders. Most of the important stakeholders were present, these were: Hoogheemraadschap and the municipalities Zaanstad and Wormerland. Expert were available from Royal HaaskoningDHV for the traffic advice and design and Goupappel Coffeng for the mobility plans. Stakeholders that were missing in the iRoom session were: neighbours. entrepreneurs, emergency services and Schuttevaer. These stakeholders will be involved in the project in a later phase.

2. Application of VDC

A. Program & organisation

- *What is the scope of the iRoom session?*
  The scope of the session was presented at the start. The scope was to reach agreement between stakeholder on: requirements, risks and issues. This was presented during the introduction of the session.

- *What issues are addressed in the iRoom session?*
  The session was split in two major issues. At first the session was about traffic measures that have to be taken once the bridge will be closed for traffic. For this the analysis was and some alternatives were discussed with the participants.

- *What was the program of the iRoom session?*
  The program was presented at the introduction of the session. However, no clear time schedule was presented. The program was started with an introduction of the iRoom and the participants. The program was split into two subjects: the traffic measures and the temporally bridge. At the results traffic studies were presented by Goupappel Coffeng. Then the session would continue on the temporary bridge and will discuss on: Considerations location, issues, program of requirements and risks. There was many planned for this iRoom session in the timeframe that was available.

  1. Opening & introduction
  2. Results traffic studies
  3. Information exchange
  4. Considerations location temporary bridge
  6. Bottlenecks
  7. Program of Requirements
  8. Risks
  9. Follow-up

- *How was the session organised?*
  The session was organised a by various individuals. There was no main facilitator throughout the session. Each subject of the program was presented by someone who was had the expertise. This had the advantage that the presenter exactly was aware of the bottlenecks and progression of these subjects. However this resulted in that the session was fragmented and little integrated. The host of the iRoom session was the project leader of Royal HaskoningDHV. He introduced the session and was responsible for the progress. The Smartboards were operated by a designer who was familiar with the use of the iRoom.

B. Use of iRoom

- *How are the stakeholders positioned in the iRoom?*
  There were six tables for two persons placed in the iRoom session. These tables were positioned in a curve of two rows towards the Smartboards. The stakeholders from the same organisations were seated together. Because the tables were positioned in rows stakeholders were not able to see each other as they all were positioned towards the Smartboards. This was not ideal in some discussions as stakeholders had to turn around completely. The use of individual tables had its benefits as stakeholders were easily able to walk towards the Smartboards for sketches.

- *How were the Smartboards used during the iRoom session?*
  Three Smartboards were used during the iRoom session. In general the Smartboards present the following during the iRoom session:

Left Smartboard:	Presentation
Centre Smartboard:	CAD-drawings
Right Smartboard:	Aerial photos

  The Smartboard were mainly used for presentation and visualisations purposes. For example one screen was used to demonstrate the traffic simulations. Another screen showed some aerial photos and the other screen photos on a street level. This gave the participants a complete picture of the problem and were able to seek for possible solutions.

The interaction with the Smartboards remained limited throughout the session. During the introduction of the session the participants were introduced shortly to the possibilities of the iRoom and were invited to come up front if they wanted to clarify problems. However the session was more focussed on presentation and did not clearly invited participants to use the Smartboards interactively.

C. Visualisations and metrics

- *How are product, organisation and process visualisations used?*
  Visualisations were used very often. For example using aerial photos and pictures on sight, possible locations for the bridge could be assessed. This gave the participants an overall view of the situation that will had to be solved..

  The use of visualisations on the process and organisation was not used during this iRoom session. Interest of stakeholders were not mapped out or visualised. Also the planning was not discussed using visualisations.

- *How are product, organisation and process metrics used?*
  For the temporary bridge metrics were used to measure the performance of certain alternatives. At first the preliminary program of requirements was discussed and presented to the participants. From this a small multi-criteria decision analysis was made to rank location alternatives of the bridge. The participants were ask to define criteria and set the weight factors. However, the participants were not prepared for this exercise and had problems in defining the importance of the criteria.

- *What was the VDC maturity level of the session?*
  In this session visualisations and metrics were used individually. Integration and automatization of processes were not observed during the iRoom session. Therefore this session is in the first maturity level according to the VDC theory.

D. Design activities

- *Which design steps are taken in the iRoom and how are they applied?*
  Clear steps were not observed explicitly during this iRoom session. This was probably due to the large number of topics of the session. At first the traffic measures were discussed. After this the session focussed on the temporary bridge with locations, requirements and risk. This resulted in that participants tended to focus on solving the bottlenecks that were presented on a detailed level. For example there was a long debate about the flow of traffic that was coming out of an industrial terrain that generated much congestion on one of the major roads. Participants considered on possible adjustments that could be made. This process was not observed very structured. The result was that eventually no real progression was made other than that all participants agreed that this was one of the major bottlenecks in the project. During the second part of the session the steps were more obvious.

3. Results of application VDC

A. Task related outcome

- *Was the objective of the iRoom achieved?*
  The objective was to define program of requirements engineering. However during the session many effort and time went to the traffic measures part of the session. This made that there was less time to available define these requirements. As a result, in particular, this last step is less achieved.

- *Did the use of the iRoom result in new insights and solutions?*
  The iRoom certainly gave a contribution on new insights the participants. Especially for the traffic measures is by using visualisations has ensured that the perception is enlarged. However, it was not observed that the iRoom directly resulted in new solutions.

B. Process related outcome

- *Did the iRoom contribute to the involvement of stakeholders?*
  Stakeholders were involved in the project to clarify their principles. They were asked to brainstorm on design solutions for the traffic measures. This worked very well as participants actively held discussion. In addition, requirements were validated with the stakeholders. In this process participants were much more restrained. Probably most were not enough for prepared for this assignment.

- *Does the iRoom contribute to the perception of stakeholders?*
  The iRoom helped in providing a perception to the stakeholders on were the traffic would be problematic in the new situation. By using simulations and photos the perception of stakeholders on the problem was probably enlarged.

- *Does the iRoom contribute to a the shared understanding among stakeholders?*
  This was hard to conclude during the iRoom session. Mainly because the stakeholders didn't speak out their interest very explicitly. A shared understanding was created on the traffic measures. However clear no shared understanding was created on the requirements of the temporarily bridge.

- *Does the iRoom contribute to a the decision making process?*
  During the session not many decisions were made by the participants. Mostly they agreed on the proposals that were made by Royal HaskoningDHV. The stakeholders had a strong opinion on the traffic measures that had to be made. However there were restrained on the decisions they had to make on the functional design of the bridge. Probably because this was something that was new to them. It was clear that most participants were not able to come up with solutions for the problem.

- *Does the iRoom session exceeds to the expectations of the participants involved?*
  At the end the project leader of the province asked the participants if the session was valuable to them. All stakeholders responded positive to this question.

II.D Tunnelling rail crossings Ermelo

Time: 10:00 - 14:00 op 17 August 2012 & 10:00 - 14:00 op 17 September 2012
Location: iRoom Amersfoort

1. Conditions of application VDC

A. Necessity of VDC

- *Why is VDC used in this project?*
  Within the municipality Ermelo there consist three railway crossings. These crossings create an increasing problem and results in dangerous situations due to increasing railway traffic. Both cars and bicycles are faced with increasing waiting times. The situation is currently anything but optimal. Therefore the municipality of Ermelo and ProRail are exploring for a solution to this problem. Royal HaskoningDHV has been assigned to study possible alternatives for tunnelling the crossings. In this project the iRoom is used to facilitate this progress in close collaboration with the problem owners ProRail and the municipality of Ermelo. The effects of alternatives can be easily shown in the iRoom and makes it possible to achieve an acceleration in the project.

- *Which project complexity has contributed to the use of VDC?*
  In the iRoom alternatives can quickly be developed and examined with stakeholders on different aspects such as cost, quality, safety and maintainability. The iRoom can facilitate this process using visualisations based on technical data. Different project aspects can be examined both single as integral. To integrate these aspects was earlier seen as complex and due to technology not possible. Now the possibility exist it is expected that the feasibility of the project can be studied in a shorter period of time.

B. Project phase(s)

- *In which project phase(s) VDC is applied?*
  The iRoom is used in the research phase of the project. In this phase the feasibility of possible design alternatives is conceptualized. A follow-up is depending on the outcome of this phase.

C. Objective

- *What is the objective to be achieved from the iRoom session?*
  The objective of the iRoom session is to collaboratively define three alternatives per railway crossing and analyse these on different aspects and feasibility. The results of this study will be translated into a report so it can be used to make a go/no-go decision. Additionally, the iRoom has the objective to make the communication between the stakeholders more clear.

D. Stakeholders and participants

- *Which stakeholders are present and why are these involved in the iRoom session*?
  During the session the two main stakeholders were invited, the municipality of Ermelo and ProRail. In this project Ermelo is the main client. A total of seven participants from these stakeholder organisations were present during the iRoom sessions. From Royal HaskoningDHV a total of four individuals were involved in during these sessions.

2. Application of VDC

A. Program & organisation

- *What is the scope of the iRoom session?*
  The sessions were scoped to the three locations geographically: Horsterweg, Telgterweg and Stationsstraat. The design scope and principles were discussed collaboratively and were made explicit during the session for these locations. For these locations a concept for the tunnelling of the railway crossing was to be developed during the iRoom session.

- *What issues are addressed in the iRoom session?*
  Prior to the iRoom sessions, the participants were interviewed. On this basis, the important aspects and design principles were defined. During the session these were presented. These consisted all of technical design principles for the: terrain, train tracks, passage height and slope. On these basis for all locations various alternatives were generated for the longitude and cross section profile in the first iRoom session. Then these alternatives were considered in a second iRoom session of various aspects, such as cost, complexity and safety.

- *What was the program of the iRoom session?*
  For each of the iRoom sessions a script was developed. This script stated what subjects to discuss, time, action holder, actions, use of Smartboards and time. In this project phase two iRoom sessions were performed.

  During the first iRoom session at first the participants were introduced. Also an explanation of the iRoom and the rules were presented. Then the project and the design objective together with the design principles were presented to the participants. From this point the participants are invited to develop alternatives for each of the three locations. Between the session the alternatives were modelled and cost analysis were made. In the second session the alternatives were ranked using a multi criteria decision analysis. With the use of visualisations all alternatives were ranked on different criteria.

c10:00 – 10:15	1. Opening & introduction
10:15 – 10:45	2. Design principles
10:45 – 11:00	3. Explanation VDC-Model
11:00 – 12:00	4. Location Horsterweg
	- Break -
12:20 – 13:20	5 Location Telgterweg
13:20 – 14:20	6. Location Stationsstraat
14:00 – 15:50	7. Summary and plan of

- *How was the session organised?*
  During the session the project manager was given the role of facilitator of the iRoom session. He was responsible during the iRoom sessions for guarding the process and to ensure that the objective is achieved. Thereby he also made sure that all participants were equally involved during the session. By this the facilitator was more withdrawn to the side to maintain a holistic view on the process.

  The project leader was responsible for the presentation and the substance of the iRoom session. He was observed to be experienced with the use of the screens and familiar the substance of the project. Two designers helped in and were in control of the three Smartboards. The team was experienced in working together, this had a positive effect on the progress during the session.

B. Use of iRoom

- *How are the participants positioned in the iRoom?*
  A u-shape was used for the positioning of the tables. The seating was well arranged and had no negative influence on the discussion. Reaching the Smartboards was a bit problematic as participants have to completely walk around everyone to get in front of the Smartboards.

- *How were the Smartboards used during the iRoom session?*
  The participants were actively invited to use the Smartboard. This was done by presenting the rules of the game. There was clearly presented towards the stakeholders what was expected of them. They were invited to come to the boards and create their own views and alternatives to the problem. In the second session the iRoom was used to make the multi criteria analysis together with the stakeholders and visualise the created alternatives in 3D.

