COLOPHON

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Preface

Presented here is my final report on the subject of Systems Engineering (SE), the handbook public space (HOR) and Relatics. It was conducted at the consultancy firm Gebiedsmanagers B.V. and constitutes the completion of the Construction Management & Engineering Master at Delft University of Technology. In this research it is investigated how municipalities should adjust their HOR in order to implement SE in their projects. In addition it is evaluated whether the use of the information model called Relatics can help with this implementation.

This research contains 4 phases. The first phase A contained the introduction, the problem and approach. In the second phase B the results of the literature study are given. The performed casestudy on the Vlielandseweg and the use of Relatics within this case is elaborated in phase C. The final phase D will present the conclusion and recommendation as well as the epilogue and reflection.

Firstly , I would like to thank my colleagues from Gebiedsmanagers B.V. They made the daily grind of graduation tolerable. The daily walks during the lunch break ensured a little distraction so I was well focused during the afternoon. Special thanks to my first supervisor Anton Snijders. He helped with gaining more insight in the field of Systems Engineering and especially my Relatics related questions. Also thanks to Karel Ossewaarde, my second supervisor of Gebiedsmanagers B.V. His contacts with the industry provided me with the entrances for the interviews and the case study. Then I would like to thank Peter Caesar. He was my third supervisor at the company and always took the time to answer my daily questions about Systems Engineering in practice and the integrated contract type in projects.

Secondly, I would like to thank my graduation committee. Alexander Verbraeck, for always asking the right questions. This kept my focus on the scientific contribution and broadened the scope of my research and therefore my knowledge in the Systems Engineering Processes. Jos Vrancken as my first supervisor helped me with the entire process. Then, Sander van Nederveen who was my other supervisor. Even though he warned me about the time consuming process of creating a workspace, it took more time than expected.

Thirdly, I would like to thank the respondents of the municipality Pijnacker-Nootdorp Kees van Schieveen and Tim Calle. Without the support of these respondents I would have never been able to complete my graduation work.

Finally, I would like to thank my friends and family for always listening to my “boring” graduation stories. Special thanks to my friend Victorine Roos for helping me with all sorts of questions and for being my second reader. She has checked my entire report and made it a little more legible in English.
Summary
The civil infrastructure sector (Dutch: GWW-sector) has been subjected to considerable change in recent years. The Dutch government works under the “market unless” (Dutch: markt tenzij) principle. This principle means that the government withdraws from tasks that they used to conduct themselves and these tasks are handed over to the market. The contractor can then be responsible for all phases in the process of a public project and can provide a complete package of services. It is also still possible for the contractor provide a partial set of tasks.

To make this new approach manageable and to structure the activities of all parties, the clients and the contractors went looking for a way to do that. This method has been found in Systems Engineering. Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. Key elements within Systems Engineering are: Interfaces between system and context and within the system, Stakeholders of the entire lifecycle and their view on the system and requirements that need to be traceable, verification & validation to check whether the project meets all requirements and needs of all the stakeholders.

The smaller clients, like municipalities do realize the need for using systems engineering but have difficulty with the implementation. Besides this problem, the HOR was not designed to be usable for Systems Engineering. The maintenance department of the municipality has, through this book, highlighted choices that are important for the design and uniformity of public space.

Along with the rise of SE came the need to record the project information in an unambiguous way. Relatics allows project members to store and manage their information regarding requirements, assumptions, constraints, risks and tasks in an integrated way. In the civil infrastructure the use of Relatics as a tool for SE has become common practice for the contractors. However it is not known if Relatics can also help with the implementation of SE.

To achieve this goal it was decided to do a literature study, a case study and to interview the municipality. The following two research questions are answered in this report:

- How can the HOR be set up for the use of Systems Engineering?
- How can Relatics help with the implementation of Systems Engineering at municipalities?

The literature study was conducted on the three topics of this research namely SE, HOR and Relatics. This literature study provided a theoretical answer to the first research question and led to a basis for the development of the workspace in Relatics.

In order to set up the HOR for SE first of all requirements need to be formulated according to the following specifications. The requirements have to be complete, current, clear and SMART. In order to make the requirement usable for SE more information, the so-called Metadata, needs to be added and recorded. Along with capturing the requisite meta-data it is important to identify the relations between the requirements, stakeholders, functions and objects; the allocation of the requirements.

In theory the requirements of the HOR should already be formulated according to the requirements for SE. During the evaluation of the result however it became apparent that in practice the HOR needs a major update in the formulation and the necessity of the requirement. For the municipality of Pijnacker-Nootdorp it became clear that the requirements from the HOR were not useable for SE the reasons can be found in chapter 8.
The case study is used to gain practical insight into whether Relatics can help with the implementation of SE. During this case study first the current processes of the municipality were determined through interviews and then reflected on the SE processes. From this reflection it became apparent that the processes are quite familiar. Yet, in order to implement SE within the municipalities some processes have to change or should be made more explicit. The requirements definition forms the basis of the entire project. This explicit requirements definition also forms the basis of the verification process. This process also needs to be further developed.

The second step of the case study was the implementation of the HOR in the newly developed workspace. For the development of the workspace SE was also used. After the workspace was created the requirements of the HOR could be imported by using an Excel worksheet. Part of the import process was the allocation of the requirements along the different decomposition structures. Most of the above mentioned problems became clear through this process.

Finally the requirements of HOR in Relatics were use in a practical manner in the case “Vlielandseweg”. The processes used in Relatics to create a system applicable requirements definition from a general database were comparable to the processes of SE during the development stage.

The workspace and the use of the workspace was also evaluated with the users of the municipality. The respondents are not sufficiently versed in the area of SE that they can determine whether Relatics can assist with the implementation of SE. However, they see that this tool can help to save all project information in a clear and organized way. This was also concluded by the researcher when he used Relatics for the development of the workspace. The results of the different SE processes can easily be recorded in Relatics. The user however still needs to know how these processes are performed. The implementation of SE is more than only the implementation of an information model based on systems engineering. Relatics can only support the implementation and help with the management of the result of the different processes of SE, but not with the implementation of the processes within the organization.

Based on the research the following conclusions can be drawn up:

**How can the HOR be set up for the use of Systems Engineering?**
In order to set up the HOR for SE first of all the requirements need to be formulated according to specifications from paragraph 3.3 and 4.2. Both paragraphs state the same requirements to the formulation, the traceability and the allocation of the requirements. The requirements should fulfill the demands Complete, Current, Clear, SMART.

**How can Relatics help with the implementation of Systems Engineering at municipalities?**
Based on the research about Relatics in a practical manner it can be concluded that Relatics can help with the implementation of SE in the following ways:

- The result of the system lifecycle processes can easily be stored and managed
- Project members have explicit and unambiguous project information
- By using Relatics in combination with an SE expert one learns about the system lifecycle processes in practice
- Project information from documents can be stored through the document management system
- Supporting processes can be accommodated in Relatics (Project planning, Project assessment and control, Risk management and Configuration management)
- It supports the decision making process.
- Changes to the requirements can be made traceable and explicit
- The requirements formulation can be checked
- The requirements analysis becomes easier
- The requirements can be structured to gain insight
- The verification process will be standardized
Besides the above mentioned conclusion and answering the two main research questions other conclusion can be draw up because of this research. In this research a workspace for Relatics is created. Creating a workspace gave the researcher more insight into SE because all the relations between the different decomposition structures needed to be clear. Therefore, a lot of theoretical knowledge about the system lifecycle processes was gained. Especially the verification process, which is accommodated into the workspace, has given more insight into the different relations.

The researcher has also given a description on how to use to workspace in order to retrieve the applicable requirements from the SE-HOR for the first set of requirements of the requirements definition in paragraph 8.3.1. The second set of requirements for the requirements definition (project specific requirements) can be found in paragraph 8.3.3. During the case study “Vlielandseweg” these processes have been gone through. In the comparison with the system lifecycle processes it became clear that the processes are very alike. Therefore Relatics can help to gain insight into the system life cycle processes.

The gained experience in SE, the HOR and Relatics have also led to a list of factors that affect the implementation of SE. These factors are comparable with factors found in the literature of Van den Houdt and Rijkswaterstaat.
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Phase A: Introduction, Problem & Approach

1 Introduction

1.1 Context
The civil infrastructure sector (Dutch: GWW-sector) has been subjected to considerable change in the recent years. The introduction of new kinds of contracts changed the construction sector from a regional market to a dynamic world. The government is slowly changing its role and contractors are being asked to provide a “complete package”. It is also still possible for the contractor to provide a partial set of tasks.

The Dutch government works under the “market unless” (Dutch: markt tenzij) principle. This principle means that the government withdraws from tasks that they used to conduct themselves and these tasks are handed over to the market. The contractor can then be responsible for all phases in the process and can provide a complete package. They can be responsible for a projects design, build, management and maintenance, exploitation, demolition and finance or a selection of these phases. With this principle the client now mainly focuses on the interfaces to society, the formulation of the requirements for the project and the monitoring of these requirements during the various phases (Rijkswaterstaat, Bouwend Nederland, Vereniging van Waterbouwers, ProRail, & NLingenieurs, 2007). This principle will create a solution space to be filled by the market. This space is intended to encourage the market to come up with creative and sustainable solutions. It also seeks to increase the effectiveness and efficiency of a project (Luiten, Stijns, Siemes, Leemhuis, & Boes, 2004). Municipalities, provinces and Rijkswaterstaat have worked for years with the UAV-1989, now UAV-2012 contract. In this type of contract they use the regulation procurement projects (RAW-system) (Dutch: regeling aanbesteding werken systematiek) in which they have full control of what is to be built. This contract type has a proven track record, but because of the different approach of the government a new integrated contract type was needed. Contractors, engineering firms and suppliers can now offer the client a full service package. It also optimizes the effectiveness of a project because it is approached from different viewpoints and multiple phases (Luiten et al., 2004; ONRI, 2005).

To make this new approach manageable and to structure the activities of all parties, the clients and the contractors went looking for a way to do that. This method has been found in Systems Engineering. Systems Engineering was first used in the telecommunication industry as a method to achieve interoperability between different parts of the telephone industry. In the fifties of the twentieth century, the more general application of Systems Engineering was established. This method was developed in parallel with the aerospace industry, the defense industry and the commercial sector. Systems Engineering developed towards a method to cope with increasingly complex problems (Rijkswaterstaat, Bouwend Nederland, Vereniging van Waterbouwers, ProRail, & NLingenieurs, 2009; SEATC, 2000).

Systems Engineering is defined by the International Counsel of Systems Engineering (INCOSE), “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.” This is just one of the many definitions that can be found in the literature. This is also reflected in the variety of practical applications.

Since becoming aware of Systems Engineering it has been frequently applied in the civil engineering sector. In the Dutch Civil engineering sector, systems engineering was first applied in the HSL-Zuid project and is since then a widely used method. This method has been picked up by ProRail and Rijkswaterstaat and they have tried to develop Systems Engineering for the Dutch civil infrastructure sector. They have done this by making several guides.
In the guide (Dutch: leidraad) Systems Engineering (Rijkswaterstaat et al., 2007), Systems Engineering is described as an integrated and structured set of methodologies to successfully implement and manage projects. The principles that are central to Systems Engineering are: put client demand central, system thinking, transparency, efficiency, best value for money, balance in design freedom and contractual agreements, verification & validation, coordination with project management and openness.