  Left Smartboard: 3D Models, Aerial photos
  Centre Smartboard: Aerial photos, Multi Criteria Decision Analysis
  Right Smartboard: Presentation, Whiteboard

C. Visualisations and metrics

- *How are product, organisation and process visualisations used?*
  Product visualisations were used extensively. With the use of a VDC model various 3D visualisations of alternatives were easily presented on the Smartboards. This helped the stakeholders in examine the alternatives on various criteria such as: integration in the environment, safety, cost, complexity and support.

  Visualisations of the process were not observed during the iRoom session. The need for these type of visualisation can be seen as doubtful during this early phase of the project. There was no request to visualise the process. The same counts for organisational visualisation as there were also not observed. However it could have potentially provided an added value if the needs of stakeholders were visualised during the session.

- *How are product, organisation and process metrics used?*
  The use of metrics was observed as limited during the sessions and only product measures were used. These metrics were not used very explicitly during the sessions and used only on a modest detailed level.

  During the session various alternatives were generated for the design problem. Prior to this the synthesis of these alternatives the design principles were introduced. This gave the limitations of to the project. After the alternatives were developed they were examined during the second sessions. In this the different alternatives were ranked on different criteria. With the use of visualisations an estimation were been made. Prior to the session cost estimations were made for each alternative.

- *What was the VDC maturity level of the session?*
  Visualisations and metrics were used individually. With the use of the VDC-model that was made some integration was achieved. However true integration and automatization of design processes was not achieved during this session. By this the session can be typed as level 1 according to the VDC theory.

D. Design approach

- *Which design steps are taken in the iRoom and how are they applied?*

  - *Problem Definition*
    During the first steps of the sessions the problem shortly introduced presented with the help of a map view on the Smartboards. The problem was scoped to the various technical design freedoms that were presented to the stakeholders.
    a visualisations of the site. This gave the problem description a very technical character as various technical limitations to the project were presented.

  - *Value System Design*
    By presenting the technical limitations of the project became clear what alternatives would be suitable. However no thought has gone on what would be is a desired solution. Therefore this design step was observed as limited.

  - *Synthesis of Alternatives*
    The alternatives were generated collaboratively with the use of the Smartboard. By using sketches the participants were asked the make some designs for the new tunnels. All stakeholders were asked to implement their ideas. To guide this process some rules were presented in advance. The alternatives were generated on sequence of location on an abstract level. For each location various technical variations were set.

  - *System Modelling and Analysis*
    Once various alternatives were defined by the stakeholders a 3D model was made for each alternative. Between the two iRoom sessions for each alternative a cost analysis was made. With the use of the 3D model the stakeholders were able in the second session to analyse safety, integration in the environment and complexity on an abstract level.

  - *Refinement of Alternatives*
    During the analysis of the alternatives various refinements to the alternatives were suggested. However, due to time constraints these refinement were not able to be analysed during the iRoom sessions. Therefore some side-notes were made in were these refinements were suggested by the stakeholders.

  - *Decision Making*
    During the iRoom session the alternatives were ranked with the help of a multi criteria decision analysis. This was made in collaboration with the participants. First, the criteria were discussed and weighted. This gave some discussion during the iRoom sessions. Then a ranking was made for the alternatives. In a visualisation the results were presented to the stakeholders.

  - *Planning for action*
    At the end of the session a summary was made and a short evaluation of the session. During the session additional tasks were listed. These tasks are worked out in the report of the session.

3. Results of application VDC

A. Task related outcome

- *Was the objective of the iRoom achieved?*
  During the sessions for each locations three different alternatives were created successfully. The iRoom clearly contributed to this achievement. With the use of visualisations the stakeholders were more easily to construct and examine these alternatives.

- *Did the use of the iRoom result in new insights and solutions?*
  By addressing this project in the iRoom the effects of the proposed alternatives were instantly visible for the stakeholders. This gave the stakeholder a clear insight in which design solutions are possible on what costs and risks. On this basis, design considerations are made on which the iRoom is directly responsible during this project.

B. Process related outcome

- *Did the iRoom contribute to the involvement of stakeholders?*
  The stakeholders were actively involved during this iRoom session. All participants created ideas and had their suggestions and opinions on the design tasks. A productive setting was observed during the iRoom sessions.

- *Does the iRoom contribute to the perception of stakeholders?*
  The iRoom clearly contributed to the perception of the stakeholders. For example by conducting a multi criteria decision analysis with the help of 3D visualisations gave the stakeholders a clear perception on how the different alternatives relate to each other. Because they took part in this process, they are also aware of the design considerations.

- *Does the iRoom contribute to a the shared understanding among stakeholders?*
  It was observed that iRoom resulted in creating a shared understanding among stakeholders. in a number of cases, the participants did not understand each other clearly. To clarify certain ideas the participants were easily able to sketch this in the 3d models that were created.

- *Does the iRoom contribute to the decision making process?*
  At the final stages of the two sessions the different alternatives were analysed and ranked. This resulted in a consensus between the stakeholders, the iRoom has contributed to this. However the alternatives were analysed quickly and in a limited amount of detail. This attracts the value of this consensus into question. The position of stakeholders can change, as they suggested during the session, namely, if further analysis concludes on different results.

II.E Western Ring Road Alkmaar

Time: 14:00 – 16:30 op 24 April 2012
Location: iRoom Amersfoort

1. Conditions of application VDC

A. Necessity of VDC

- *Why is VDC used in this project?*
  The iRoom was used to actively involve the project group in a process where possible alternatives for the Western Ring Road are examined on feasibility. In an earlier study it was observed that the road will result in major congestions. There for a study to alternatives is executed. The iRoom was used to facilitate this process.

- *Which project complexity has contributed to the use of VDC?*
  The complexity in this project is the integration of the renewed Western Ring Round in the environment. In addition, there is a complexity in estimating the effects on a network level.

B. Project phase(s)

- *In which project phase(s) VDC is applied?*
  The project is a follow-up of a problem exploration. Now a research is executed to define possible alternatives. The iRoom is used in the research phase. During this project there were two iRoom sessions planned. The first session took place at the second step of this phase and the observed session at the fourth step (five steps in total) of this project phase.

C. Objective

- *What is the objective to be achieved from the iRoom session?*
  The objective of the first session was used to identify the problems, create a reference for the variation study and to identify possible solutions per intersection. The objective of the second iRoom session was to combine the alternatives at intersection level into three alternative solution for the whole West Ring Road of Alkmaar.

D. Stakeholders and participants

- *Which stakeholders are present and why are these involved in the iRoom session*?
  The stakeholders involved were: Province Noord-Holland, Municipalities of Alkmaar, Bergen and Heiloo. Absent in the iRoom was the "klankbordgroep" who has the role of advising and examining results on behalf of major market players.

2. Application of VDC

A. Program & organisation

- *What is the scope of the iRoom session?*
  The scope of the iRoom session was to find agreement between stakeholders on possible alternatives of the western ring road Alkmaar based on effectiveness, cost and embedding on a crossing, road and network level.

- *What issues are addressed in the iRoom session?*
  The project consist of seven intersections. For all these intersections 3 alternatives had been generated and had to be addressed during the session.

- *What was the program of the iRoom session?*
  At the introduction the program with a time planning was presented. The session started with a presentation of the results of alternatives per crossing. This was followed by a break. After this a break was planned. This was followed by a ranking of the possible alternatives. After this alternatives on a string level had to be created. Finally the session will be summarized and a planning for action be made.

  1. Opening & review previous session (+/- 20 min)
  2. Results traffic studies per crossing (+/- 60 min)
  - Break (+/- 15 min)
  3. Ranking alternatives (5 min)
  4. Defining string alternatives (+/- 60 min)
  5. Summary results (5 min)
  6. Plan of action (5 min)

- *How was the session organised?*
  The project leader was the facilitator of the iRoom session. This worked well, as he was well-informed on the project. Also he was familiar with the facilities in the iRoom. The Smartboards were controlled by an operator that was available. Also an expert of the models was present in the iRoom.

B. Use of iRoom

- *How are the stakeholders positioned in the iRoom?*
  The participants were seated side-by-side in front of the Smartboards. The effect was that the participants were mainly focused on the Smartboards and the facilitator. The interaction between the participants was not stimulated by this setup as they could not easily see each other.

- *How were the Smartboards used during the iRoom session?*
  Three Smartboards were used in the iRoom session. In general the Smartboards present the following during the iRoom session:

  Left Smartboard: 3D Models, Aerial photos
  *Centre Smartboard:*Simulations
  Right Smartboard: Presentation, Simulation results, Multi Criteria Decision Analysis

  The Smartboard were used extensively. As stakeholders had ideas they came to the front and explained them using sketches over the visualisations on the Smartboards. This worked well during this session and created a shared understanding among the participants. Also the Smartboards were used to visualise the routes of bicycles and agricultural traffic by letting participants sketch over the maps.

C. Visualisations and metrics

- *How are product, organisation and process visualisations used?*
  Only product visualisations were shown during this variation study. Product visualisations showed the integration of the alternatives in the environment on one screen. Participants were quickly able to obtain a perception of the impact on the alternative and interfaces with the surrounding. The other screen showed visualisations using simulations of the traffic. This visualised if a certain alternative was able to deal with the traffic or not. Organisation and process visualisations were not used.

- *How are product, organisation and process metrics used?*
  Performance metrics were used extensively during this session. In the first iRoom these metrics were defined. In this iRoom the performance of the alternatives was presented on the basis of cycle time and conflict load. The metrics were used to ease the decision making process.

- *What was the VDC maturity level of the session?*
  In this session visualisations and metrics were used individually. Integration and automatization of processes was not observed during this iRoom session. Therefore this session is in the first maturity level according to the VDC theory.

D. Design activities

- *Which design steps are taken in the iRoom and how are they applied?*
  The observed iRoom session was the second of a series of two. The first iRoom session discussed the steps from problem definition to synthases of alternatives. The second iRoom discussed the steps System Modelling and Analysis until planning for action.

  - *Problem Definition*
    (discussed in the first session, not observed)

  - *Value System Design*
    (discussed in the first session, not observed)

  - *Synthesis of Alternatives*
    (discussed in the first session, not observed)

  - *System Modelling and Analysis*
    Using simulations the alternatives that were defined by the participants during the first session were analysed. This analysis has been conducted between the two iRoom sessions as it takes time to do such kind of traffic simulations. The results were presented in the iRoom in the second session. This made it easy to see for the stakeholders on how the alternatives perform relative to the objectives. Additionally, 3D models have been fitted in Google maps.

  - *Refinement of Alternatives*
    On basis of the analysis alternatives were in some occasions refined so that they might perform better. However it was not possible to adjust the simulations instantly to the refinements.

  - *Decision Making*
    The alternatives have been ranked to support the decision making. During the session three strings of alternatives had to be chosen for further studies. This ranking helped the participants in this process. This ranking has been done on aspects such as traffic performance, cost, safety and environment.

  - *Planning for action*
    Three alternatives for the Western Ring Road have been made in the iRoom by the participants. The next step was to simulate these alternatives and examine the impact in a network level.

3. Results of application VDC

A. Task related outcome

- *Was the objective of the iRoom achieved?*
  The objective of the iRoom session was to find agreement between the stakeholders on three possible strings of alternatives. This objective was achieved in the iRoom session.

- *Did the use of the iRoom result in new insights and solutions?*
  The use of the iRoom clearly resulted in new insights and solutions. The iRoom helped stakeholders defining possible solutions. By using analyses they could be ranked on effectiveness. By this alternatives were refined and directly and new solutions were made.

B. Process related outcome

- *Did the iRoom contribute to the involvement of stakeholders?*
  Stakeholders were involved in the iRoom session. All participants had some opinions on certain alternatives and came with suggestions for refinement. The session had a very interactive setting.

- *Does the iRoom contribute to the perception of stakeholders?*
  The iRoom did contribute to the perception of stakeholders by using the visualisation of simulations and 3D models integrated in the environment. This gave them a holistic view on the alternatives. Stakeholders were actively involved in this progress.

- *Does the iRoom create a the shared understanding among stakeholders?*
  The iRoom helped in creating a shared understanding among stakeholders. With the use of the Smartboards ideas of stakeholders were shared. For example one insisted that they also had to think about the impact on bicycle routes. With the use of sketches his ideas for certain routes and helped in creating a shared understanding.

- Does the iRoom contribute to the decision making process?
  The iRoom did contribute to the decision making. This was achieved in several ways. For example in the iRoom the alternatives that were defined in the first session were analysed in the meantime. During the second session these alternatives were ranked and presented to the participant. They could easily see what alternatives were effective and this gave the participants guidance in their decision making.

- *Does the iRoom session exceeds to the expectations of the participants involved?*
  Participants suggested that they expected that the session would be more interactive and the string level of alternatives would have been able to simulate during the session. This was not possible as the simulations require some preparation.

Annex III Interview questionnaire

Introduction

- What is the scope of this project?
- What is your role and responsibility in this project?
- What are the main stakeholders in this project?

Expectation of application iRoom

- What was the motivation to apply the iRoom in this project?
- What was the objective to apply the iRoom in this project?
- What were the expectations on the application of the iRoom?

Experiences of application iRoom

- How did you experience the iRoom session in this project?
- What task related added value did you experience using the iRoom?
  - *Achieved objective*
  - *New insights and solutions*
  - *Productivity*
  - …
- What process related added value did you experience using the iRoom?
  - *Involvement*
  - *Perception*
  - *Shared understanding*
  - *Consensus*
  - …
- How did you experience the organisation and facilities of the iRoom session?
  - *Facilitation*
  - *Tools*
  - *Configuration*
  - …
- How did you experience the design approach in the iRoom?
  - *Visualisations*
  - *Metrics*
  - *Design steps*
  - …

Recommendations on application iRoom

- What conditions are in your opinion suitable for an iRoom session?
  - *Project phase*
  - *Problem*
  - *Complexity*
  - …
- What are the factors of success for using the iRoom?
- What role is suited for Systems Engineering in the iRoom?
- Are there any other recommendations on the iRoom?

Annex IV

Interview reports

A total of eight interviews have been conducted from five different cases. As the interviewees were in Dutch the reports are therefore reported so. The following interviews were held:

- *Border ditch Blaricummermeent*
  - Roel Trijbels – Project manager at project bureau Blaricummermeent
  - Ruud Zethof – Head of department Public Roads at municipality Huizen
- *Renewal St. Sebastiaansbrug*
  - Hans Millenaar – Project manager at province Zuid-Holland
  - Erik Steeneken – Project manager Tramline 19 at region Haaglanden
  - Timo van Eijk – Project coordinator at municipality Delft
- *Traffic measures renewal Zaanbrug*
  - Robert Visser – Project manager at province Noord-Holland
  - Simon Bukman – Project manager at municipality Over-gemeenten
- *Tunnelling rail crossings Ermelo*
  - André Hagen – Project manager at ProRail
  - Fons Kortrijk – Project manager at municipality Ermello

These interview reports have all have been validated with the interviewees once completed.

IV.A Municipality of Blaricum

Project: Blaricummermeent
Geïnterviewde: Roel Trijbels

Introductie

- Wat is de scope van dit project?
  Het maken van een (definitief) ontwerp voor de herinrichting van de zogenaamde "grenssloot" tussen de gemeente Huizen en de projectlocatie "De Blaricummermeent" in de gemeente Blaricum. De gemeente grens ligt in het midden van de huidige sloot, die als gevolg van dit project opnieuw ingericht dient te worden. Bij het vervaardigen van dit ontwerp is naast beide gemeenten ook Waternet als toekomstige beheerorganisatie van de nieuwe grenssloot betrokken.

- Wat is uw rol en verantwoordelijkheid binnen dit project?
  In mijn functie als projectleider hoofdplanstructuur van projectbureau De Blaricummermeent ben ik de (gedelegeerde) ambtelijke vertegenwoordiger van de gemeente Blaricum voor dit deelproject betreffende de herinrichting van de grenssloot.

- Welke stakeholders zijn betrokken in dit project?
  Naast de ambtelijke vertegenwoordigers van de beide gemeenten en Waternet zijn met name de bestuurders van deze organisaties belangrijke stakeholders, vanwege de "politieke gevoeligheden" rondom dit project.

Verwachting toepassen iRoom

- Wat was de aanleiding om de iRoom toe te passen in dit project?
  Het idee om de iRoom in te zetten werd geopperd door een adviseur van Royal HaskoningDHV. We hadden een ruimtelijk ontwerp probleem met de grensloot. Op ambtelijk niveau was er een wederzijdse behoefte om overeenstemming the krijgen overdit probleem. Bestuurlijk gezien ligt er een groot spanningsveld rondom deze sloot. Daarom hebben we besloten om dit probleem gezamenlijk op te lossen in de iRoom.

- Met welk doel wordt de iRoom binnen dit project ingezet?
  Om gezamenlijk tot een (ambtelijk) gedragen ontwerp voor de herinrichting van de grenssloot te komen, dat vervolgens teruggekoppeld kan worden aan de verschillende bestuurders voor verdere besluitvorming.

- Welke verwachting had u bij het gebruik van de iRoom?
  Om met behulp van de beschikbare technieken in de iRoom in een "snelkookpan omgeving" de ruimtelijke knelpunten m.b.t. het ontwerp efficiënt op te lossen. Daarnaast leek het iedereen een leuke ervaring om in de iRoom te gaan zitten, zonder al te hoge verwachtingen.

Ervaring toepassen iRoom

- Wat vond u van het gebruik van de iRoom binnen dit project?
  De iRoom is zeer geschikt om in een constructieve setting samen te werken aan bijv. een ruimtelijk (3D) knelpunt tussen verschillende stakeholders. De iRoom heeft zijn dienst bewezen. Op ambtelijk niveau is er een overeenstemming. Nu moeten er nog politieke besluitvorming plaatsvinden.

- Welke taak gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Doelstelling:* Ja, er is ambtelijke overeenstemming bereikt over het ontwerp van de grenssloot. Op deze manier was het eenvoudig om de ruimtelijke knelpunten in beeld te brengen en gezamenlijk naar oplossingen hiervoor te zoeken.
  - *Nieuwe oplossingen en inzichten:* In de iRoom zijn we tot nieuwe inzichten gekomen. Tijdens de sessie was een beheerder van de sloot van Waternet uitgenodigd, die uitleg heeft gegeven over de ontwerpeisen m.b.t. het varend onderhoud van de sloot. In de iRoom konden we dit idee verder uitwerken naar een oplossing.
  - *Productiviteit:* In dit project hadden we een ruimtelijk probleem. De sloot had raakvlakken met de omgeving. Hierdoor konden we nog niet tot een gezamenlijk gedragen DO komen. De iRoom zie ik hierbij als een soort katalysator door dit probleem integraal op te lossen waarbij iedereen de intentie heeft om eruit te komen.

- Welke proces gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Betrokkenheid:* Ja, iedereen was enthousiast en de iRoom sprak mensen aan.
  - *Beeldvorming:* Ruimtelijk knelpunten (3D) zijn moeilijk te visualiseren, maar door inzet van iRoom werden deze knelpunten beter inzichtelijk gemaakt.
  - *Gemeenschappelijk inzicht:* Ja, in de iRoom kon iedereen zijn ideeën vertalen door ze te presenteren op de schermen. Hierdoor kreeg iedereen een gemeenschappelijk inzicht in de mogelijke ontwerpoplossingen.
  - *Consensus:* Ja, van alle kanten, beter dan voorgaande overleggen, in de iRoom veel constructiever. In ieder geval ambtelijk, maar dat was het doel.

- Hoe heeft u de organisatie en faciliteiten van de iRoom sessie ervaren?
  Professionele hulpmiddelen en goede procesbegeleiding door Royal HaskoningDHV toegepast.
  - *Facilitatie:* De facilitator had kennis van zaken. Daarnaast was hij objectief en onpartijdig. We hebben bewust voor een onafhankelijke facilitator gekozen, dit was een van de voorwaarden omdat gedurende het project iedereen al enigszins bevooroordeeld was.
  - *Tools:* Doordat er gebruik gemaakt werd van meerdere Smartboards ontstond er een compleet beeld. Het gebruik hiervan was goed en voorbereid.
  - *Opstelling:* De tafelopstelling voldeed en was goed.

- Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?
  - *Visualisaties:* Door gebruik te maken van de aanwezige hulpmiddelen kon snel en efficiënt een ruimtelijk (3D) knelpunt worden opgelost. De visualisaties gaven een compleet beeld van het ruimtelijke knelpunt.
  - *Metrics:* De mate waarop we afwegingen hebben gemaakt was voldoende. Echter bleek achteraf toch op een aantal punten deze afweging anders uit te pakken. In de sessie werd op hoofdlijnen ontworpen. Gedurende de sessie is het dat moeilijk om de investerings- en onderhoudskosten goed in te schatten. Dit zou dan eerst moeten worden uitgewerkt en eventueel in een tweede sessie kunnen worden besproken.
  - *Ontwerpstappen:* De gemaakte ontwerpstappen voldeden prima. We hebben gelijk de knelpunten behandeld. Dit had ook iedereens voorkeur, want er was al veel besproken. Echter kwam Waternet in deze sessie in een keer met een hoop aantal aanvullende eisen t.a.v. varend onderhoud. Dit leidde tot extra benodigd ruimtebeslag voor de sloot waardoor ik vroeg me af waarom dit niet eerder kon worden aangegeven.

Aanbevelingen toepassen iRoom

- Onder welke project condities vindt u het zinvol om de iRoom in te zetten?
  Vooral bij ruimtelijke knelpunten waar stakeholders met verschillende meningen bij zijn betrokken, maar die wel de intentie hebben om deze samen op te lossen.

- Wat ziet u als succesfactoren voor het gebruik van de iRoom?
  Door professionele hulpmiddelen en goede procesbegeleiding kunnen lastige vraagstukken voor stakeholders inzichtelijk worden gemaakt en kan in een constructieve omgeving naar oplossingen hiervoor worden gezocht.

- Welke rol ziet u voor Systems Engineering binnen de iRoom?
  In dit geval is geen Systems Engineering toegepast, maar hiervoor zijn misschien wel mogelijkheden, bijv. om bij complexe vraagstukken door gebruik te maken van de aanwezige hulpmiddelen goede functionele specificaties op te stellen.

- Heeft u nog overige aanbevelingen?
  Niet alleen binnen Royal HaskoningDHV maar ook bij externe klanten meer reclame maken voor de iRoom, bijv. door een brochure (1 A4-tje) met een korte, heldere uitleg over de mogelijkheden van de iRoom aan collega's te verstrekken dat meegenomen kan worden bij (acquisitie)gesprekken.

IV.B Municipality of Huizen

Project: Blaricummermeent
Geïnterviewde: Ruud Zethof

Introductie

- Wat is de scope van dit project?
  De gemeente Blaricum ontwikkelt de wijk Blaricummermeent. Deze wijk grenst aan Huizen. Op het grensgebied moet de openbare ruimte (wegen, rotondes, duiker, Grenssloot) worden aangelegd dan wel aangepast.

- Wat is uw rol en verantwoordelijkheid binnen dit project?
  Ik ben afdelingshoofd openbare werken en in die zin verantwoordelijk voor het beheer van de openbare ruimte. In het project Blaricummermeent ben ik eerste aanspreekpunt voor de gemeente Huizen.

- Welke stakeholders zijn betrokken in dit project?
  Dit is een gezamenlijke opgave van de gemeente Blaricum, de gemeente Huizen en het waterschap Waternet.