In the manual "oplossingsvrij specificeren" from the CROW (2011), Systems Engineering is described as a method to approach all kinds of processes systematically. By linking all parts of a project in a systematical way, deliberate design decisions can be made. The method aims to achieve a structured and manageable way to describe the constructed or analyzed system. The manual “oplossingsvrij specificeren" focuses on various aspects of the design process and focuses on the solution freedom in the requirements and functions. All the requirements and conditions that are given should be formulated in such a way that the designer is free to choose a solution (CROW, 2011). This method can be questioned because absolute freedom in the design phase may result in solutions that are not desirable. Therefore, it may be better to formulate the requirements as a function. We must look at the intended product as a system and the system should fulfill the functions of the intended product.

In the context of this research, the following definition is used:
Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. Key elements within Systems Engineering are: Interfaces between system and context and within the system, Stakeholders of the entire lifecycle and their view on the system and requirements that need to be traceable, verification & validation to check whether the project meets all requirements and needs of all the stakeholders.

Along with the rise of SE came the need to record the project information in an unambiguous way. Relatics is a tool which can be used to record and manage information in an unambiguous and transparent way. In the civil infrastructure structure the use of Relatics as a tool for SE has become common practice for the contractors. On the client side, it is mainly used for large projects (see annex A).

This research into Systems Engineering was commissioned by the Delft University of Technology and Gebiedsmanagers B.V. and serves for the completion of the Master Construction Management and Engineering. At Gebiedsmanagers B.V. a case study will be carried out to obtain data and to gain user experience in the practical application of this research. The case, “Vlielandseweg" is a road reconstruction project on which the client would like to use Systems Engineering already in an early stage to make uniform customer requirements specifications for the further development. They also want to apply the tool Relatics to this development. However, there are no examples of using this tool for smaller area development projects.

1.2 Reading guide
This report is divided into four phases. An overview of the contents of each part is presented below.

Phase A – Introduction
Part A consists of two chapters. The first chapter provides a general introduction to the research problem. The second chapter presents the research methodology. The research goal, questions and approach can be found here.

Phase B – Literature study
Part B contains a literature research and concentrates on the theoretical aspects of SE, the HOPR and Relatics. Chapter 3 elaborates on the theory related to SE. First the meaning of SE and the SE processes are described in more detail. Then the interpretation of the general literature by the civil construction industry and application of SE in the industry are discussed. In chapter 4 the HOR will be elaborated.
Again first the HOR is discussed in general and second the processes of the HOR will be described. Chapter 5 focuses on Relatics. After giving more insight into what Relatics is, other software-tools are reviewed in order to see what can be learned from those. The conclusion of this literature study will be given in chapter 6. Here the three different topics are compared based on the literature.

**Part C - Case study**
Chapter 7 focuses on the case study "Vlielandseweg" from the municipality Pijnacker-Nootdorp. First the current processes will be described and reflected on the lifecycle processes. Second the project definition of the "Vlielandseweg" is given.

In chapter 8 the HOR processes are implemented into Relatics. It starts with the description of the creation of the workspace. Then the workspace will be filled with information from the HOR. Finally, the filled workspace is used for the requirements definition of the Vlielandseweg.

The evaluation of the workspace will be done in chapter 9. First the processes for using Relatics will be evaluated with the system life cycle processes. Second the workspace will be evaluated through an interview with the users of the municipality.

**Part D – Conclusion and recommendation**
The combined results of Part B and C are used to formulate the final conclusions and recommendations.

Chapter 10 covers the final validated recommendations and conclusions. In this chapter the main research question is answered. Based on this, recommendations are presented to improve the implementation of SE with the use of Relatics. Then the limitations of this research are stated. Based on the limitations, options are given about possible future research on SE, the HOR and Relatics. Furthermore, the scientific contribution of the results is discussed.

The epilogue and reflection of this research can be found in Chapter 11. This chapter contains my personal reflection on the process and results of the graduation project behind the thesis.
2 Research design

This study consists of three main topics in the field of small development or reconstruction projects in municipalities or small private companies. The combination of these three subjects is the conceptual model of my research. The interpretation of this conceptual model is the specification of my research: the incorporation of systems engineering in the handbook public space (Dutch: Handboek Openbare Ruimte, HOR) supported by the use of Relatics in order to help municipalities with the use and implementation of Systems Engineering. The conceptual model is shown in Figure 2-1.

![Conceptual research model](image)

2.1 Problem statement

The guide drawn up by Rijkswaterstaat, ProRail, Netherlands Building and ONRI presents the content of Systems Engineering within the civil infrastructure sector. This guide, like Systems Engineering, is constantly undergoing changes due to growth and learning processes. For example, in 2007 the first version of the guidance was mainly published to create uniformity in order to understand one another. The second version of the guide discussed, in particular the various techniques of Systems Engineering. The third guideline is about improving and making project processes unambiguous

According to Schreinemakers, honorary member of INCOSE-NL, the Dutch civil infrastructure sector can be described as follows: "In the Dutch civil infrastructure sector it is sometimes stated that projects could be more efficient and optimized. However, we must not forget that the implementation of Systems Engineering takes time. It is for this sector not worthwhile to use complex systems as Model Based Systems Engineering (MBSE), while basic techniques such as specifying requirements or verification & validation have yet to be learned. The Capability Maturity Model Integrated (CMMI), Table 2-1, of the Carnegie Mellon Institute shows us that maturing is a gradual process and that we cannot achieve the highest attainable at once" (Schreinemakers, 2011).

CROW, has also made a guide from the "oplossingsvrij specificeren" point of view. Their opinion on the lack of using Systems Engineering in the civil engineering sector is that: "Kennis van Systems Engineering wordt binnen infrastructuurprojecten nauwelijks toegepast omdat deze kennis slecht toegankelijk is voor de GWW-sector. Hierdoor wordt het bestaande begrippenkader en de methoden en technieken van SE nauwelijks toegepast"
The pace of implementation of Systems Engineering differs in the construction sector. The leading group consisting of Rijkswaterstaat, ProRail, some contractors and engineering firms had the ambition in 2009 to achieve the third CMMI level within two years. The remainder of the sector should accomplish this level within five years. (Rijkswaterstaat et al., 2009)

Even though the grip on Systems engineering is not yet fully found in the municipalities, they do realize the need for using systems engineering. According to van den Houdt the experience and expertise regarding SE differs among clients. As a result, the choice of clients to choose a contract type, which requires the implementation of SE, differs as well (van den Houdt, 2013). The reason that the municipality has not yet found the full grip is partly because the knowledge is not accessible. It could also be due to the fact that the largest group of employees of the municipality is between 45 and 55 years old. In other words, the municipalities are aging and thus the methods and techniques as well. These people prefer to use the RAW system and often are still holding on to this method. In addition, the older generation within the municipality is more determined. They know what they want and how they want it to be done. These preferences can be well specified with the help of the RAW system. Because of this the development of systems engineering in municipalities was blocked. One solution could be the adoption of younger well-trained staff. However, the influx of new staff in 2012 dropped to 3.9%. The main reason for this are the cutbacks that governments have to make (A+O fonds Gemeenten, 2013).

Besides the problem that many municipalities have problems with implementing Systems Engineering, there is also the problem that the HOR is not usable for Systems Engineering. The maintenance department of the municipality has, through this book, given choices that are important for the design and uniformity of public space. These selections have been prepared with background knowledge of the maintenance department and are needed to get a good design. Without this handbook, the maintenance department has no “requirements” that the contractors should take into account in advance. This could lead to a design for public space that only looks for the cheapest solution while the maintenance is not taken into account. While this was one of the goals for using integrated contracts and Systems Engineering The HOR is not yet usable for Systems Engineering because the requirements are not set up for the use of Systems Engineering.

There are three reasons why a client is unable to provide a complete set of requirements that offer enough design freedom for the contractor:

- The client is unfamiliar with functional specification, resulting in an incomplete or over-complete list of requirements;

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<table>
<thead>
<tr>
<th>Level</th>
<th>Focus</th>
<th>Process areas</th>
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<tbody>
<tr>
<td>5</td>
<td>Continuous process improvement</td>
<td>Process change management, preventing defects, Technological change management</td>
</tr>
<tr>
<td>4</td>
<td>Quantitative management</td>
<td>Quantitative project management, Quality management system, Performance of organizational processes</td>
</tr>
<tr>
<td>3</td>
<td>Process standardization</td>
<td>Verification &amp; Validation, Risk management, Requirements analysis and design considerations</td>
</tr>
<tr>
<td>2</td>
<td>Basic project management</td>
<td>(Sub)contract management, Configuration management, Requirements management</td>
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<td>1</td>
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The client believes to know what he or she wants. This desire is translated into detailed requirements, offering less solution freedom;

A relative large amount of binding documents is applicable to the requirements, restricting the solution freedom.

In general, the functionality of the requirements makes it very difficult for the contractor to translate the requirements into smart requirements. The ambiguous and vague formulation of these requirements by client seems to cause the problem (van den Houdt, 2013). According to Officier, the context of the requirements is not always clear for designers. In addition, the formulation of verifiable requirements is a process that is not well understood by the client (Officier, 2013).

In several large infrastructure projects, working with a software package such as Relatics has proven to offer a benefit when working with Systems Engineering (Annex A: Interview Professionals). As a result, many engineering firms, contractors and Rijkswaterstaat have already begun to implement Relatics in their larger projects. Relatics allows project members to store and manage their information regarding requirements, assumptions, constraints, risks and tasks in an integrated way. All this should ensure greater transparency, flexibility and better cooperation between the various parties (Relatics, 2013). The following inefficiencies of the construction industry can be associated with the current industry fragmentation and paper back communication recur:

- The time and costs of projects are difficult to estimate correctly and control (Smith, 2010)
- Litigations often occur due to inaccuracies and fail to reach targets (Smith, 2010)
- Changes are very costly and waste too much time (Laiserin, 2009)
- Duplicated data collection – information is not passed on fluently during the project lifecycle (Smith, 2010)
- Not enough collaboration during design and construction processes (De Ridder, 2001)

Problem statement:
The municipalities in the Netherlands have difficulties with the application of Systems Engineering in their projects. A reason for this is that the HOR is not yet usable for SE because the requirements are not set up for the use of SE. In the civil infrastructure the use of Relatics as a tool for SE has become common practice for the contractors. However it is not known if Relatics can also help with the implementation of SE.

2.2 Research objective
In more and more projects the use of Systems Engineering is prescribed for the design and management of a project. This is in line with the ambitions set out in the guideline of 2009. The Municipality Pijnacker-Nootdorp has the ambition to use Systems Engineering with the reconstruction project “Vlielandseweg”. They don’t have any experience in the field of SE and the project can therefore be used in a case study. This study can be used to implement Systems Engineering with the municipality and to see how their HOR needs to be adjusted in order to use it for SE.

Research objective:
The goal of this research is to investigate how municipalities can adjust their HOR in order to implement Systems Engineering. In addition, it is investigated whether Relatics can help with the implementation of Systems Engineering within municipalities.

2.3 Research Questions
From the research objective, as described above, two main research questions can be derived. Based on the answers to these questions recommendations can eventually be given to help municipalities.
These main research questions cover the entire research but cannot be answered without multiple sub-questions. The research activities that are carried out will be based on these sub-questions. In order to answer the sub-questions, Literature studies on Systems Engineering, HOR and Relatics are carried out as well as empirical studies on the case Vlielandseweg.

### Sub questions:

- What is Systems Engineering?
- How are requirements formulated for the use in Systems Engineering?
- What is the HOR?
- How are requirements formulated in the HOR?
- What is Relatics?
- How are requirements formulated for the use in Relatics?
- What are the pros and cons of Relatics?
- What other Systems engineering software tools are available and what are the pros and cons of those?
- What are the differences in formulating requirements between SE and Relatics?
- Which problems arise when setting the HOR up for SE and Relatics?

### 2.4 Delineation of research

By performing research, the delineation is of major importance, since it is a critical success factor in the feasibility of the process. In the previous sections the major topics are already mentioned that will be discussed in this research. In order to carry out a thorough research, it is important to have clear definitions of the subjects in an early stage to avoid misunderstandings. Furthermore, it is of interest to determine what is and what isn’t going to be investigated in order to avoid ambiguity. Hence, this section provides the definitions, Table 2-2, of the research topics. In general, the research focuses on

<table>
<thead>
<tr>
<th>Subject</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems Engineering</td>
<td>According to the definition stated in section 1.1</td>
</tr>
<tr>
<td>Handboek Openbare Ruimte(HOR)</td>
<td>Handboek openbare ruimte of the municipality Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Relatics</td>
<td>Software tool to support Systems Engineering</td>
</tr>
</tbody>
</table>

A short additional motivation of this delineation and its implications for the research are given below:

- **Systems Engineering**: This research with the main topic of Systems Engineering is performed from the perspective of the client. The client has the greatest influence on the project during the initiation and design phase. In these phases, the requirements are defined and form the framework for the solution space of the project. This research will within the framework of Systems Engineering focus on the formulation and specification of requirements.
2.5 Research methodology

The research is conducted by following a research strategy. The strategy is determined by making a choice between three important components:

- Performing a broad or specific research?
- Applying a qualitative or quantitative research?
- Performing a practical or literature based research?

This research can best be described as a specific, qualitative practical research. The gap in theory between formulating HOR to SE and Relatics is done in a literature study, so most relevant knowledge and insights were gained from experiences and projects.

The model below, Figure 2-2, is the design of the research that should meet the research objective. This model is designed with the method of Verschuren en Doorewaard. Through the use of different colors a distinction is made between theory, empirical steps and results.

![Figure 2-2 Research model](image)

In order to reach the research goal, the research is divided into 6 phases which are elaborated below.

2.5.1 Phase A: Problem and approach

Phase 1 presents the research context, research design and research methodology. A clear formulation of these components is important since it is a frame work for the entire research process. It also contributes to the actual realization of the design objective. The problem Approach is discussed in chapter 1 of this report.

2.5.2 Phase B: Literature study

In the literature study a deeper and more thorough analysis is performed on the relevant topics to become more familiar with them. After analyzing the specific literature, cross linking between the subjects can
provide insights. This activity can make my research relevant in a scientific and practical way because patterns could be identified, so it entails an essential part of my research. After this phase the first research question will be answered.

2.5.3 Phase C: Case study
The case study is used to perform the actual setting up of HOR to SE and Relatics. By doing this, insight will be gained on where problems will occur. This insight can then be used for recommendations of the setting up of other books of other municipalities. Also during this case study experience is gained in the use of Relatics. Through interviews more insight is gained on the current use of the HOR, the current processes of the municipality and the workspace is evaluated.

2.5.4 Phase D: Conclusion and recommendations
The last research phase is the final aspect in the graduation research. This part aims to fulfill the research objective and to provide a summary of the answers of the research questions. Conclusions are drawn and recommendations for the future are made for the public client here. After these research phases a final graduation process step is executed, namely the reflection. This contains an evaluation of the process and project as followed in the graduation period and a critical review of the practical and scientific relevance of the outcome.
Phase B: Literature study

3 Systems Engineering

The problem and approach have been discussed in phase 1, a literature study is performed in this 2nd phase. A literature study is necessary in order to obtain sufficient knowledge about the research related topics: Systems Engineering, Handbook Public space and Relatics. Therefore, in this chapter the following sub-questions are addressed:

- What is Systems Engineering?
- How are requirements formulated for the use in Systems Engineering?

To answer these sub-questions, first SE is elaborated on as it is envisioned by the scientific literature. The scientific literature on SE in a general sense is incredibly comprehensive and detailed. The intention of this chapter is not to come up with a better or more accurate description of the SE methods. Therefore the elaboration on SE is kept short meaning to provide a basic understanding. In the previous chapter the definition of SE that will be used in this research is already given. Nevertheless, this chapter (§3.1) starts with a short elaboration of the definitions of SE found in the literature. In the following paragraph (§3.2) the intended goals, the SE processes and its relative activities as applied by the civil construction industry are outlined. In order to answer the second sub-question an elaboration of requirements within SE is given in the next paragraph (§3.3).

In the concluding paragraph (§3.4) of this chapter the sub-questions will be answered.

3.1 Definition of Systems Engineering

The origin of SE can’t be traced back to a particular date in history. Systems engineering principles have been practiced at some level since the building of the pyramids and probably before. The modern origins of SE can be traced to the beginning of the 20th century. Since the effects of World War II, Systems Engineering was first recognized as a distinct activity. After the publication of a number of textbooks in the 1950s and 1960s, SE was identified as a distinct discipline. During the second half of the 20th century, the recognition of systems engineering as a unique activity evolved as a necessary and logical result to the rapid growth of technology, became more general. (Kossiakoff, Sweet, Seymour, & Biemer, 2011). The formal recognition of the discipline of SE came in 2002 with the introduction of the international standard ISO/IEC 15288. Since then SE is recognized as a preferred mechanism to establish agreement for the creation of products and services to be traded between two enterprises, the acquirer and the supplier (INCOSE, 2006).

Before we continue it is important to define what we mean by SE. There is no unambiguous definition of SE available in scientific literature or working practice and SE can be seen as a profession, a process and a perspective as illustrated by the following representative definitions (INCOSE, 2006).

Systems Engineering is a discipline that concentrates on the design and application of the whole (system) as distinct from the parts. It involves looking at a problem in its entirety, taking into account all the facets and all the variables and relating the social to the technical aspects (Ramo, 2006).

Systems Engineering is an iterative process of top-down synthesis, development and operation of a real-world system that satisfies, in a near optimal manner, the full range of requirements for the system (Eisner, 2008).

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem. 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, 2006).
The systems engineering perspective is based on systems thinking. Thinking is systems makes it possible to apply SE to virtually every sector, because a product, service or project can always be defined in terms of systems. A system can be defined as a set of interrelated components working together towards some common objective (Kossiakoff et al., 2011). The system’s whose lifecycle is under consideration is called the system-of-interest and is the top-most product in hierarchy. The system components or elements are defined as members of a set of elements that constitute to a system. The systems engineering process has an iterative nature that supports learning and continuous improvement (van den Houdt, 2013).

Complexity can lead to unexpected and unpredictable behavior of systems, hence, one of the objectives is to minimize undesirable consequences. This can be accomplished through the inclusion of and contributions from experts across relevant disciplines coordinated by the systems engineer (INCOSE, 2006). So, the aim of this interdisciplinary approach is to reduce complexity and is realized to look at the whole system by applying a life cycle perspective. By looking at the system as a whole, also all stakeholders can be identified. Every stakeholder has its own perspective of the function that the system needs to fulfill and what requirements the system must meet. This places the system in a context where it interacts with other systems. The interaction or interfaces of the system with its context and within the system identifies complexities that normally remain hidden.

In the next paragraph the application of SE in the construction industry is given.

3.2 Application of Systems Engineering in the construction industry

In the previous paragraph a short elaboration on: what is SE? Is given and some relevant definitions are compared. This paragraph focuses on the application of SE in the civil construction industry in two subsections. First the intended goals of SE in general and in the Dutch construction industry are given. Second, SE in the Dutch civil construction industry is elaborated through the six lifecycle phases and the processes involved.

3.2.1 Intended goals of Systems Engineering

Given the definition in paragraph 3.1 it follows that the goal of SE is to create a whole solution to some complex problem. The dynamic environment in which most complex problems are embedded underlines the importance of the life cycle perspective. Having a life cycle perspective enables and preserves the success of the system during its life cycle (van den Houdt, 2013).

INCOSE (INCOSE, 2006) describes an informative life cycle model with six stages: conceptualization; development; production; utilization; support and retirement. In a SE approach more emphasis is put on the conceptualization phase, which enables easier and more rapid subsequent phases by reducing risks from the beginning of the project life cycle. As a result, the overall costs and schedule of the project can be decreased, while the project quality remains the same or is increased. As illustrated in the left graph of Figure 3-1, cost overrun as well as variance in cost overrun lessens with increasing Systems Engineering Effort (SEE). At low SEE, a project has difficulty predicting its overrun. The same is apparent for the schedule overrun as illustrated in the right-hand graph in Figure 3-1 (Honour, 2004; INCOSE, 2006). The saved time and costs can be beneficial for both the client and the contractor. The client receives the desired product or project at a lower price and higher quality, while the contractor may reduce failure costs and thus increases its profits (van den Houdt, 2013).
Research by USP Marketing Consultancy showed that the failure costs in the Dutch civil construction industry amounted to 11.4% of the annual turnover in 2008. With a total revenue of 55 billion euro, this means that the failure costs reached 6.2 billion euro. Another tendency was that civil projects, on average, overturned their schedule two to three times (Rijkswaterstaat et al., 2009).

The implementation of SE in the Dutch civil construction industry is a joint initiative of Rijkswaterstaat, ProRail, Bouwend Nederland, NLingenieurs and Vereniging van Waterbouwers. These actors formed the so-called “Werkgroep Leidraad Systems Engineering” and produced the report “Leidraad voor Systems Engineering binnen de GWW-sector” (SE guide). The parties introduce a method for the completion of infrastructure projects. This method should function as a structural entrenched process focused on the to be achieved objectives and on the usefulness and necessity (Rijkswaterstaat et al., 2009).

According to the SE guideline the application of SE should help to achieve the following goals:

- **Expediency**: meet the needs of the client, within socially justifiable costs;
- **Effectiveness**: efficiently reducing failure costs and better utilization of the available resources;
- **Transparency**: demonstrable and controllable deliver what has been agreed upon.