Verwachting toepassen iRoom

- Wat was de aanleiding om de iRoom toe te passen in dit project?
  Na een aantal ontwerpvergaderingen bleek het moeilijk om over een aantal samenhangende ontwerponderdelen overeenstemming te krijgen. Dat was de aanleiding om een ontwerpsessie te beleggen, met alle partijen en ter plaatse een gezamenlijk ontwerp te maken.

- Met welk doel wordt de iRoom binnen dit project ingezet?
  Doel van deze sessie is om partijen bij elkaar brengen en direct resultaten laten zien. De uitkomst is een gezamenlijke geaccepteerd ontwerp.

- Welke verwachting had u bij het gebruik van de iRoom?
  Ik had verwacht dat de iRoom zou bijdragen aan een interactieve sessie, waarin alle medewerkers oog hebben voor elkaar en zicht hebben op een gezamenlijke geaccepteerd ontwerp.

Ervaring toepassen iRoom

- Wat vond u van het gebruik van de iRoom binnen dit project?
  Goed, dit was een behoorlijke stap in het ontwerpproces en heeft bijgedragen om ons over een dood punt te helpen.

- Welke taak gerelateerde meerwaarde heeft u ervaren met het inzetten van de iRoom?
  - *Doelstelling:* Ja, in plaats van volgtijdelijke acties, wordt direct gewerkt (en getoond) aan haalbare oplossingen.
  - *Nieuwe oplossingen en inzichten:* Nee, het inzetten van de iRoom heeft niet geleid tot nieuwe oplossingen. Die hadden elders ook bedacht kunnen worden, ik heb niets nieuws gehoord. Wel heeft de iRoom ervoor gezorgd dat er een gedragen oplossingen is gekomen.
  - *Productiviteit:* Door de iRoom konden we dit ontwerpprobleem sneller oplossen.

- Welke proces gerelateerde meerwaarde heeft u ervaren met het inzetten van de iRoom?
  - *Betrokkenheid:* Door deel te nemen aan zo'n sessie ben je (verplicht) betrokken bij het eindresultaat. Toch was de sessie van één tot vier aan de lange kant. Terugkijkend liep hierdoor op het eind de energie eruit.
  - *Beeldvorming:* In de iRoom worden gemaakte keuzes gemaakt, vervolgens zijn deze resultaten direct zichtbaar. Dit draagt bij aan de beeldvorming van alle deelnemers.
  - *Gemeenschappelijk inzicht:* De iRoom draagt hier aan bij door zijn visuele hulpmiddelen. Problemen en oplossingen konden hiermee direct geschetst worden.
  - *Consensus:* Ja, door gebruik te maken van de iRoom is er een overeenstemming.

- Hoe heeft u de organisatie en faciliteiten van de iRoom sessie ervaren?
  - *Facilitatie:* De ruimte en facilitatie was prima, maar ik vond het aantal ondersteunende mensen erg groot en dus kostbaar.
  - *Tools:* Deze interactieve borden werken prima.
  - *Opstelling:* Neutraal, de opstelling voldeed.

- Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?
  - *Visualisaties:* Dit is de kracht van de iRoom. De 2D tekenen in combinatie met enkelen technische CAD-tekeningen voldeden in deze sessie.
  - *Metrics:* Dit hebben we niet veel gebruikt. Gedurende de sessie kwam ineens een hoop nieuwe informatie op tafel. Hierdoor is het lastig alles goed in te schatten. Na de sessie werden de uitkomsten uitgewerkt in het ontwerp, toen pakte sommige zaken toch anders uit. Daarmee bleven tegenstrijdige belangen alsnog een issue.
  - *Ontwerpstappen:* De sessie verliep prima. Ondanks vond ik dat er veel mensen bij elkaar waren. Ik vroeg me af of dat nou echt nodig was voor zo'n slootje.

Aanbevelingen toepassen iRoom

- Onder welke project condities vindt u het zinvol om de iRoom in te zetten?
  De inzet van de iRoom kan altijd zinvol zijn, maar zeker als er aanleiding om een proces te versnellen of weer op gang te brengen. Veelal is er dan sprake van complexe opgaven.

- Wat ziet u als succesfactoren voor het gebruik van de iRoom?
  Visualisatie van oplossingen en alle ontwerpers in één ruimte met één doel. Voorwaarde is wel dat iedereen zich van te voren hieraan committeert.

- Welke rol ziet u voor Systems Engineering binnen de iRoom?
  Weet ik niet.

- Heeft u nog overige aanbevelingen?
  Ik ben benieuwd naar de kosten van 2 uur iRoom (inclusief bemensing).

IV.C Province Zuid-Holland

Project: Vernieuwen St. Sebastiaansbrug
Geïnterviewde: Hans Millenaar

Algemeen

- Wat is de scope van het project waarin de iRoom gebruikt is?
  Het project gaat om de vervanging van de St. Sebastiaansbrug te Delft. De huidige brug voldoet niet meer aan de eisen en is in slechte staat. Hierdoor is de brug tevens niet in staat om tramlijn 19 te faciliteren die de TU Delft moet verbinden naar het station. De brug moet hierdoor geheel worden vervangen en beschikbaarheid geven aan tram, bus, auto, fietsers en voetgangers. De activiteiten bevatten voorlopig ontwerp, definitief ontwerp en de realisatie van een nieuwe basculebrug. Voorafgaand is een haalbaarheidsstudie gedaan, hierin was Royal HaskoningDHV ook betrokken.

- Wat is uw rol en verantwoordelijkheid binnen dit project?
  Projectmanager voor het ontwerpproces namens de provincie Zuid Holland. De provincie is verantwoordelijk voor het voorlopig ontwerp, definitief ontwerp en realisatie. Dit proces is deels uitbesteed aan de markt maar de provincie is hierin eindverantwoordelijke. In een eerdere fase in geprobeerd het project als Design & Construct aan te besteden. Echter bleek al snel dat de markt niet op risico's zat te wachten, er had zich slechts 1 marktpartij ingeschreven. Daarom wordt het project nu als RAW-bestek op de markt gebracht. Het gaat om een standard oplossing, hiervoor is een innovatief contract niet nodig. Lastig is om te gaan met de omgeving en het besluitvormingsproces. Hoe ga je om met deze risico's, dit kan de markt niet.

- Hoe ziet de projectorganisatie er precies uit?
  Ingenieursbureau Royal HaskoningDHV heeft na een aanbesteding samen met Zwarts en Jansma Architecten opdracht gekregen voor het ontwerp en realisatie van de St. Sebastiaanbrug. Royal HaskoningDHV was al eerder betrokken in de haalbaarheidsstudie van dit project en zal verantwoordelijk zijn voor het technisch ontwerp. Zwarts en Jansma architecten is verantwoordelijk zijn voor het architectonisch ontwerp. Het ontwerp zal worden getoetst door Q-team. Daarnaast is regio Haaglanden betrokken in dit project. Deze zijn verantwoordelijk voor de realisatie van tramlijn 19.

Verwachting toepassen iRoom

- Wat was de aanleiding om de iRoom toe te passen in dit project?
  Door Royal HaskoningDHV werd geopperd om de iRoom te gebruiken in dit project om zo belangrijke stakeholders nauwer bij het project te betrekken. Samen met de gemeente Delft en de regio Haaglanden moeten wij met een gedragen oplossing komen voor de St Sebastiaansbrug. De iRoom is ingezet om dit proces te faciliteren.

- Met welk doel wordt de iRoom binnen dit project ingezet?
  De iRoom wordt gebruikt voor het voortgangsoverleg. Betrokken in dit overleg zijn de provincie Zuid-Holland, Royal HaskoningDHV en Zwarts en Jansma Architecten. Voor dit overleg is de iRoom niet noodzakelijk. Wel is de iRoom een fijne ruimte om dit overleg te faciliteren doordat tekeningen en andere bestanden gemakkelijk opgevraagd kunnen worden. Daarnaast heb ik deelgenomen in de iRoom toen deze werd ingezet bij de haalbaarheidsstudie. Hierbij waren de gemeente Delft en regio Haaglanden betrokken.

- Welke verwachting had u bij het gebruik van de iRoom?
  Mijn eerste kennismaking met de iRoom was bij de haalbaarheidsstudie. Voorafgaand aan die sessie heb ik mijn verwachting gebaseerd op de folder die ik meegekregen heb.

Verwachting was dat de iRoom beeldvorming zou vergemakkelijken. Daarnaast had ik het idee dat eenvoudig informatie kan worden uitgewisseld. Bij het gebruik maken van fysieke documenten (tekeningen) kan je snel en op elke plek zaken bekijken en bespreken met elkaar. Bij het digitaliseren ontstaan weer andere mogelijkheden waarbij handig situatie in lagen over elkaar heen kunt projecteren waardoor de verschil snel in beeld komen.

Ervaring toepassen iRoom

- Wat vond u van het gebruik van de iRoom binnen dit project?
  Ik zie de iRoom als een gemakkelijk instrument. Groot voordeel van het gebruik zit het in het eenvoudig kunnen delen van digitale informatie. Beeldvorming zie ik hierbij als de grootste toegevoegde waarde.

- Welke taak gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Doelstelling:* Van te voren had er beter nagedacht kunnen worden over het doel van de sessie. Nu werd de iRoom gebruikt in een soort van ontwerpoverleg. Echter had de iRoom een duidelijkere rol kunnen krijgen.
  - *Nieuwe oplossingen en inzichten:* In de haalbaarheidsstudie in de iRoom werd duidelijk dat het mijnbouwplein lager ligt dan verwacht. Hierdoor ontstaat een probleem met de helling van de brug. Dit is iets dat visueel inzichtelijk werd naar de deelnemers in de iRoom. Toch had dit probleem sterker opgepakt kunnen worden. Door bijvoorbeeld de impact duidelijk zichtbaar te maken. Zo hadden we dit ook gelijk naar een oplossing kunnen brengen.
  - *Productiviteit:* Ik zie als meerwaarde dat je in de iRoom snel bestanden kan oproepen en tonen. Vervolgens kan je hier interactief mee spelen. Zo kan het proces in een agenda op een groot scherm besproken en aangepast worden. Echter zou er naar mijn mening meer mogelijk moeten zijn dan ik heb waargenomen in de iRoom.

- Welke proces gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Betrokkenheid:* Nee, niet meer betrokken. Maar wel een meerwaarde in discussie om bijvoorbeeld het kruispunt in de scope van het project te nemen. Dit heeft alleen niet veel met de iRoom specifiek te maken.
  - *Beeldvorming:* Beeldvorming is erg belangrijk. De iRoom is een goed instrument dat gebruikt kan worden om ontwerp alternatieven te bespreken. Het kan ontwerpen meer tastbaar maken. Ik zie het als een soort ontwerpatelier. Verschillende ontwerpen zouden over elkaar heen gelegd kunnen worden waardoor inpassing en knelpunten duidelijk worden.
  - *Gemeenschappelijk inzicht:* In de iRoom kan je gemakkelijk informatie uitwisselen. Echter konden de deelnemers in de haalbaarheidsstudie lastig inschatten wat de impact het voor hun betekende. Met gebruik van kleur effecten hadden de eisen van iedere stakeholder inzichtelijk kunnen worden gemaakt.
  - *Consensus:* De iRoom heeft niet direct tot consensus geleid. In een andere ruimte hadden we een zelfde resultaat gehaald. Door een betere voorbereiding had dit mogelijk wel kunnen bijdragen.

- Hoe heeft u de organisatie en faciliteiten van de iRoom sessie ervaren?
  - *Facilitatie:* De iRoom ziet er gelikt uit, bediening moet je er wel op afstemmen. Het is een ruimtelijke omgeving die zich leent voor een dergelijke sessie.
  - *Tools:* Digitaal bestand in kaart, wirwar van lijstjes. Mijn advies is om dit professioneler in te steken. Profileer je met zo'n product flitsender. Op dit moment was er weinig voorbereiding, er moet meer mogelijk zijn.
  - *Opstelling:* Dit was prima.

- Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?
  - *Visualisaties:* Dit was goed, ik ben echter van mening dat veel meer mogelijk moet zijn dan wat ik heb gezien.
  - *Metrics:* Dit hebben we niet gebruikt.
  - *Ontwerpstappen:* Aan de voorkant had meer kunnen worden geïnvesteerd. Duidelijk was dat de sessie beter voorbereid had kunnen worden. Echte ontwerpstappen waren er nu niet. Dit was niet anders dan in een normaal overleg, echter nu met hulp van de instrumenten van de iRoom.

Aanbevelingen toepassen iRoom

- Onder welke project condities vindt u het zinvol om de iRoom in te zetten?
  In het project is discussie geweest over de plaatsing van het fietspad. De mijnbouwplein is lager dan verwacht, hierdoor is een probleem geweest met de heling en inpassing in de omgeving. In de iRoom kunnen dit soort knelpunten zichtbaar gemaakt worden over bestaand ontwerp. Zo zou doormiddel van kleur effecten duidelijk gemaakt worden wat de impact hiervan is op het bestemmingsplan en de eisen. Het creëren van beeldvorming is dus erg belangrijk.

  De iRoom kan gedurende het gehele proces gebruikt worden. Inpassingsvraagstukken in de ruimtelijke omgeving lenen zich erg goed voor een iRoom sessie. Belangrijker is om na te denken waarvoor de iRoom ingezet gaat worden en na te denken welke mensen vervolgens moeten deelnemen.

- Wat ziet u als succesfactoren voor het gebruik van de iRoom?
  - *Duidelijk doel:* Belangrijk is om een duidelijk doel voor ogen te hebben wat te bereiken met de iRoom sessie. Nu wordt de iRoom met name gebruik in het ontwerp overleg. Geef hem echter een duidelijke rol.
  - *Voorbereiding:* Voorafgaand meer investeren. Duidelijk was dat in de huidige voor de iRoom sessies weinig voorbereiding getroffen was. Er zou meer geïnvesteerd moeten worden in begeleiding. Hiermee kan je verkeerde verwachtingen en resultaten voorkomen. Dit zorgde ervoor dat er in de iRoom sessie geen besluiten konden genomen worden om dat de informatie niet aanwezig was.
  - *Juiste mensen:* Belangrijk dat de juiste mensen aan tafel zitten. Gaat het om een verkeerskundig vraagstuk zorg dan dat er een verkeerskundige aan tafel zit.

- Welke rol ziet u voor u voor Systems Engineering binnen de iRoom?
  De gemeente Delft wil op afstand betrokken zijn bij dit traject. Bij de sessies waren met name procesmensen aanwezig die screenen op uitgangspunten (PvE) en geen techneuten. De rol van de iRoom hierin maakt het daarom echter lastig. Binnen dit project zijn de eisen van de gemeente Delft, regio Haaglanden en de provincie Zuid-Holland door Royal HaskoningDHV gebundeld. Vervolgens is dit nieuwe PvE gevalideerd bij deze stakeholders waarbij zij afwijkingen moesten melden. Echter konden de stakeholders dit traject niet helemaal volgen waardoor het door elkaar heen is gaan lopen. Het SE ontwerp is te beperkt door deze bundeling en de voorgeschiedenis van het project. Daarnaast zit er geen toekomstvisie in het eisenpakket van de gemeente. Zou is er niet nagedacht over mogelijke verbreding van de brug.

- Heeft u nog overige aanbevelingen?
  Advies is om het professioneler in te steken. Profileer je met zo´n product flitsend.

IV.D Region Haaglanden

Project: Vernieuwen St. Sebastiaansbrug
Geïnterviewde: Erik Steeneken

Introductie

- Wat is de scope van dit project?
  Vernieuwen van de St. Sebastiaansbrug te delft. In 2004 is gestart met het besluit om tramlijn 19 over de brug heen te leggen naar de TU Wijk. Het project werd steeds groter en daarna werd het initiatief overgenomen door de provincie Zuid Holland om de brug te reconstrueren. Uit onderzoek van Movaris bleek dat de aanbruggen waren doorgescheurd. Daarbij werd in 2009 besloten dat de brug hoger moest worden. Hierdoor moest de brug geheel vervangen worden. Toen der tijd is het project aanbesteed volgens Design & Construct. Dit is echter mislukt omdat maar één aannemer zich had ingeschreven.

- Wat is uw rol en verantwoordelijkheid binnen dit project?
  Project- en procesmanagement namens regio Haaglanden voor tramlijn 19.

- Welke stakeholders zijn betrokken in dit project?
  De provincie Zuid-Holland is de hoofdopdrachtgever. Ook een deel van het project wordt bekostigd door regio Haaglanden en de gemeente Delft.

Verwachting toepassen iRoom

- Wat was de aanleiding om de iRoom toe te passen in dit project?
  Ik ben uitgenodigd in de iRoom door Royal HaskoningDHV en de provincie Zuid-Holland om overeenstemming te krijgen over het schetsontwerp voor de St. Sebastiaansbrug.

- Met welk doel wordt de iRoom binnen dit project ingezet?
  Ik was betrokken toen de iRoom werd ingezet bij het maken van het schetsontwerp. Het doel was om hierover overeenstemming te krijgen. De onderwerpen waren hierin het kruispunt bij Zuidpoort en conflicten met het VRI-ontwerp.

- Welke verwachting had u bij het gebruik van de iRoom?
  Samenwerking is belangrijk, alleen kun je het namelijk niet. Door de audio visuele middelen was ik voorafgaand erg enthousiast over dit concept.

Ervaring toepassen iRoom

- Wat vond u van het gebruik van de iRoom binnen dit project?
  De grootste fout was dat er verschillende mensen aan tafel zaten. Dit waren allen procesmensen en geen ontwerpers. Doordat RoyalHaskoningDHV met verschillende berekeningen kwam over de kruispunten haakte de meeste aanwezigen af. Het licht ging bij mij en de andere uit. Het bespreken van cyclus tijden was te technisch en zorgde voor veel misverstanden.

  Daarnaast zijn er wat project gerelateerde zaken die blijven terug komen. Zo past de brug niet in het bestemmingsplan. Er ontstond bijvoorbeeld ook veel discussie over de 4,8% helling voor fietsers dat niet aan de richtlijn voldoet. Echter waren daar al eerder afspraken over gemaakt. Ik begreep niet waarom dit nu weer een probleem was. Daarnaast ben ik van mening dat een tafelbrug geschikter is dan een basculebrug.

  Royal HaskoningDHV had dit meer kunnen voorbereiden. Er had moeten worden na gedacht welke mensen er uitgenodigd worden en wat men wil bereiken. Betrokkenen

waren hierdoor onvoldoende voorbereid en zowel de provincie als de gemeente zaten er hierdoor verkeerd in.

- Welke taak gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Doelstelling:* Er had meer moeten worden nagedacht over wat men wil bereiken. Het doel van de sessie was voorafgaand niet helder. Dit uiten zich in de sessie.
  - *Nieuwe oplossingen en inzichten:* De iRoom heeft niet direct geleid tot nieuwe inzichten en oplossingen.
  - *Productiviteit:* Mogelijkheid om tijdens een vergadering te ontwerpen. De iRoom geeft naar mijn mening deze mogelijkheid. Echter wat ik nu heb gezien was een gelikte presentatie. Het was gewenst om werkelijk te kunnen ontwerpen.

- Welke proces gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Betrokkenheid:* Ik kan me voorstellen dat betrokkenheid vergroot wordt. Echter aan mijn betrokkenheid mankeert het niet. Door de lange historie in het project wist ik al veel.
  - *Beeldvorming:* De iRoom had kunnen bijdragen aan de beeldvorming. Door bijvoorbeeld de verschillen te tonen met een tafelbrug had de iRoom een bijdrage kunnen leveren bij deze discussie. Zo kon de architect mij overtuigen met visualisaties dat te tramlijn een bocht over de brug moet maken. Jansma heeft hierdoor meer bereikt dan Royal HaskoningDHV zonder dat hij een iRoom nodig had.
  - *Gemeenschappelijk inzicht:* Nee, er zaten verschillende mensen aan tafel dit waren geen ontwerpers. Hierdoor ging bij veel mensen het licht uit en er ontstonden veel misverstand. De mogelijkheden zijn er wel, alleen dan moet het anders ingestoken worden.
  - *Consensus:* De houding van de gemeente is lastig in dit project. Er is geen besluitvorming als je niet goed samenwerkt. Hierdoor heeft de iRoom er niet voor gezorgd dat er een consensus kwam. De deelnemers zaten er verkeerd in en daardoor was de besluitvorming onvoldoende verankerd.

- Hoe heeft u de organisatie en faciliteiten van de iRoom sessie ervaren?
  - *Facilitatie:* Er had meer aandacht kunnen besteed worden aan hoe de sessie aan te sturen. Dit had mogelijk het resultaat van de sessie kunnen verbeteren.
  - *Tools:* De mogelijkheden zijn er in de iRoom. Zo zou je er live kunnenontwerpen tijdens een vergadering. Echter werd het nu niet zo gebruikt en dat was jammer.
  - *Opstelling:* Dat was prima.

- Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?
  - *Visualisaties:* Ik was enthousiast over de audio visuele middelen in de iRoom. Echter had de visualisaties overtuigender ingezet konden worden als dit goed was voorbereid.
  - *Metrics:* We hebben het over cyclus tijden gehad voor het kruispunt bij zuidpoort. Echter ging toen bij velen het licht uit en ontstonden veel misverstanden. Dit was te technisch in gestoken.
  - *Ontwerpstappen:* Er zijn niet echt stappen gemaakt. Dit was eerder een mooie presentatie van de technische knelpunten. Het was gewenst om tijdens de vergadering te kunnen ontwerpen en zo stappen te maken.

Aanbevelingen toepassen iRoom

- Onder welke project condities vindt u het zinvol om de iRoom in te zetten?
  De iRoom kan altijd wel gebruikt worden zolang er maar een duidelijk doel voor ogen is.

- Wat ziet u als succesfactoren voor het gebruik van de iRoom?
  - *Juiste mensen aan tafel:* Dit keer was duidelijk dat de verkeerde mensen aan tafel zaten, voor het schetsontwerp hadden deze technischer moeten zijn.
  - *Goede voorbereiding:* Dit overkomt verschillende verwachtingen, de huidige voorbereiding

- Welke rol ziet u voor Systems Engineering binnen de iRoom?
  Ik ben niet echt bekent met Systems Engineering

- Heeft u nog overige aanbevelingen?
  Ik was enthousiast over de iRoom voorafgaand. Het resultaat vond ik echter teleurstellend. Het gaat over communicatie. De iRoom zou dit op een goede manier kunnen ondersteunen.

IV.E Municipality of Delft

Project: Vernieuwen St. Sebastiaansbrug
Geïnterviewde: Timo van Eijk

Algemeen

- Wat is uw rol en verantwoordelijkheid binnen dit project?
  Projectcoördinator voor de St. Sebastiaansbrug namens de gemeente Delft. Mijn rol is het bewaken van het programma van eisen zoals dat door de gemeente is opgesteld. Hierbij moet ik de Delftse uitgangspunten afstemmen en assisteer ik projectleider Jacqueline Klaassen bij het bewaken van de projectscope en projectaspecten kwaliteit en tijd. Daarnaast neemt gemeente Delft deel aan het besluitvormingsproces. Dit is van te voren afgesproken in een samenwerkingsovereenkomst met de provincie.

- Hoe ziet de projectorganisatie er precies uit?
  Provincie Zuid-Holland heeft de regie in handen voor het project. De gemeente is een van de drie samenwerkende partijen binnen het project St. Sebastiaansbrug en zodoende ook medefinancier.