The intended goals of SE correspond to the goals of Project Management (PM). Yet there is a big difference between SE and PM. This difference may be best explained on the basis of a figure that explains the relationship between Integral Project Management (IPM) and SE, see Figure 3-2. The following figure illustrates how PM relates to IPM and how IPM relates to SE. IPM identifies five processes namely:

1. Project Management: focused at assuring the quality, time and money;
2. Environmental Management: The relationship between the environment and the stakeholders need to be in balance throughout the project;
3. Technical Management: to control a project within the technical processes;
4. Contract Management: to control the risks that arise between the client and the market (agreement process);
5. Risk Management: focused on managing the risks that in the project may arise.
As can be seen in the above picture, SE and PM have a lot of interfaces. In daily practice SE is carried out in the context of a project, whose basic purpose is to design and build some type of system. Thus, there is almost always a strong connection between project management and SE, whether it is formally recognized or not. Like project management, SE deals with a variety of methods for designing and building a system that are largely independent of the domain itself (Eisner, 2008).

According to the Project Management Body of Knowledge (PMBOK) there are nine aspects that if managed well, should result in a good project management. The main advantages of a PM approach are that it is based on international standards from the Project Management Institute. PM solves problems by splitting them up in solvable, smaller projects and rapid decision-making, just as SE (van den Houdt, 2013). The weaknesses of the project managerial approach can be partly compensated by other management methods from the IPM.

Besides these goals a set of guiding principles is presented in the guideline. These principles give direction within the civil engineering sector. They indicate what the parties may expect from each other when working with SE (Rijkswaterstaat et al., 2009). The guideline acknowledges that the implementation of SE is an intensive process of change, which requires a cultural change from both the client and the contractor. Over the past five years in more and more projects SE was applied. However, the optimization of SE practices across projects, let alone the entire industry, is hardly addressed by any of the clients or contractors (Rijkswaterstaat et al., 2009).

### 3.2.2 Systems Engineering in the Dutch civil construction industry

The previous paragraph already mentioned the six lifecycle phases as described by INCOSE. The SE guide also defines six lifecycle stages or phases that need to be followed to successfully implement SE within the entire lifecycle. These phases are: concept phase, development phase, execution phase, operational phase, maintenance and renewal phase and demolition phase. For each of the phases their underlying processes will be discussed. Figure 3-3 schematically displays each phase and its underlying relationship with SE.
Concept phase
It is common in many industries that research studies lead to new ideas which then mature into the initiation of a new project (system-of-interest). The concept phase is executed to access new business opportunities and to develop preliminary system requirements and a feasible design solution. The first step is to identify, clarify, and document stakeholders’ requirements and needs. On the basis of these requirements and needs direction is given to the possible solution space (INCOSE, 2006).

Development phase
The development phase is executed to develop a system-of-interest that meets acquirer requirements and can be produced, tested [verified], evaluated, operated, supported, and retired (INCOSE, 2006). The development of a system can be understood as a thinking, working and decision process where information is collected and processed. This phase is iterative, goal-oriented and problem-solving, where functions and requirements are analyzed and the solution is specified. Successive choices bring the designer closer to the final solution. The needs of the client at the start of this phase is converted to a execution ready design (Rijkswaterstaat et al., 2009).

Execution phase
In this phase the specified system is actually build. The realization of complex systems is, as the development phase, a step-by-step process. The difference is that the specification occurs top-down (decompose) while the realization is bottom-up (integrate). All elements are integrated into a working system. Another important aspect of this phase is to test the functionality of the constructed system, the verification and validation activities. The goal of these activities is explicitly and objectively demonstrate whether the result complies with the specifications and the intended use (Rijkswaterstaat et al., 2009).

Operational phase / Maintenance- and renewal phase
The operational phase is the period when the system is exploited or ready to be exploited. The Maintenance or renewal phase takes place within de operational phase. In this period support activities are implemented to keep the system in operation. Depending on the contract type the contractor can still be responsible for the system during this phase of the lifecycle (Rijkswaterstaat et al., 2009).

Demolition phase
The lifecycle of a system always ends with demolition. This phase is intended to put a system out of operational services a functions and the demolishment of the structure. For the successful implementation of SE within the sector this life cycle stage is of minor importance and is therefore not further investigated (Rijkswaterstaat et al., 2009).

Besides the different phases in a life cycle of a system, the international standard groups the activities that may be performed during the life cycle of a system into four process groups. The four process groups and the processes included in each group are depicted in Figure 3-4.
Before delineation is made about which groups apply to the Dutch civil construction industry, they are briefly explained:

- **The agreement processes**: Organizations are producers and users of systems. One organization (acting as an acquirer) can task another (acting as a supplier) for products or services. This is achieved using agreements.

- **Organizational Project-Enabling Processes**: The Organizational Project-Enabling Processes are concerned with ensuring that the resources needed to enable the project to meet the needs and expectations of the organization's interested parties are met.

- **Project Processes**: The Project Processes are concerned with managing the resources and assets allocated by organization management and with applying them to fulfill the agreements into which the organization or organizations enter.

- **Technical Processes**: The Technical Processes are concerned with technical actions throughout the life cycle. They transform the needs of stakeholders first into a product and then, by applying that product, provide a sustainable service, when and where needed in order to achieve customer satisfaction.

In the context of this research delineation needs to be made about which process groups are applicable. The framework of this research is the Dutch civil construction industry and therefore only the agreement processes and the technical processes are applicable. The processes shown in Figure 3-4, form together the six lifecycle phases of a system. In Figure 3-5 one can see in what phase each process returns. Herein has been taken into account the delineation of the groups.
As can be seen from the figure above, a lot of processes overlap. All these overlaps cause transfer moments during the development of a system. The transfer moments between client and the contractor is determined by the acquisition process. During this process the client determines which contract type he wants to use. Depending on the contract type the definition of requirements is determined. This process will be discussed in the next paragraph.

During the transfer moments, it is desirable that the choices already made are traceable. This can be made possible by working more explicit and capture the choices. By working explicit it becomes clear why some choices are made and is traceable how the system meets the customer requirements. Key support processes here are verification and validation. Verification proves that a solution satisfies the requirements objectively and explicitly. Validation shows that a solution is suitable for the intended use. (Rijkswaterstaat, Bouwend Nederland, Vereniging van Waterbouwers, ProRail, & NLingenieurs, 2013).

An important part of this research is about the requirements within SE, as can be seen from the sub-questions. Within the technical processes group the first two processes, Stakeholders Requirements definition process and Requirements analysis process, deal with the requirements. This will be addressed in the next paragraph.

### 3.3 Requirements within Systems Engineering

As stated in the second sub-question that is addressed in this chapter, the formulation of requirements plays an important role in implementing SE with municipalities. The formulation of requirements is part of the Stakeholders requirements definition process.

The next sub-sections describe processes where requirements play a major role. It starts with the stakeholder requirements definition process. Then the requirement analysis process will be elaborated and finally the architectural design process will be discussed.
3.3.1 Requirements definition process

The purpose of the Stakeholder Requirements Definition Process is to define the requirements for a system that can provide the services needed by users and other stakeholders in a defined environment (ISO/IEC 15288, 2008).

The process activities are described below (ISO/IEC 15288, 2008):

- **Elicit stakeholder requirements**
  - Identify the individual stakeholders or stakeholder classes who have a legitimate interest in the system throughout its life cycle.
  - Elicit stakeholder requirements from the identified stakeholders.

- **Define stakeholder requirements**
  - Define the constraints on a system solution that are unavoidable consequences of existing agreements, management decisions and technical decisions.
  - Define a representative set of activity sequences to identify all required services that correspond to anticipated operational and support scenarios and environments.
  - Identify the interaction between users and the system.
  - Specify health, safety, security, environment and other stakeholder requirements and functions that relate to critical qualities.

- **Analyze and maintain stakeholder requirements**
  - Analyze the complete set of elicited requirements.
  - Resolve requirements problems.
  - Feed back the analyzed requirements to applicable stakeholders to ensure that the needs and expectations have been adequately captured and expressed.
  - Establish with stakeholders that their requirements are expressed correctly.
  - Record the stakeholder requirements in a form suitable for requirements management through the life cycle and beyond.
  - Maintain stakeholder requirements traceability to the sources of stakeholder need.

As can be seen from the above the final step in the stakeholder requirements definition process is the analysis of the requirements. This is a different activity than the requirements analysis process, which will be elaborated in the next paragraph. This step focuses on problems in the formulation of the requirement. This activity starts with an initial set of requirements from the elicitation or requirements definition stage. Individual requirements as well as the set as a whole are analyzed for various attributes and characteristics. Some characteristics are desirable, such as "feasible" and "verifiable." Other characteristics are not, such as "vague" or "inconsistent." (Kossiakoff et al., 2011)

A good system specification meets a number of characteristics, these are (Rijkswaterstaat et al., 2013):

- **Complete.** The specification is integral and runs over all disciplines and all lifecycle phases of the system. It contains the known components and all the requirements. Attention is needed for: the environment and all stakeholders, context objects, internal objects or system components, functions, interfaces and aspect requirements, performance requirements and constraint requirements. It is important to create consistency among these perspectives by viewing from the different angles. Furthermore it is necessary to structure this ever-growing set of requirements. Completeness also calls attention to the following aspects: reliability, availability, maintainability, safety and health, environmental nuisance, sustainability and design.

- **Current.** The specification applies to the established system, belonging to the stakeholders and their interests. It’s good to capture new insights because scope and contract modifications can be prevented or can be properly dealt with later on in the project.
• **Clear.** The specification is clearly formulated, the objects are defined and the boundaries are clear. Requirements are hereby unambiguous. This calls for attention to the definitions and formulation of requirements.

• **SMART.** A good specification and/or requirement is: Specific (unambiguously described), Measurable (achieved quality), Acceptable (for stakeholders and/or management), Realistic (achievable) and Time-bound (when the goal should be reached).

The benefits of well-written requirements are shown in Table 3-1 Benefits of well-written requirements (NASA, 2007)

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish the basis for agreement between the stakeholders and the developers on what the product is to do</td>
<td>The complete description of the functions to be performed by the product specified in the requirements will assist the potential users in determining if the product specified meets their needs or how the product must be modified to meet their needs. During system design, requirements are allocated to subsystems (e.g., hardware, software, and other major components of the system), people, or processes.</td>
</tr>
<tr>
<td>Reduce the development effort because less rework is required to address poorly written, missing, and misunderstood requirements</td>
<td>The Technical Requirements Definition Process activities force the relevant stakeholders to consider rigorously all of the requirements before design begins. Careful review of the requirements can reveal omissions, misunderstandings, and inconsistencies early in the development cycle when these problems are easier to correct thereby reducing costly redesign, remanufacture, recoding, and retesting in later life-cycle phases.</td>
</tr>
<tr>
<td>Provide a basis for estimating costs and schedules</td>
<td>The description of the product to be developed as given in the requirements is a realistic basis for estimating project costs and can be used to evaluate bids or price estimates.</td>
</tr>
<tr>
<td>Provide a baseline for validation and verification</td>
<td>Organizations can develop their validation and verification plans much more productively from a good requirements document. Both system and subsystem test plans and procedures are generated from the requirements. As part of the development, the requirements document provides a baseline against which compliance can be measured. The requirements are also used to provide the stakeholders with a basis for acceptance of the system.</td>
</tr>
<tr>
<td>Facilitate transfer</td>
<td>The requirements make it easier to transfer the product to new users or new machines. Stakeholders thus find it easier to transfer the product to other parts of their organization, and developers find it easier to transfer it to new stakeholders or reuse it.</td>
</tr>
<tr>
<td>Serve as a basis for enhancement</td>
<td>The requirements serve as a basis for later enhancement or alteration of the finished product.</td>
</tr>
</tbody>
</table>

### 3.3.2 Requirement Analysis process

Requirement analysis has become a critically important element of SE. All of the later elements of SE are carried out with one dominant question in mind: are we in fact satisfying the system requirements in the best possible manner (Eisner, 2008)?