Verwachting toepassen iRoom

- Wat was de aanleiding om de iRoom toe te passen in dit project?
  We zijn door Royal HaskoningDHV uitgenodigd in de iRoom om de uitgangspunten voor het schetsontwerp te bespreken. Wij hadden een groot pakket aan eisen opgesteld voor de St. Sebastiaansbrug. Hierover was overeenstemming nodig tussen de belanghebbende.

- Met welk doel wordt de iRoom binnen dit project ingezet?
  Doel van het overleg was om suggesties te doen voor het schetsontwerp. Hierin werd door Royal HaskoningDHV een aantal punten uit het ontwerp gepakt. Hier zijn geen besluiten over genomen.

- Welke verwachting had u bij het gebruik van de iRoom?
  Ik was onbekend met de iRoom en wist niet precies wat het was. Ik verwachte een interactieve omgeving met als toegevoegde waarde live snel ontwerpen naar het resultaat of discussiepunten. Dat zorgt voor een versnelling van het besluitvormingsproces.

Verwachting toepassen iRoom

- Wat vond u van het gebruik van de iRoom binnen dit project?
  De samenstelling was onjuist. Er moesten diverse ontwerpkeuzes gemaakt worden. Dit konden wij echter niet gelijk doen omdat dit bestuurlijk lastig is. Er werd gebruik gemaakt van 3 schermen, hierop werd het volgende getoond: Foto van de omgeving, presentatie, digitale tekening. Hierdoor kon gedurende de presentatie of discussies direct op het onderwerp ingezoomd worden. Dat was prettig, ondanks de opstartproblemen.

- Welke taak gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Doelstelling:* Doel was om suggesties te doen voor het schetsontwerp. Echter zijn hier geen besluiten over genomen.
  - *Nieuwe oplossingen en inzichten:* Nee, lastig in te zien wat dit voor mij betekende. Ons doel was het bewaken van het PvE namens de gemeente Delft. In de sessie kon ik daar geen inschatting van maken. Hierdoor gaf het mij geen nieuwe inzichten.
  - *Productiviteit:* Nee, de iRoom heeft niet tot een versnelling van het project gezorgd.

- Welke proces gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Betrokkenheid:* Nee, ik heb niet het idee dat men nu meer betrokken is geraakt door de iRoom sessie. Het project heeft al een voorgeschiedenis daardoor is iedereen al betrokken bij het project. Wel zou de iRoom ingezet kunnen worden om het draagvlak bij andere stakeholders van voor tot achter te vergroten.
  - *Beeldvorming:* De iRoom heeft geen bijdrage geleverd aan het vergroten van de beeldvorming. Het schetsontwerp werd wel duidelijker en een ontwerp konden aanwezigen sneller doorgronden doordat de tekenaar snel bepaalde punten aan en uit kon zetten. Echter had een simpele beamer mogelijk hetzelfde resultaat gegeven.
  - *Gemeenschappelijk inzicht:* Nee niet specifiek. Wel ontstond naar aanleiding van de presentatie een discussie over of er verkeer mogelijk zou kunnen zijn op de busbaan. Hierdoor zouden mogelijk de eisen veranderd moeten worden. Echter had een beamer presentatie dezelfde discussie kunnen opleveren.
  - *Consensus:* Ik had de verwachting dat de iRoom de besluitvorming zou kunnen versnellen. Echter heeft de iRoom heeft hier geen effect op gehad. Een gewoon overleg had hetzelfde resultaat gegeven.

- Hoe heeft u de organisatie en faciliteiten van de iRoom sessie ervaren?
  - *Facilitatie:* Dit had beter gekund. Voornamelijk door meer te investeren aan de voorkant. Zo had het doel had duidelijker moeten worden geformuleerd en nageleefd.
  - *Tools:* Er waren er wat opstartproblemen met het tekenen op de smartboard. De iRoom heeft de potentie om mensen te overdonderen. Echter als je moet wachten tot alles werkt is de magie van de iRoom snel verdwenen.
  - *Opstelling:* Ik stel voor om een U-setting te gebruiken. Dit werkt prettig in vergaderingen, de opstelling was dus goed.

- Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?
  - *Visualisaties:* Dit was wel leuk. Doordat bepaalde lagen snel konden worden getoond konden we daardoor snel het ontwerp doorgronden.
  - *Metrics:* Metrics zijn niet toegepast gedurende de sessie.
  - *Ontwerpstappen:* Echt constructieve ontwerpstappen heb ik niet ervaren. Nu meer een presentatie waarbij we werden geïnformeerd dan een echte ontwerpsessie.

Aanbevelingen toepassen iRoom

- Onder welke project condities vindt u het zinvol om de iRoom in te zetten?
  De iRoom kan in verschillende fase van het project gebruikt worden. Wel is het belangrijk dat er een duidelijk doel voor ogen zijn waarvoor de iRoom ingezet zal worden. De iRoom is niet een doel op zichzelf. De iRoom kan goed worden ingezet in de beginfase van het project om uitgangspunten helder te krijgen, project scope te bespreken of een work breakdown structure te maken. Maar ook later kan de iRoom goed worden ingezet om alternatieven te bespreken. De iRoom kan dan worden ingezet om het effect van verschillende alternatieven weer te geven. De iRoom kan het draagvlak en de samenwerking versterken gedurende het gehele project, zowel intern als extern. Meerwaarde zit vooral bij het ontwerp en minder qua proces en organisatie.

- Wat ziet u als succesfactoren voor het gebruik van de iRoom?
  De Juiste mensen aan tafel, setting en een duidelijk doel

- Welke rol ziet u voor Systems Engineering binnen de iRoom?
  De iRoom kan goed gebruikt worden om eisen te valideren binnen dit schetsontwerp. Zo zouden de verschillende eisen van de partijen met kleur kunnen worden weergegeven.

IV.F Province Noord-Holland

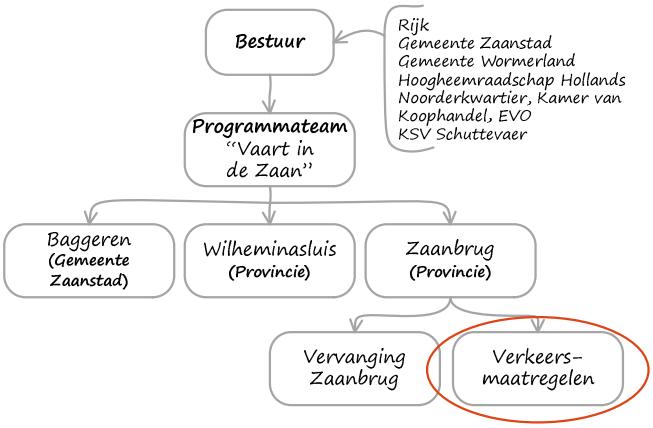
Project: Verkeersmaatregelen vernieuwen Zaanbrug
Geïnterviewde: Robert Visser

Algemeen

- Wat is de scope van dit project waarin de iRoom sessie gebruikt is?
  De scope van het project gaat om de verkeersmaatregelingen voor vervanging van de Zaanbrug in Zaandam. Dit project is een onderdeel van het programma "Vaart in de Zaan". Besloten in dit programma is om de Zaanbrug geheel te vervangen om zo de brug te verbreden. Hierdoor kunnen grotere schepen gemakkelijker door de Zaan manoeuvreren. Daarnaast is de huidige brug aan vervanging toe. De brug verbindt de gemeente Zaanstad met Wormerland. Wanneer deze burg vervangen wordt zijn aanzienlijke verkeersmaatregelen nodig omdat de brug een periode niet toegankelijk is voor autoverkeer. Hierdoor moeten er omleidingen uitgewerkt worden om de hinder te beperken, waarvoor er ook infrastructurele aanpassingen gedaan worden. Daarnaast zal er een tijdelijke brug geplaatst moeten worden voor fietsers en voetgangers. Over de locatie van de nieuwe brug is veel discussie geweest. Gezien er weinig vertrouwen is tussen de stakeholders zorgt dit zorgt voor extra complexiteit in het project.

- Wat is uw rol en verantwoordelijkheid binnen dit project?
  De provincie verzorgt namens de beide gemeenten het projectmanagement voor de vernieuwing van de Zaanbrug. De verkeersmaatregelingen zijn daar een onderdeel van. Van dit laatste ben ik de project en procesmanager.

- Hoe ziet de projectorganisatie er precies uit?



  Royal HaskoningDHV heeft samen de opdracht gekregen om een deel van de verkeersmaatregelen uit te werken naar een bestek. Het gaat hierbij om de fysieke verkeersmaatregelen. Daarnaast moet er een functioneel bestek komen voor de tijdelijke brug. Ook dit gedeelte is bij Royal HaskoningDHV neergelegd.

  De overige verkeersmaatregelen zoals het mobiliteitsmanagement, monitoring en omleidingen Openbaar Vervoer worden uitgewerkt door een ander ingenieursbureau.

Verwachting toepassen iRoom

- Wat was de aanleiding om de iRoom toe te passen in dit project?
  Het idee om de iRoom te gebruiken kwam vanuit RHDHV. Tussen de betrokken stakeholders is er veel discussie over de locatie in de nieuwe brug. In de iRoom kunnen we dit probleem gezamenlijk oppakken.

- Met welk doel wordt de iRoom binnen dit project ingezet?
  In dit project worden twee iRoom sessies ingezet. Deze eerste iRoom sessie wordt ingezet om eisen en wensen van stakeholders scherp te krijgen. Daarnaast om mogelijke verkeersmaatregelen te bespreken naar aanleiding van de verkeerssimulaties van Goudappel. Tot slot wilden we de uitgangspunten helder krijgen voor het functioneel aanbesteden van de tijdelijke brug. De tweede sessie zal plaatsvinden aan het eind van de ontwerpfase om het ontwerp met de verschillende stakeholders vast te stellen.

- Welke verwachting had u bij het gebruik van de iRoom?
  Ik had in een eerder project al kennis gemaakt met de iRoom. Ik was dus al op de hoogte van de mogelijkheden en kende het systeem. Van de iRoom verwacht ik dat je met goede interactie inzichtelijk kan krijgen wat de knelpunten in het project zijn. Vervolgens verwacht ik dat je met interactief ontwerpen een gedragen oplossing kan krijgen. Een iRoom sessie vereist dus een goede samenwerking.

Ervaring toepassen iRoom

- Welke vond u van het gebruik van de iRoom binnen dit project?
  Deze setting had ook ergens anders gekund, de iRoom was dus niet noodzakelijk. Een simpele beamer had hetzelfde resultaat gegeven. Het prettige is wel dat je ergens anders bent, en dat geldt voor alle betrokkenen. Je bent als het ware “uit je comfort zone”. Ik vraag me af of de sessie echt succesvol is geweest en of we het resultaat behaald hebben dat ik vooraf voor ogen had. Er ging namelijk heel veel aandacht naar de modellen omdat deze in twijfel worden getrokken. Het simulatiemodel klopte niet en dit zorgde voor veel tegengas. Het kunnen schetsen gaf echter in de iRoom wel meer duidelijkheid. Toen we eenmaal aankwamen bij het bepalen van de uitgangspunten voor de tijdelijke brug was iedereen al op. De sessie was aan de lange kant en veel energie is verloren gegaan in het eerste gedeelte. Er hadden meer pauzes genomen kunnen worden. Daarnaast waren de betrokkenen weinig instaat om zelf creatief deel te nemen. Waarschijnlijk zaten voor het onderdeel van het specificeren van de tijdelijke brug niet de juiste mensen aan tafel.