The purpose of the Requirements Analysis Process is to transform the stakeholder, requirement-driven view of desired services into a technical view of a required product that could deliver those services (ISO/IEC 15288, 2008).

The activities belonging to the requirement analysis process are described below (ISO/IEC 15288, 2008):

- Define system requirements.
  - Define the functional boundary of the system in terms of the behavior and properties to be provided.
Define each function that the system is required to perform.

Define necessary implementation constraints that are introduced by stakeholder requirements or are unavoidable solution limitations.

Define technical and quality in use measures that enable the assessment of technical achievement.

Specify system requirements and functions, as justified by risk identification or criticality of the system, that relate to critical qualities, such as health, safety, security, reliability, availability and supportability.

- Analyze and maintain system requirements.
  - Analyze the integrity of the system requirements to ensure that each requirement, pairs of requirements or sets of requirements possess overall integrity.
  - Feed back the analyzed requirements to applicable stakeholders to ensure that the specified system requirements adequately reflect the stakeholder requirements to address the needs and expectations.
  - Demonstrate traceability between the system requirements and the stakeholder requirements.
  - Maintain throughout the system life cycle the set of system requirements together with the associated rationale, decisions and assumptions.

At the time the requirements are analyzed, it is important to capture the requirements statements along with the metadata associated with each requirement. The metadata is the supporting information necessary to help clarify and link the requirements. The method of verification must also be thought through and captured for each requirement at the time it is developed. The verification method includes test, inspection, analysis and demonstration. Examples of the types of metadata are provided in Table 3-2.

### Table 3-2 Requirements Metadata

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement ID</td>
<td>Provides a unique numbering system for sorting and tracking</td>
</tr>
<tr>
<td>Rationale</td>
<td>Provides additional information to help clarify the intent of the requirement at the time they were written (reason, document assumptions, document relationships, document design constraints).</td>
</tr>
<tr>
<td>Traced from</td>
<td>Captures the bidirectional traceability between parent requirements and lower level (derived) requirements and the relationships between requirements.</td>
</tr>
<tr>
<td>Owner</td>
<td>Person or group responsible for writing, managing, and/or approving changes to this requirement.</td>
</tr>
<tr>
<td>Verification method</td>
<td>Captures the method of verification (test, inspection, analysis, demonstration) and should be determined as the requirements are developed.</td>
</tr>
<tr>
<td>Verification lead</td>
<td>Person or group assigned responsibility for verifying the requirement.</td>
</tr>
<tr>
<td>Verification level</td>
<td>Specifies the level in the hierarchy at which the requirements will be verified.</td>
</tr>
</tbody>
</table>

In addition to the above table with metadata of each requirement it is necessary to type each requirement in order to maintain the transparency. The complete list of types of requirements that could be included are (FAA, 2006; NASA, 2007):

- Functional Requirements.
- Performance Requirements.
- Interface Requirements.
- Operational Requirements
- Constraint Requirements.
- Regulatory Requirements
- Reliability, Maintainability, and Availability/Supportability.
- Safety Requirements.
- Health Hazard Requirements.
- Human Performance Interface Requirements.
- Productibility Requirements.
The above types of requirements are derived from the NASA and FAA. This means that not all types of requirements are applicable for the civil construction industry. E.g. producibility requirements are requirement that are applicable for a system or a product that needs to be produced multiple times. The handbook specifying from the CROW (CROW, 2011) describes only four types of requirements that are applicable to the construction industry. These are: Functional requirements, aspect requirements, process requirements and interface requirements. Within the aspect requirements the requirements for availability, reliability, maintainability and safety are described. The functional specification consists of the preparation of requirements for a result from a desired function. In order to make a complete definition of a function possible, use is made of the same four types of requirements (Ministerie van Verkeer en Waterstaat, 2005).

3.3.3 Architectural Design Process
The purpose of the Architectural Design Process is to synthesize a solution that satisfies system requirements (ISO/IEC 15288, 2008).

The activities that belong to the architectural design process are described below (ISO/IEC 15288, 2008):

- Define the architecture.
  - Define appropriate logical architectural designs.
  - Partition the system functions identified in requirements analysis and allocate them to elements of system architecture. Generate derived requirements as needed for the allocations.
  - Define and document the interfaces between system elements and at the system boundary with external systems.

- Analyze and evaluate the architecture.
  - Analyze the resulting architectural design to establish design criteria for each element.
  - Determine which system requirements are allocated to operators.
  - Determine whether hardware and software elements that satisfy the design and interface criteria are available off-the-shelf.
  - Evaluate alternative design solutions, modeling them to a level of detail that permits comparison against the specifications expressed in the system requirements and the performance, costs, time scales and risks expressed in the stakeholder requirements.

- Document and maintain the architecture
  - Specify the selected physical design solution as an architectural design baseline in terms of its functions, performance, behavior, interfaces and unavoidable implementation constraints.
  - Record the architectural design information.
  - Maintain mutual traceability between specified design and system requirements.

In the previous process requirements are decomposed in a hierarchical structure starting with the highest level requirements. These high-level requirements are decomposed into functions and allocated across the system. In this process these requirements are then further decomposed and allocated among the subsystems and elements. This decomposition and allocation process continues until a complete set of design-to-requirements is achieved. At each level of decomposition (system, subsystem, component, etc.), the total set of derived requirements must be validated against the stakeholder expectations or higher level parent requirements before proceeding to the next level of decomposition. The traceability of requirements to the lowest level ensures that each requirement is necessary to meet the stakeholder expectations (NASA, 2007). The requirements decomposition and allocation is schematically shown in Figure 3-6.
3.4 Systems Engineering implementation factors

The second research question is about how Relatics can help with the implementation of SE at municipalities. Before this question can be answered more insight is needed about the factors that potentially influence the implementation. According to van den Houdt (van den Houdt, 2013) the success factors behind the implementation of SE are divided into three categories:

- **Systems Engineering Process**: In this category the factors that are directly related to the Systems Engineering activities. Most of these factors are derived from the technical processes of SE: requirements analysis process and the verification and validation process.

- **Management and organization**: The implementation of SE within an organization and its projects is considered a change in the way of working in the civil construction industry. A vast amount of managerial and organizational factors need to be considered to facilitate a smooth implementation of SE.

- **Project context**: These factors potentially affect the implementation of SE based on the project context variables. These factors are primarily based on the nature of the project and its environment. Examples are the contract type used by the project and the trust between client and contractor.

In the context of this research these factors are delineated to the SE processes. Within the System Engineering processes several factors are determined, as shown in the previous sections. Van den Houdt describes these factors which potentially affect the implementation of SE, as can be seen in Figure 3-7 (van den Houdt, 2013).
This chapter discussed SE as it is envisioned by the scientific literature. This literature study is done in order to answer the sub-questions that were addressed in this chapter, these were:

- What is Systems Engineering?
- How are requirements formulated for the use in Systems Engineering?

**What is Systems Engineering?**

The origin of SE can’t be traced back to a particular date in history. The modern origins of SE can be traced to the beginning of the 20th century. The formal recognition of the discipline of SE came in 2002 with the introduction of the international standard ISO/IEC 15288. Still, there is no unambiguous definition of SE available in scientific literature or working practice and SE can be seen as a profession, a process and a perspective (INCOSE, 2006). The definition that is used in this research is:

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. Key elements within Systems Engineering are: Interfaces between system and context and within the system, Stakeholders of the entire lifecycle and their view on the system and requirements that need to be traceable, verification & validation to check whether the project meets all requirements and needs of all the stakeholders.

The general goals of SE are to reduce costs, time and complexity. Within the construction the following goals are attributed to the implementation of SE:

- **Expediency**: meet the needs of the client, within socially justifiable costs;
- **Effectiveness**: efficiently reducing failure costs and better utilization of the available resources;
- **Transparency**: demonstrable and controllable deliver what has been agreed upon.

The intended goals of SE correspond to the goals of Project Management (PM). Yet there is a big difference between SE and PM. This difference may be best explained on the basis of a figure that explains the relationship between Integral Project Management (IPM) and SE, see Figure 3-2.
The incorporation of the lifecycle phases in SE can be seen in the V-model. The V-model as seen in Figure 3-5 primarily reflects the technical processes. Within the technical processes group the first two processes, Stakeholders Requirements definition process and Requirements analysis process, deal with the requirements.

**How are requirements formulated for the use in Systems Engineering?**

The purpose of the stakeholder’s requirements definition is to elicit, negotiate, document and maintain stakeholders’ requirements for the system of interest within the defined environment. The process transforms the stakeholder’s expectations into a definition of the problem and then into a complete set of validated technical requirements expressed as “shall” statements that can be used for defining a design solution. The requirements should enable the description of all inputs, outputs, and required relationships between inputs and outputs. Besides that requirements should be expressed as shall statements, there are several more characteristics for a good system specification. The benefits of well-written requirements can be found in Table 3-1. The requirement has to be:

- Complete
- Current
- Clear
- SMART

The formulation of requirements in SE is more than only the correct writing of the requirement. In order to make the requirement usable for SE more information, the so-called Metadata, see Table 3-2, needs to be added. There are several analysis techniques available to acquire the needed information (see 3.2.2). These techniques include, among others, creating WBS, PBS, function tree and object tree. Along with capturing the requisite meta-data it is important to identify the relations between the requirements, stakeholders, functions and objects (the allocation of the requirements), as can be seen in Figure 3-6.
4 Handbook Public Space
The previous chapter discussed the literature about SE. this chapter will focus on the literature about the HOR. In this chapter the following sub-questions are addressed:

- What is the HOR?
- How are requirements formulated in the HOR?

To answer these sub-questions, first the HOR is elaborated as it is envisioned by the CROW. The scientific literature on the HOR is really scarce and therefore the literature of the CROW is used. The intention of this chapter is gain more insight in the HOR. The most important subjects are: what is the HOR and how should the guideline be created and used. The first paragraph (§4.1) starts with the elaboration on what is the HOR. In the second paragraph (§4.2) the next subject and the second sub-question will be addressed. Paragraph 4.3 described the position of the HOR in the technical processes of SE. In the concluding paragraph (§4.4) of this chapter the sub-questions will be answered.

4.1 What is the HOR?
The design, construction and management of public space require the input and knowledge from many parties. A guideline design of public space (Dutch: Leidraad Inrichting Openbare Ruimte) has its origin in the desire to coordinate and communicate the choices. Capturing the standard choices and solutions creates space for discussion. The initiative for the establishment of a program of requirements for the public space is often at maintenance departments. They want to formulate the constraints for the design and testing the designs on the application of the constraints.

However, a successful guideline design of public space is wider and is shaped and supported by all parties involved in the public space. The guide is part of the policy for the public space. It is not a checklist which is used during the design process to make demands. The added value lies in the joint selection of certain requirements and the view on the coherence, amplification or contradictions (CROW, 2008).

The guideline design of public space is defined as follows (CROW, 2008): "The collection of knowledge, experiences, requirements and conditions for the public space imposed by the municipality. The guideline is a kind of database out of which the customer requirements specifications can be composed.

A guideline design of public space is made for the following reasons (CROW, 2008):

- improving communication about public space;
- the realization of the objectives of a municipality by understanding the relationship between the various requirements;
- managing input and exchange of knowledge about public space in the design process;
- decision making including all qualities of that public space, e.g. the future management and maintenance, the financial, technical, organizational and legal resources;
- the preparation of specifications and contracts for external contractors.

The guideline public space needs to be a practical instrument that leads to better communication and better considerations about the policy, design and maintenance. Through standardization, the discussion can focus on the specific and deviated solutions. This applies to both knowledge of the design- and the operational- and maintenance phase. The latter phases got relatively little attention in the past, but are now the reason to make a guideline design of public space with the following goals (CROWN, 2008):

- capturing unambiguous requirements, knowledge and experience;
- ensuring the future quality of public space;
- clear communication with external parties;
- a clear set of requirements and instructions will improve the communication and information between the municipality and external parties;
More efficient planning is possible because standard solutions are available.

In order to make a guideline to a successful instrument, involvement and support of all parties is needed. On the one-hand the process and the position of the guideline should be formally established in procedures and policy, on the other hand people should want to work with the guideline form themselves. This gives some requirements to the guideline (CROW, 2008):

- the information must match and support the working level;
- the guideline should help to formulate an unambiguous assignment which makes clear what qualities and aspirations are important and have priority;
- the guideline should not be a collection of arbitrary requirements. The selection of requirements should be part of the process;
- The guideline requires input from all parties who use or maintain the public space.

The next paragraph describes how the guideline should be created and be used. Within this paragraph the second sub-question will be addressed.

4.2 Creating and using the guideline

The guideline is a dynamic document. In addition to one-off actions for the creation and filling of the guide, constant action remains needed to keep the requirements up to date and appropriate.

The following processes can be distinguished, also see Figure 4-1 (CROW, 2008):

- Setting up: the design and structure of the guide, and the visualization of the organizational processes and responsibilities;
- Filling: the guide needs to be filled with all the knowledge and requirements of municipal policies, laws and regulations, national guidelines and experience of the organization;
- Use: drawing up a customer requirements specification, based on the guideline;
- Maintain: updating the guideline with new developed insights

Figure 4-1 Processes of the HOR

4.2.1 Setting up process

The process for setting up the guide is about organizing and accessing information. The choice of the organization method is mostly determined by the choice of automation or paper. Considerations for this choice are (CROW, 2008):

- Requirements on paper give a direct view of the structure and content;
• Version management, paper documents often remain outdated, while an automated document on a central computer always has the latest version;
• An automated file provides better accessibility in more complex and larger amount of information;
• In an automated file, also external information can be linked.

During this first phase it is also important to make agreements for the last two phases, use and maintain: who decides on the content, who will fill the requirements, who may change, who determines the customer requirements specification, etc.

An example of the structure of the guideline can be seen in Figure 4-2. From this figure it becomes clear that the guideline is a breakdown of the different target groups that need to work with the guideline. It also describes the phases within the design process (CROW, 2008).

![Figure 4-2 structure of guideline design public space](image)

Besides capturing the requirements, it is also important to control the input of the maintenance department in the design. This department determines the boundary conditions for the development phase and checks the final design to this.

### 4.2.2 Filling of the guideline process

This phase involves the gathering of all the knowledge and requirements of municipal policies, laws and regulations and experiences. Possible sources for filling a guide (CROW, 2008):

• Laws and regulations are general for each municipality. Often there is chosen for referrals for laws and regulations. Disadvantage of these referrals is that the user still needs to seek for the document, but the information is always current and complete;
At the policy level, this information is often municipal-specific and must therefore be prepared by municipality. The challenge is to translate these often abstract requirements so they are usable for the guideline.

Own knowledge. Usually a tremendous amount of experience and knowledge is available in municipalities. This is often difficult and labor intensive to determine. Requesting used working papers, checklists, etc. is a start. Some of these experience are hard requirements, other are more recommendations.

After gathering the requirements, the relevant requirements will be selected, arranged, properly formulated and should be supplemented. The abstraction levels of requirements are structured with the aid of a pyramid, see Figure 4-3. The principle behind this is that lower level requirements should be justified by higher level requirements (CROW, 2008).

![Figure 4-3 requirements pyramid](image)

Like in the previous chapter a distinction is made between the different types of requirements. The guideline design of public space (CROW, 2008) describes five types of requirements. These are:

- Functional requirements
- Aspect requirements
- Process requirements
- Interface requirements
- Object requirements

A solution will be rarely if ever able to meet all the requirements. Therefore it makes sense to make a distinction between hard and softer requirements. For this the following format is used (CROW, 2008):

- Laws, regulations and decisions: these requirements may not be derogated;
- Norms, these requirements may be derogated with proper motives;
- Directives, these requirements may be derogated with proper motives;
- Recommendations, these requirements may be derogated with proper motives.

During the identification of requirements from existing documents it will show that these are not always clearly formulated. Once a requirement will be included in the guideline design public space (CROW, 2008), it is recommended to formulate the requirement such that it is clear. In Table 4-1 below, a checklist on how to formulate requirements is given.
Table 4-1 checklist "how to formulate requirements"

<table>
<thead>
<tr>
<th>Item</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>Is the requirement necessary, current and feasible?</td>
</tr>
<tr>
<td></td>
<td>Is the requirement testable?</td>
</tr>
<tr>
<td></td>
<td>Is the requirement formulated for a free solution as much as possible?</td>
</tr>
<tr>
<td>Design/Formulation</td>
<td>Is the requirement clearly and unambiguous formulated?</td>
</tr>
<tr>
<td></td>
<td>Does the requirement contain the verb &quot;shall&quot;?</td>
</tr>
<tr>
<td></td>
<td>Is the requirement singular?</td>
</tr>
<tr>
<td></td>
<td>Is the requirement concisely and positively formulated?</td>
</tr>
<tr>
<td>Context</td>
<td>Is the requirement not contradictory and not overlapping with other requirement?</td>
</tr>
<tr>
<td>Traceable</td>
<td>Has the requirement a unique title and a unique number?</td>
</tr>
<tr>
<td></td>
<td>Does the requirement come from a higher level of abstraction?</td>
</tr>
<tr>
<td></td>
<td>Does the requirement refer to a binding document from which the requirement originates?</td>
</tr>
</tbody>
</table>

4.2.3 Use process
The guideline, filled with only correct formulated requirements, has now become a parent file that can be used to draw up customer requirements specifications for other projects. The use of the guideline can be summarized as selecting the project relevant standard requirements supplemented with project-specific requirements. In the concept phase of a project, a project team should be formed that will develop the specific project requirements. It is important that all disciplines are represented, including the maintenance department. This group considers the requirements for a project from the guideline. The choices, consequences, decision-making and responsibilities must be clear. Depending on the type and scope of the project, these choices are made. The goal is to make relatively quick choices from standardized requirements in the guideline. The time saving gives room for discussion on the objectives of the project and the formulation of project-specific requirements.

4.2.4 Maintain process
A guideline only holds its value if it remains current and continues to provide good basic information. A guideline that is no longer current doesn't contribute to the goal of improving and accelerating the communication in the design process.

The vision of how public space should be designed, used and maintained is subject to change and should regularly be updated. Updating means adding new requirements and deleting outdated ones. It is necessary to avoid that outdated and modified variants wander through the organization, this causes that ambiguities arise. This requires in any case controlling the following points:

- A clear procedure for modifying and updating the guideline;
- The provision of sufficient capacity for modifying and updating the guideline;
- The designation of a responsible manager for the guideline, which may make changes;
- Version control; making clear what the latest version is.

The information for actualizations results from:

- Evaluations of the guideline and the preparation of project-specific requirements;
- New insights from daily practice of the operational and maintenance phase;
- New policies, laws and regulations and national directives.

Updating the guideline is a regularly occurring process and it should at least be done at the end of each project. Frequently, such as every three years, a more complete and formal adoption and recalibration should be performed.
4.3 Technical processes

The previous chapter about SE elaborated the life cycle phases and processes that are applicable for the Dutch civil construction industry. The previous paragraph described the processes that are applicable to the HOR. This paragraph compares the processes that are covered by the HOR with the technical processes that are applicable for the Dutch civil construction industry. Here the delineation is made for the processes that will be used in the next phase, the case study.

The content of the HOR is applicable for the entire life cycle of a system, yet the use process only comes back in the stakeholder requirement process, where the bill of requirements is made. The acquisition process which determines the contract type also indirectly determines the use of the guideline process. As can be seen in Figure 4-4

![Figure 4-4 Life cycle and HOR processes](image)

As can be seen from the figure above the vertical lines with UAV above them are the tender moments. Depending on the contract type these moments can differ. Also depending on the contract type is the time until the client is responsible for the processes. In other words, the client determines the transfer point to contractor. From that moment on the contractor is responsible for the process and the client needs to monitor the agreement.

4.4 Intermediate conclusions

This chapter discussed the literature study that was performed in order to gain insight into the HOR. In this chapter the following sub questions were addressed:

- What is the HOR?
- How are requirements formulated in the HOR?

What is the HOR?

The design, construction and management of public space require the input and knowledge from many parties. A guideline design of public space (Dutch: Leidraad Inrichting Openbare Ruimte) has its origin in the desire to coordinate and communicate the choices. The guideline design of public space is defined as follows (CROW, 2008): “the collection of knowledge, experiences, requirements and conditions for the public
space imposed by the municipality. The guideline is a kind of database out of which the customer requirements specifications can be composed.

A guideline design of public space is made for the following reasons (CROW, 2008):

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- managing input and exchange of knowledge about public space in the design process;
- decision making including all qualities of that public space, e.g. the future management and maintenance, the financial, technical, organizational and legal resources;
- the preparation of specifications and contracts for external contractors.

The guideline is a dynamic document. In addition to one-off actions for the creation and filling of the guide, constant action remains needed to keep the requirements up to date and appropriate.

The following processes can be distinguished, also see Figure 4-1 (CROW, 2008):

- Setting up: the design and structure of the guide, and the visualization of the organizational processes and responsibilities;
- Filling: the guide needs to be filled with all the knowledge and requirements of municipal policies, laws and regulations, national guidelines and experience of the organization;
- Use: drawing up a customer requirements specification, based on the guideline;
- Maintain: updating the guideline with new-developed insights.

How are requirements formulated in the HOR?