- Welke taak gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Doelstelling:* Ik weet niet of de sessie echt nut had. Er ging veel aandacht uit naar de modellen. Toch ontstond er leuke discussies gedurende de sessie, al had ik graag gezien dat we verder hadden gekomen. Daardoor was de sessie wel waardevol.
  - *Nieuwe oplossingen en inzichten:* Niet direct in nieuwe oplossingen, wel in nieuwe inzichten. Zo kwamen we er achter dat van te voren bedachte oplossingen in de modellen niet haalbaar bleken te zijn. Daar zit dan ook gelijk de kracht van de iRoom.
  - *Productiviteit:* Ik had verwacht dat de iRoom de samenwerking zou vergroten. Ik weet niet of de iRoom daar direct aan bijgedragen heeft. Echter doordat iedereen bij elkaar zit in dezelfde ruimte zou je eerder met een gedragen voorstel op tafel kunnen komen.

- Welke proces gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Betrokkenheid:* Ik ben van mening dat de betrokkenheid van de gemeentes wordt vergroot door de iRoom in te zetten in dit project. Dit zie ik ook als een van de grootste krachten van de iRoom.
  - *Beeldvorming:* Voor de verkeersmaatregelen hebben de simulatiemodellen de beeldvorming weten te vergroten. Er ontstond in ieder geval een constructieve discussie. Bij het tweede gedeelte van de sessie leek de beeldvorming niet veel vergroot te worden.
  - *Gemeenschappelijk inzicht:* De kracht van de iRoom kwam duidelijk naar voren bij de ontsluiting van het industrieterrein. Door gezamenlijk een oplossing te vinden voor

dit probleem werd helder dat dit een knelpunt is binnen dit project. Dit geeft draagvlak aan het probleem.
    - *Consensus:* Deze sessie was nog verkennend, daardoor hebben we nog niet een oplossing kunnen vaststellen. Dit zou moeten gebeuren in een volgende sessie. Wel hebben we kunnen vaststellen waar de knelpunten liggen.

- Hoe heeft u de organisatie en faciliteiten van de iRoom sessie ervaren?
    - *Facilitatie:* De facilitatie was goed, echter ging veel tijd verloren aan de simulaties. Hierdoor verliep het oorspronkelijke programma anders dan gepland. Dit was echter niet te wijten aan de facilitatie.
    - *Tools:* De Smartboards geven de mogelijkheid om gezamenlijk interactief te ontwerpen. Ik vond de tools prettig om mee te werken.
    - *Opstelling:* De tafelopstelling had anders gekund. Nu zat iedereen achter elkaar gericht naar het scherm. Dit is niet handig om samen te discussiëren.. Ik stel dus voor om meer een U-tje als opstelling gebruikt. Op deze manier hoeft niet iedereen zich steeds om te draaien.

- Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?
    - *Visualisaties:* Op zich was dit goed. Wel zou ik het idealer zou ik het vinden om met 3D modellen te werken. Dit maakt het net wat begrijpelijker voor de meeste deelnemers.
    - *Metrics:* Door gebruik te maken van het simulatiemodel werd het allemaal meer meetbaar. Ondanks dat dit tot veel tegengas zorgde dit wel voor meer draagvlak voor de problematiek.
    - *Ontwerpstappen:* We hebben veel tijd verloren aan de resultaten van de simulaties. Hierdoor kwam eigenlijk het gedeelte waarin we de uitgangspunten wilde definiëren voor de tijdelijke brug niet helemaal tot zijn recht.

Aanbevelingen toepassen iRoom

- Welke momenten in het project zijn volgens u geschikt een iRoom sessie?
  In ieder project zijn er een aantal fases waarin de iRoom geschikt is. Zou denk ik dat de iRoom goed gebruikt kan worden in de definitie, ontwerp en aanbestedingsfase. In de oriëntatie, contracttering en uitvoering denk ik dat de iRoom minder geschikt is.

- Wat ziet u als succesfactoren voor het gebruik van de iRoom?
    - *Uitgangspunten helder:* Belangrijk is dat dat iedereen de uitgangspunten helder heeft. Door tijdig iedereen op de hoogte te brengen kan iedereen zich op de juiste manier voorbereiden.
    - *Duidelijk doel:* Belangrijk is om een duidelijk doel voor ogen te hebben wat te bereiken met de iRoom sessie. Nu wordt de iRoom met name gebruik in het ontwerp overleg. Geef hem echter een duidelijke rol.
    - *Juiste mensen:* Iedereen moet er bij zitten. Maar met name de gemeentes en Hoogheemraadschap zijn essentieel om in een dergelijk project om bouwvergunningen te verkrijgen.

- Welke rol ziet u voor Systems Engineering binnen de iRoom?
  Systems Engineering is vrij nieuw voor mij en ik heb er zelf weinig ervaring mee. Wel geloof ik dat dit de manier van werken wordt. Daarom wil ik SE oppikken in het werk dat ik doe. In dit project wordt SE met name gebruikt voor de brug; deze wordt functioneel opgesteld. De iRoom zou kunnen worden gebruikt om eisen te bespreken met gemeentes. Daarnaast zouden ook SBS of OBS besproken kunnen worden in de iRoom.

IV.G Municipality of Wormerveer

Project: Verkeersmaatregelen vernieuwen Zaanbrug
Geïnterviewde: Simon Bukman

Algemeen

- Wat is de scope van dit project waarin de iRoom sessie gebruikt is?
  Vanuit de gemeente Wormerland ben ik betrokken bij het vervangen van de Zaanbrug. De provincie is de aanjager in dit project en wil de vaarweg de Zaan geschikt maken voor groter scheepsvaartverkeer. Een van de knelpunten is de Zaanbrug omdat de doorvaartbreedte deze brug is te smal voor grotere schepen. Daarnaast is deze gelegen na een bocht waardoor schepen moeilijk haaks de brug kunnen passeren. Wanneer de brug vervangen wordt zal deze een jaar niet beschikbaar zijn. Hiervoor moeten tijdelijk verkeersmaatregelen getroffen worden in de gemeente Zaanstad en Wormerveer.

- Wat is uw rol en verantwoordelijkheid binnen dit project?
  Ik ben beleidsadviseur ruimtelijke ordening bij de gemeente Wormerveer. Voor de Zaanbrug ben ik de projectleider en vertegenwoordig daarbij de belangen van de gemeente. Daarnaast leg ik verantwoording af aan de wethouders.

- Hoe ziet de projectorganisatie er precies uit?
  De provincie is de initiatiefnemer. Daarnaast is de Zaanbrug gemeenschappelijk goed van de Gemeente Wormerveer en Zaanstad. Hierdoor hebben al deze partijen een verschillend belang rondom dit project.

Verwachting toepassen iRoom

- Wat was de aanleiding om de iRoom toe te passen in dit project?
  Het idee om de iRoom in te zetten kwam uit de Provincie en Royal HaskoningDHV. Voorafgaand aan de iRoom sessie is er een onderzoek gedaan naar de impact op het verkeer bij het afsluiten van de Zaanbrug. De aanleiding om de iRoom in te zetten is om de belanghebbende te betrekken en gezamenlijk op basis van dit onderzoek te knelpunten te bespreken en oplossingen te ontwikkelen.

- Met welk doel wordt de iRoom binnen dit project ingezet?
  Het doel van de sessie was om heel goed inzichtelijk te krijgen waar de problemen en mogelijke oplossingen zitten in dit project. Hierbij gaat het om een beeld te vormen wat er precies gaat gebeuren als de Zaanbrug wordt afgesloten, dit kan van te voren erg lastig zijn om in te schatten.

- Welke verwachting had u bij het gebruik van de iRoom?
  Van te voren had ik de verwachting dat de iRoom zou bijdragen om in grote stramienen inzichtelijk te krijgen in wat we precies gaan maken. De gebruikte techniek met behulp van de videoschermen was zoals ik had verwacht. Dit is ook wat je nodig hebt om verkeersstromen in kaart te brengen en werkte dan ook erg instructief.

Ervaring toepassen iRoom

- Welke vond u van het gebruik van de iRoom binnen dit project?
  Als presentatievorm heb ik de iRoom als erg positief ervaren. Het is een goede manier om het project inzichtelijk te krijgen, anders dan met traditionele tekeningen. De knelpunten zaten op andere plekken dan ik had verwacht en juist nieuwe die we niet van te voren op papier hadden voorzien. Lastig was de grote van de groep, ik kende lang niet iedereen en daarmee was ook niet duidelijk welk belang iedereen had. Ik had de

behoefte hier meer aandacht aan te besteden in de iRoom of de groep te verkleinen. Mogelijk hadden we een beter resultaat kunnen behalen met minder mensen aan tafel.

- Welke taak gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Doelstelling:* Ja, absoluut in de beeldvorming. Het blijkt allemaal ingewikkelder te zijn dan we van te voren hadden gedacht. Hierdoor heeft de iRoom zeker een bijdrage geleverd in de ontwikkeling van deze maatregelen.
  - *Nieuwe oplossingen en inzichten:* Ja, in de zin van dat de bedachte oplossing niet inpasbaar is. Hierdoor hebben we het probleem scherper kunnen definiëren. Daarnaast hebben we kunnen verkennen naar andere oplossingen.
  - *Productiviteit:* Ja, voorafgaand was er verliep de afstemmingen veel meer via schriftelijke rapportages. Hiervoor ging de provincie één voor één bij de verschillende stakeholders langs. Hierdoor kon niet iedereen volledig geïnformeerd worden. In de iRoom zit iedereen bij elkaar en kan dezelfde informatie tot zich nemen. Dit gaat sneller en werkt efficiënter.

- Welke proces gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom*?*
  - *Betrokkenheid:* Ja, eerst door middel van schriftelijke rapportages. Nu iedereen bij elkaar. Hierdoor ben je directer betrokken doordat iedereen in dezelfde ruimte bij elkaar zit.
  - *Beeldvorming:* Ja, absoluut.
  - *Gemeenschappelijk inzicht:* Ja, iedereen zit er bij en krijgt dezelfde informatie duidelijk gepresenteerd. Dit zijn twee aspecten van de iRoom die hieraan bijdragen.
  - *Consensus:* De vraag is of dit door de techniek komt, al denk ik van wel. Er kwamen in ieder geval wel discussiepunten uit waarover consensus was. Die hadden we elders mogelijk niet zo bedacht. Echter volgens mij hadden we nog een stap verder kunnen gaan om ook een oplossing in de sessie uit te werken. Deze had van te voren al voorbereid kunnen worden.

- Wat vind u faciliteit en tools die gebruikt worden in de iRoom?
  - *Faciliteit:* Prima, voor mij is Robert Visser van de provincie de projectleider. Die heeft een onafhankelijk bureau ingeschakeld om deze sessie te faciliteren. Dit werkte voor mij positief. Ik zou het ingewikkelder vinden als de provincie zelf de facilitatie op zich had genomen.
  - *Tools:* Positief, als je voor het eerst de iRoom binnenkomt dan kijk je je ogen uit.
  - *Opstelling:* Het was niet echt een fijne discussieoptelling. Echter zaten we met een te grote groep. De vraag is of het een meerwaarde had om met zoveel mensen deel te nemen aan de iRoom. Mogelijk hadden we ook direct voor het boord kunnen staan, dit had interactiever kunnen zijn.

- Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?
  - *Visualisaties:* Op zich werd goed in beeld gebracht waar de problemen zitten. Echter waren niet alle foto´s adequaat. Echter doordat de beelden gebruikt worden in combinatie met lokale kennis geven alsnog een compleet beeld op.
  - *Metrics:* Ik had het heel leuk gevonden om als je bijvoorbeeld een opstelstrook twee keer zo lang kon maken en dan direct het resultaat op de verkeersstromen kon zien. Echter is dit blijkbaar nog niet mogelijk. Nu was alles gebaseerd op één moment in de avondspits. Echter bleek de ochtendspits net zo belangrijk te zijn. Dit is niet gesimuleerd en gaf daardoor eigenlijk niet een compleet beeld.
  - *Ontwerpstappen:* Er zat een prima opbouw in. Voor mij was de tijdelijke brug van minder belang omdat het minder ingrijpend is en daar ook wel een overeenstemming in vinden. Ik vond het daarom goed dat er meet tijd werd gestoken in de verkeersmaatregelen voor het autoverkeer.