During the identification of requirements from existing documents it will show that these are not always clearly formulated. Once a requirement will be included in the guideline design public space, it is recommended to formulate the requirement such that it is clear. In Table 4-1, a checklist on how to formulate requirements is given. Besides the formulation of the requirements (which should be SMART) this table also gives insight into the needed metadata to keep to requirements traceable.

After gathering the requirements, the relevant requirements will be selected, arranged, properly formulated and should be completed. The abstraction levels of requirements are structured with the aid of a pyramid, see Figure 4-3. The principle behind this is that lower level requirements should be justified by higher level requirements (CROW, 2008).

Like in the previous chapter a distinction is made between the different types of requirements. The guide design of public space (CROW, 2008) describes five types of requirements. These are:

- Functional requirements
- Aspect requirements
- Process requirements
- Interface requirements
- Object requirements

A solution will be rarely if ever able to meet all the requirements. Therefore it makes sense to make a distinction between hard and soft requirements. For this the following order is used (CROW, 2008):

- Laws, regulations and decisions,
- Norms,
- Directives,
- Recommendations.
5 Relatics

The previous chapter discussed the literature study that was performed on the HOR. This chapter will focus on the literature about Relatics. In this chapter the following sub-questions are addressed:

- What is Relatics?
- What are the pros and cons of Relatics?
- How are requirements formulated for the use in Relatics?
- What other Systems engineering software tools are available and what can be learned from those?

To answer these sub-questions, first Relatics is elaborated on as it is envisioned by the literature. Unfortunately the scientific literature on Relatics is incredibly scarce. The only documents that where found where brochures of the program. These brochures where made by the company PKM solutions, who has created Relatics, and are therefore subjective. Nevertheless, the researcher tried to give an objective evaluation on what the program is and what it can do. This is described in the first paragraph (§5.1). In the following paragraph (§5.2) Will describe if and how requirements should be formulated.

In order to answer the final sub-question of this chapter and to get an objective view on Relatics a comparison is made with comparative software; this will be done in paragraph 5.3.

In the concluding paragraph (§5.4) of this chapter the sub-questions will be answered.

5.1 What is Relatics

The success of a project or organization is highly dependent on the quality of the information. Direct insight into critical project information, such as opportunities and risks, current stock or requirements and verifications prevents errors during a project or in an organization. Optimal control of information flows prevents errors. Managers need information to practice their profession. They try to gather the information necessary to support decision-making and to control their organization. Information technology has become one way to provide managers with information. In cases where information technology does not show its promised expectations, effort and costs to develop and implement this technology are in vain. The real issue, however, arises at a higher level. It is not the failure of the information technology, but the unsuccessful attempt to improve the quality of management information that is important (Lohman, 1999).

A collection was made of different problems, issues and difficulties that could directly or indirectly obstruct management information to be effective for organizational performance. This collection was clustered into five bottlenecks by Lohman which are described below(Lohman, 1999):

- Quality of data does not meet the specified requirements
- Data cannot be transformed into requested information
- Provided and requested information was unrelated
- Discrepancy between the information requested and required
- Information use does not contribute to organizational performance

In order to overcome these bottlenecks, Lohman founded a company which designed a program called Relatics. Relatics is a web-based semantic database which makes it possible to capture, manage and unlock information in an unambiguous and consistent way (Relatics, 2009).

When analyzing the last sentence several keywords emerge, namely: web-based, semantic and database. The definitions are given below (Wikipedia).

**Web-based:** a web-based application is any application software that runs in a web browser.  
**Semantics:** is the study of meaning. It focuses on the relation between signifiers, like words, phrases,
signs and symbols, and what they stand for, their denotation.

**Database:** is an organized collection of data. The data are typically organized to model relevant aspects of reality in a way that supports processes requiring this information.

**Semantic database:** is a conceptual data model that includes the capability to express information that enables parties to the information exchange to interpret meaning (semantics) from the instances.

The use of several information forms, like Excel, Word and hardcopies, can cause contradictions, redundancy, inaccessible and uncontrollable information. With Relatics it can be defined what information needs to be managed. Because Relatics is a full web-based application, every user can access the same available information everywhere and anytime. This reduces contradictions, redundancy, inaccessibility and uncontrollability. Once Relatics is configured, one speaks of an information system.

Relatics knows two kinds of users who can use the program, a functional designer who creates and configures a template and an end-user who actually uses the program. Before Relatics can be used a template needs to be configured for the end-user. For the use and configuration of these templates several training programs are available:

- End-Users training;
- Basic configuration;
- Advanced configuration;
- The development of reports;
- System integration.

In the context of this study, the researcher has followed and passed the basic configuration training. From that experience more practical insight was gained on Relatics. Indeed Relatics is flexible, transparent and easy to use. But, in order to create a fully operational template one should follow the other training programs as well. Once an operational template is created it is easy to use in multiple projects or organizations.

### 5.2 Requirements within Relatics

Relatics can be used to capture, manage and unlock information in an unambiguous and consistent way. The kind of information that needs to be managed is entirely up to the intended goal. On the basis of the goal a template is configured. This means that any kind of information can be managed within Relatics. As long as the information need is about the relation between the elements. Otherwise a relational database would suffice. Therefore there are no requirements from Relatics on how requirements should be formulated. In other words, it is the responsibility of the end user to formulate the requirements in the right way in Relatics. A benefit of Relatics is that, when it is properly configured, one can keep track of the changes that have taken place in the requirement text unlike e.g. Excel. Also

### 5.3 Other software tools

Section 5.1 explains what Relatics is and one could do with it. Once Relatics is configured it becomes an information model with all the possibilities of this. Section 5.2 elaborated Relatics as an extension of this research to the requirements and the formulation of requirements. In the next phase as part of the case study a Relatics model will be created. Before that model is created it's good to have a look at current developments in the Dutch civil construction industry in terms of information modeling. This will be done in this paragraph. The intention of this paragraph is to briefly evaluate other software tools and to discover features that might be usefull for the Relatics model that will be created in the next phase.

Currently, building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering and construction (AEC) industries (Panaitescu, 2014). Therefore this working method as part of a tool will be evaluated. Requirements management plays a major role in Systems Engineering. Part of the workspace that will be created in the next phase will be to manage the...
requirements from the HOR. Therefore the second tool that will be elaborated is a Requirement management tool. Another topic of SE is the consideration of the system as a whole and over its entire lifecycle. So, the third and last tool that will be elaborated is a Product Lifecycle Management (PLM) tool. If in the next sections is referred to Relatics, it is an information model for SE.

5.3.1 Bim tools
As already explained BIM is one of the most promising developments in AEC industries, but what is BIM?

A commonly accepted definition of BIM is: “Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.” (U.S. National BIM Standard - NBIMS)

The digital representation of characteristics of a facility is a conjunction of a 3D visual model, a linked database and drawings. Depending on the objective of BIM, features can be added. The simplest BIM starts with a 3D model for visualization. The architect and the engineer make drawings for the VO and DO phase. In this concept BIM is mainly used for building buildings instead of civil construction works. The most comprehensive form covers the entire lifecycle of a building, including model integration with suppliers and a facility management model for the use phase. This model also allows the extraction of material quantities. If the 3D components or assemblies are linked with time- or schedule-related information one speaks of 4D BIM. If it is combined with costs it is called a 5D BIM.

As can be seen from the definition A BIM is a shared knowledge resource for information. To share the knowledge several BIM Agreements are made at the start of the project to ensure this. One of these agreements is the use of the same language. By using an object library all the stakeholders use the same information and the information can be shared between different tools. Information is also stored in so-called exchange formats. These exchange formats are:

- IFC, for the exchange of information and the geometry of buildings;
- IFD, Materials and objects libraries
- IDM for processes.

What can be learned from BIM?

Like Relatics, BIM is an information model in which information is recorded on buildings or other projects. The difference between the two is that BIM records the information in a 3D visualization and Relatics records the information on paper. BIM is suitable to make a proper design, while Relatics is suitable for recording the information to which the design has to comply (requirements, laws and regulations). It can therefore be quite possible that Relatics will be used as a BIM tool along the visualization tools. In fact, the company Infranea has already developed a BIM-connector tool. This connector provides a dynamic link between the SE system Relatics and the 3D geometry defined in CAD systems such as MX, Civil 3D, Revit. This connector is a great progress in the development of BIM and Relatics but the connector is not yet widely used in the Dutch civil construction industry. For the moment it's recommended that the following features (if possible) are implemented in Relatics:

- Use of object library;
- Exchange the information in the standard formats;
- Add the time features in the WBS in Relatics
- Add the cost features in the WBS in Relatics

5.3.2 Requirements management tools
Effective requirements management practices have a positive impact on the success of systems and product development. Rational DOORS software is designed to capture, trace, analyze and manage changes to information while maintaining compliance to regulations and standards. Control of
requirements is key to reducing costs, increasing efficiency, and improving the quality of your products (IBM Corporation, 2012).

Rational DOORS provides (IBM Software, 2014):

- **Requirements management.** The purpose of requirements management is to ensure that an organization documents, verifies and meets the needs and expectations of its customers and internal or external stakeholders.
- **Traceability.** Requirements traceability is concerned with documenting the life of a requirement and providing bi-directional traceability between various associated requirements. It enables users to find the origin of each requirement and track every change that was made to this requirement. For this purpose, it may be necessary to document every change made to the requirement.

**What can be learned from Requirements management tools?**

As can be seen from the above, the features provided by Rational DOORS are focused on RM. In Relatics the requirements also need to be managed. These requirements need to be documented, verified and kept traceable. The documentation also means adding all the necessary information including the required metadata. The following features need to be added in order to manage the requirements:

- Document the requirements,
  - including the metadata
- Keep the requirement traceable by
  - Using a convenient navigation tree
  - Connecting it to the document
  - Document the changes of the requirements over time
- Validate the requirement text
- Make verification of the requirement possible

The reviewed tool covers many issues surrounding RM. However, it is not discussed how to deal with requirements, laws and regulations that change during a project. This will be further investigated in the next phase.

**5.3.3 PLM software**

As already told in paragraph 5.1, direct insight in information prevents errors. PLM software allows companies to manage the entire lifecycle of a product efficiently and cost-effectively. The Teamcenter PLM software provides the right information at the right time so better product decisions can be made. The benefits of Teamcenter are improving productivity, teamwork, manageability and success. With the aid of Teamcenter it is expected that (Siemens industry software, 2013):

- Time and effort is reduced with a single source for generating and managing requirement documents;
- Quality is improved by linking requirements to functional, logical and physical implementation;
- Compliance is ensured by defining, managing and tracing consumer requirements across the entire product lifecycle.

The PLM platform on which Teamcenter is based is very broad and consists of (Siemens PLM Software, 2011):

- Systems Engineering & requirements management;
- Portfolio, program & project management;
- Engineering process management;
- Bill of materials management;
- Content & document management;
- Formula package & brand management;
- Supplier relationship management;
- Mechatronics process management;
- Manufacturing process management;
- Maintenance, Repair & overhaul;
- Reporting analytics;
- Communication collaboration.

What can be learned from PLM-tools?