Aanbevelingen toepassen iRoom

- Welke momenten in het project zijn volgens u geschikt een iRoom sessie?
  Die zitten met name aan de voorkant. Bijvoorbeeld voor het definiëren van de problemen zoals we nu hebben gedaan. Met plaatjes wordt de discussie makkelijker. Problemen die te visualiseren zijn daardoor geschikter om in de iRoom te behandelen de iRoom.

- Wat ziet u als succesfactoren voor het gebruik van de iRoom?
  Met ze alle bij elkaar zitten in een dergelijke sessie samen met de faciliteiten van de iRoom is in de basis interessant. Echter of de oplossing geslaagd kan pas achteraf worden bepaald.

- Welke rol ziet u voor Systems Engineering binnen de iRoom?
  Nee, daar zie ik geen link mee. Ik ben er ook niet zo bekend mee.

IV.H ProRail

Project: Spooronderdoorgangen gemeente Ermelo
Geïnterviewde: André Hagen

Algemeen

- Wat is de scope van dit project waarin de iRoom sessie gebruikt is?
  We hebben de iRoom toegepast tijdens een haalbaarheidsstudie naar drie spoorwegonderdoorgangen binnen de gemeente Ermelo.

- Wat is uw rol en verantwoordelijkheid binnen dit project?
  Ik ben de project manager voor dit project namens ProRail in opdracht van de gemeente Ermelo. Hierbij probeer ik deze klant zo goed mogelijk door dit proces te bedienen.

- Hoe ziet de projectorganisatie er precies uit?
  De gemeente Ermelo is in dit project de initiatiefnemer. Daarnaast zullen wij het project tot uitvoering brengen en hebben wij Royal HaskoningDHV ingeschakeld voor deze haalbaarheidsstudie.

Verwachting toepassen iRoom

- Wat was de aanleiding om de iRoom toe te passen in dit project?
  Royal HaskoningDHV heeft eerder aangegeven graag de iRoom in te willen zetten in projecten. De vraag van de gemeente Ermelo leek ons geschikt om in de iRoom te behandelen. Met name omdat het om drie verschillende locaties gaat. Er moet er in het ontwerp met veel rekening gehouden worden met een heleboel knelpunten, behuizing en verkeersstromen. In de iRoom konden wij de gemeente in dit proces meenemen.

- Met welk doel wordt de iRoom binnen dit project ingezet?
  De iRoom wordt ingezet voor de gemeente Ermelo. De probleem eigenaar is de gemeente die middels het gebruik van de iRoom het belang van deze onderdoorgangen kan inbrengen. Door gebruik te maken van de iRoom kan de gemeente een besluit nemen voor een vervolg van dit project. Wij proberen hierin zo goed mogelijk aan bij te dragen.

- Welke verwachting had u bij het gebruik van de iRoom?
  Eerder heb ik een demonstratie sessie bijgewoond. Hier werd ik niet direct super enthousiast omdat de toepassingen nog niet overeenkwamen met de verwachtingen. Echter krijg ik de indruk dat de aanpak zich heeft doorontwikkeld. De verwachting had ik dat Royal HaskoningDHV zowel ProRail en de gemeente Ermelo meenemen in het ontwerpproces en dit snel en gevisualiseerd verschillende ontwerpalternatieven kan bieden.

Ervaring toepassen iRoom

- Welke vond u van het gebruik van de iRoom binnen dit project?
  Ik vond het gebruik van de iRoom goed. Het is anders als je drie grote schermen tot je beschikking hebt waar je actief aan het ontwerpen ben. Ook vond ik dat je met deze aanpak de betrokkenen actief kunt betrekken bij het proces en het eindresultaat. Dit zie ik dan ook als de grootste kracht.

- Welke taak gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?
  - *Doelstelling:* Ja, we hebben voor alle locaties verschillende alternatieven ontwikkeld.
  - *Nieuwe oplossingen en inzichten:* Voor bijvoorbeeld de Telgterweg bleek het na de tweede sessie bleek het lastig een onderdoorgang in te passen nadat we meerdere

locaties hadden bekeken. In een kort tijdsbestek hebben we het stuk spoor en de locatie kunnen beschouwen. We zijn tot de conclusie gekomen dat er geen andere locatie mogelijk was waar een onderdoorgang past.
- *Productiviteit:* Ja, anders gaan er weken over zulke besluiten heen.

- Welke proces gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom*?*
  - *Betrokkenheid:* Ja, iedereen heeft vanuit zijn discipline kunnen kijken naar het probleem en ook daarbij inbreng geven. Iedereen is bij elkaar, en dat is anders dan in een traditioneel proces.
  - *Beeldvorming:* Ja, met behulp van de drie grote schermen konden we allen 3d goed in inzichtelijk krijgen.
  - *Gemeenschappelijk inzicht:* Ja, doordat iedereen bij elkaar zit in de iRoom is iedereen betrokken en beschikt over dezelfde informatie.
  - *Consensus:* Ja, iedereen is het met elkaar eens geworden in de iRoom.

- Wat vind u faciliteit en tools die gebruikt worden in de iRoom?
  - *Faciliteit:* Het is goed voorgesproken hoe we de iRoom gingen gebruiken. Ik heb er dan ook geen op- of aanmerkingen voor.
  - *Tools:* Met behulp van de middelen in de iRoom kun je de uitgangspunten goed voor ogen houden. Ook kan je zien hoe verschillende alternatieven scoren. Echter valt hier nog winst te halen. Het zou beter zijn van te voren de criteria te bespreken. Daarbij was ene score van 1 tot 5 beter geweest. Nu was er erg veel discussie over de criteria. Daar valt nog winst te halen.
  - *Opstelling:* De opstelling was ruim en iedereen had goed zicht.

- Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?
  - *Visualisaties:* De visualisaties zegen er goed uit en gaven goed inzicht in bijvoorbeeld diepte en doorkijk. Dit was allemaal prima.
  - *Metrics:* Het gebruik maken van metrics kan beter. Hier valt nog winst te halen
  - *Ontwerpstappen:* We hebben er nu voor gekozen om de locaties een voor een te behandelen, dit werkte goed. Wel had er aan de voorkant meer aandacht kunnen worden besteed aan de criteria.

Aanbevelingen toepassen iRoom

- Welke momenten in het project zijn volgens u geschikt een iRoom sessie?
  De iRoom is vooral handig in de eerste fasen van een project. Vooral als er verschillende alternatieven moeten worden ontwikkeld en er nog geen idee is hoe het allemaal gaat worden. Met de iRoom kan je dan gezamenlijk in een relatief korte tijd en gezamenlijk een probleem behandelen.

- Wat ziet u als succesfactoren voor het gebruik van de iRoom?
  Het is vooral belangrijk dat het proces strak gemanaged word. Dat het wel binnen de kaders blijft van het project. Hiervoor moeten de uitgangspunten en de speelruimte strak worden neergezet en moet er niet van alles worden bijgehaald. Dat is dat ook een valkuil want ik kan me ook voorstellend dat een iRoom sessie verkeerd kan uitpakken. Verwachtingsmanagement is daarbij erg belangrijk.

- Heeft u nog overige aanbevelingen?
  Ik ben tevreden over het proces en resultaat. Dat is niet uit het oog verloren. De gemeente had vooraf geen verwachtingen omdat ze de iRoom niet kenden. Het doel is uiteindelijk om een haalbaar en maakbaar ontwerp te maken en gebleken is dat de iRoom hiervoor een goed middel is.

IV.I Municipality of Ermelo

Project: Spooronderdoorgangen gemeente Ermelo
Geïnterviewde: Fons Kortrijk

Introductie

- *Wat is de scope van dit project?*
  Door de komst van Randstadrail zal de ritfrequentie op dit baanvak fors toenemen met als gevolg langere dichtligtijden van de spoorbomen en verkeersonveiligheid voor met name de fietsers.

- *Wat is uw rol en verantwoordelijkheid binnen dit project?*
  In dit project ben ik vertegenwoordigd als de gemeentelijke projectleider voor de gemeente Ermelo.

- *Welke stakeholders zijn betrokken in dit project?*
  In dit project is het gemeentebestuur, bewonersorganisaties, ProRail en de Provincie Gelderland betrokken.

Verwachting toepassen iRoom

- *Wat was de aanleiding om de iRoom toe te passen in dit project*
  Het toepassen van de iRoom was een voorstel van ProRail en Royal HaskoningDHV. Dit werd door ons positief ontvangen.

- *Met welk doel wordt de iRoom binnen dit project ingezet?*
  De iRoom wordt ingezet met het doel om op een heel snelle en heldere wijze de gevolgen van de suggesties voor dit project zichtbaar te maken.

- *Welke verwachting had u bij het gebruik van de iRoom?*
  Met het inzetten van de iRoom verwachten wij een inkorting van de projectduur. Daarnaast hebben wij de verwachting dat ook niet technische mensen goed in het project worden meegenomen (politiek).

Ervaring toepassen iRoom

- *Wat vond u van het gebruik van de iRoom binnen dit project?*
  Het gebruik van de iRoom voldeed goed aan mijn verwachtingen.

- *Welke taak gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?*
  - *Doelstelling:* Ja.
  - *Nieuwe inzichten:* Ja, we konden goed inschatten wat de gevolgen waren voor bepaalde afwegingen.
  - *Nieuwe oplossingen:* Ja, met het gebruik van de iRoom konden de gevolgen van alternatieven snel zichtbaar worden gemaakt. Hierdoor konden wij naar de juiste oplossing werken.
  - *Productiviteit:* Ja, het gebruik van de iRoom heeft gezorgd voor een snelle doorlooptijd van het project.

- *Welke proces gerelateerde meerwaarde heeft u ervaren door het inzetten van de iRoom?*
  - *Betrokkenheid:* Door het gebruik van de iRoom konden we gezamenlijk het probleem oppakken. Echter was de betrokkenheid van iedereen al hoog en was de iRoom hiervoor niet van toepassing.

- *Beeldvorming:* Door gebruik te maken van 3d beelden konden we de gemaakte alternatieven van alle kanten bekijken. Dit hielp ons in de overweging van de ontwerpen.
- *Gemeenschappelijk inzicht:* Jazeker, in ons team zitten mensen van verschillende vakdisciplines, met vaak daardoor verschillende inzichten. Dit geeft wel een gemeenschappelijk draagvlak
- *Consensus:* Ja.

- *Hoe heeft u de organisatie en faciliteiten van de iRoom sessie ervaren?*
  - *Facilitatie:* Goed
  - *Tools:* Goed
  - *Opstelling:* Goed
- *Hoe heeft u de werkwijze en methodes die gebruikt zijn in de iRoom ervaren?*
  - *Visualisaties:* Goed, jammer dat niet de kadastrale grenzen stonden aangegeven.
  - *Meetbaarheid:* Goed
  - *Ontwerpstappen:* Goed

Aanbevelingen

- *Onder welke project condities vindt u het zinvol om de iRoom in te zetten?*
  Met name voor meer complexe ontwerpen. Daarnaast lijkt het me zinvol de iRoom voor (grotere) projecten in te zetten om plannen te presenteren aan bewoners en om de gekozen oplossingen te kunnen presenteren aan raadscommissies. Men krijgt dan meer info dan enkel via tekeningen en teksten.

- *Wat ziet u als succesfactoren voor het gebruik van de iRoom?*
  -

- *Welke rol ziet u voor Systems Engineering binnen de iRoom?*
  N.v.t.

- *Heeft u nog overige aanbevelingen?*
  Zet het breder in voor interactieve projecten met bewonersgroepen.