From all of the above it can be derived that Teamcenter is software for PLM. The main focus of PLM is on the product instead of a project. The difference is that a project is unique and a product isn’t. When comparing Teamcenter with Relatics it becomes clear that both programs have many of the same features and benefits. The main differences in features are that Teamcenter has a very easy-to-use “live” integration with MS office and CAD programs. Unfortunately, this is not possible with Relatics. A feature that can be added in Relatics is the possibility to create reports. The creation of reports however, demands an additional training. Therefore, in the model that will be created in the next phase, the report development is only briefly addressed.

5.4 Intermediate conclusion

In this chapter the following sub-questions where addressed:

- What is Relatics?
- What are the pros and cons of Relatics?
- How are requirements formulated for the use in Relatics?
- What other Systems engineering software tools are available and what can be learned from those?

What is Relatics?

The success of a project or organization is highly dependent on the quality of the information. Direct insight into critical project information, such as opportunities and risks, current stock or requirements and verifications prevents errors during a project or in an organization. Managers need information to practice their profession. They try to gather the information necessary to support decision-making and to control their organization. Information technology has become one way to provide managers with information. Relatics is a web-based semantic database which makes it possible to capture, manage and unlock information in an unambiguous and consistent way. A Semantic database is a conceptual data model that includes the capability to express information that enables parties to the information exchange to interpret meaning (semantics) from the instances. Once Relatics is configured, one speaks of an information system.

What are the pros and cons of Relatics?

With Relatics it can be defined what information needs to be managed. Because Relatics is a fully web-based application, every user can access the same available information everywhere and anytime. This reduces contradictions, redundancy, inaccessibility and uncontrollability. Once Relatics is configured, the application is flexible and easy to use, the information is transparent and collaboration among different disciplines can easily be created. The flexibility of Relatics is also its pitfall, one need extensive training before Relatics can be configured. Once Relatics is configured in the right way, it becomes very easy for the end-user the use Relatics.
How are requirements formulated for the use in Relatics?

Relatics can be used to capture, manage and unlock information in an unambiguous and consistent way. The kind of information that needs to be managed is entirely up to the intended goal. On the basis of the goal a template is configured. Therefore there are no requirements from Relatics on how requirements should be formulated.

What other Systems engineering software tools are available and what can be learned from those?

Currently, building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering and construction (AEC) industries (Panaitescu, 2014). Therefore this working method as part of a tool will be evaluated. Requirements management plays a major role in Systems Engineering. Part of the workspace that will be created in the next phase will be to manage the requirements from the HOR. Therefore the second tool that will be elaborated is a Requirement management tool. Another topic of SE is the consideration of the system as a whole and over its entire lifecycle. So, the third and last tool that will be elaborated is a Product Lifecycle Management (PLM) tool.

BIM: A commonly accepted definition of BIM is: “Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.” (U.S. National BIM Standard - NBIMS)

As can be seen from the definition A BIM is a shared knowledge resource for information. To share the knowledge several BIM Agreements are made at the start of the project to ensure this. One of these agreements is the use of the same language. By using an object library all the stakeholders use the same information and the information can be shared between different tools.

Like Relatics, BIM is an information model in which information is recorded on buildings or other projects. The difference between the two is that BIM records the information in a 3D visualization and Relatics records the information on paper. BIM is suitable to make a proper design, while Relatics is suitable for recording the information to which the design has to comply (requirements, laws and regulations). For the moment it’s recommended that the following features (if possible) are implemented in Relatics:

- Use an object library;
- Exchange the information in the standard formats;
- Add the time features in the WBS in Relatics
- Add the cost features in the WBS in Relatics

Rational DOORS: Effective requirements management practices have a positive impact on the success of systems and product development. Rational DOORS software is designed to capture, trace, analyze and manage changes to information while maintaining compliance to regulations and standards. Control of requirements is key to reducing costs, increasing efficiency, and improving the quality of your products (IBM Corporation, 2012).

In Relatics the requirements also need to be managed. These requirements need to be documented, verified and kept traceable. The documentation also means adding all the necessary information including the required metadata. The following features need to be added in order to manage the requirements:

- Document the requirements,
  - including the meta data
- Keep the requirement traceable by
  - Using a convenient navigation tree
  - Connecting it to the document
  - Document the changes of the requirements over time
- Validate the requirement text
- Make verification of the requirement possible

**Teamcenter**: As already told in paragraph 5.1, direct insight in information prevents errors. PLM software allows companies to manage the entire lifecycle of a product efficiently and cost-effectively. With the aid of Teamcenter it is expected that (Siemens industry software, 2013):

- Time and effort is reduced with a single source for generating and managing requirement documents;
- Quality is improved by linking requirements to functional, logical and physical implementation;
- Compliance is ensured by defining, managing and tracing consumer requirements across the entire product lifecycle.

The main focus of PLM is on the product instead of a project. The difference is that a project is unique and a product isn’t. When comparing Teamcenter with Relatics it becomes clear that both programs have many of the same features and benefits. A feature that can be added in Relatics is the possibility to create reports. The creation of reports however, demands an additional training while in Teamcenter this is embedded.
6 Conclusion of the literature study
The previous chapters 3, 4 and 5 described the literature study that was performed on respectively SE, HOR and Relatics. These chapters answered several sub-questions for their respective subjects. The purpose of this chapter is to provide more insight into the acquired knowledge from the literature study by comparing, or combining the different subjects.

The following sub-questions and the first research question will be addressed in this chapter:

- How can the HOR be set up for the use of Systems Engineering?
- Which problems arise when setting the HOR up in SE and Relatics?
- What are the differences in formulating requirements between SE and Relatics?

The first paragraph will compare the studied literature about SE with the literature about the HOR. Within the paragraph the first two questions that are addressed in this chapter will be discussed here.

6.1 Comparing SE and the HOR
Before answering the first research question a comparison has to be made between the literature about SE and the HOR. First the definitions are compared. Second, the formulation of requirements is compared. Then the types of requirements are compared and last the questions will be answered.

The definition of SE describes that SE is:

"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."

The definition of the HOR describes that the HOR is:

"The collection of knowledge, experiences, requirements and conditions for the public space imposed by the municipality. The guideline is a kind of database out of which the customer requirements specifications can be composed."

The definition of SE says it is intended for the realization of successful systems. SE considered both the business and technical needs of users. According to the definition of the HOR, the HOR is a collection of knowledge, experience, requirements and constraints on public space established by the municipality.

As already seen in paragraph 3.4 and 4.4 the formulation of requirements in theory with SE and the HOR is almost the same. The main difference is that within SE requirements need more additional information, the so called metadata. This metadata should provide better insight in the relation between the requirements and its function, its object, and the responsible stakeholder. By allocating the requirements over these functions, objects and stakeholders’ one can get insight in the necessity of the requirement and see if the list of requirements is complete.

Both the literature about SE as well as the HOR describes different types of requirements. Within SE the following types are defined: Functional requirements, aspect requirements, process requirements and interface requirements. The literature about the HOR also describes object requirements.

The intended goal of SE, as already described in section 3.2.1, is to reduce complexity. Several methods and techniques are given to make the system clear by structuring the information (WBS, SBS, functional analysis, requirement analysis, etc.). The relationships between the structures can reveal more insight into the complex interfaces of the system. In SE requirements need to be decomposed in a hierarchical structure starting with the highest level requirements. These high-level requirements are decomposed into functional and performance requirements and allocated across the system. These are then further decomposed and allocated among the subsystems and elements.
How can the HOR be set up for the use of Systems Engineering and which problems arise when setting up the HOR for SE?

In order to set up the HOR for SE first of all the requirements need to be formulated according to specifications from paragraph 3.3. Second the requirements should be decomposed and allocated in the structural and systematic way SE describes (WBS, SBS, RBS and FBS). As already explained there are five types of requirements, namely: functional requirements, interface requirements, object requirements, aspect requirements and process requirements. When comparing the types of requirements with the decomposition tools of SE one can see that functional requirements can be decomposed to the FBS and the aspect, interface and object requirements can be decomposed into the SBS. The process requirements can be decomposed to the WBS but the client is not allowed to define the WBS for the contractor. Therefore it is recommended that and decomposition structure is added for the allocation of process requirements. This structure consists of a decomposition of project and process management objects that need to be made to enable the realization of a successful system but is not an object of the system. Examples of these kinds of objects are: planning, risk file, project quality plan, etc. Both the objects from the SBS as the objects from the project management breakdown structure (PMBS) can be allocated to the WBS.

6.2 Comparing SE and Relatics

This paragraph will give an answer to the last research question that is addressed in this chapter. Again, before this question is answered a comparison is made between SE and Relatics.

As already seen in the previous paragraph the intended goal of SE, as already described in section 3.2.1, is to reduce complexity. Several methods and techniques are given to make the system clear by structuring the information. The relationships between the structures can reveal more insight in the complex interfaces of the system. Relatics is a web-based semantic database which makes it possible to capture, manage and unlock information in an unambiguous and consistent way.

What are the differences in formulating requirements between SE and Relatics?

As can be seen from the definition of Relatics, "Relatics is a web-based semantic database which makes it possible to capture, manage and unlock information in an unambiguous and consistent way". The kind of information that needs to be managed is entirely up to the intended goal. On the basis of the goal a template is configured. Therefore there are no restrictions from Relatics on how requirements should be formulated.

From a SE perspectives there are many requirements on how the requirements should be formulated. This can be seen in paragraph 3.3.

6.3 Comparing the HOR and Relatics

In this final paragraph of this chapter the following sub-question will be addressed:

Which problems arise when setting the HOR up in Relatics?

The answer to this question can be found in a combination of the previous two paragraphs 6.1 and 6.2. This first paragraph concludes that the HOR can be set up for the use of SE when the requirements are formulated according to specifications from paragraph 3.3. In addition, the requirements should be decomposed and allocated in the structural and systematic way SE describes. The problem that arises is that the process requirements can't be decomposed along a structured way. Therefore it is recommended that an decomposition structure is added for the allocation of process requirements.

It is apparent from the second paragraph (6.2) that in theory Relatics can constitute a framework to capture, manage and unlock the information needed for SE. The next part of this research (the case study) will examine in an empirical way if this is also the case in practice.
Phase C: Case study: Reconstruction Vlielandseweg

7 Case study: Reconstruction Vlielandseweg
The previous phase was performed to gain more insight into SE, HOR and Relatics. This phase will focus on the practical interpretation of the subjects. The goal of this phase is to investigate whether Relatics can help with the implementation of Systems Engineering within municipalities. In order to reach this goal, the following research questions are addressed in this phase:

1. How can Relatics help with the implementation of Systems Engineering at municipalities?
2. Which problems arise when setting up the HOR for Relatics?

To answer these questions, a case study will be conducted. This case study will contain two different aspects. First, as already explained in chapter 5, with the introduction of an information model also lots of processes within an organization change. The assumption is that municipalities already have got clear processes to address such a reconstruction project. This case study is used to examine what the current processes of the municipality Pijnacker-Nootdorp are for such a project. These processes are then compared to the technical processes described in chapter 4. The technical processes form the basis for the new project approach.

Second, the HOR will be implemented into a generic practical model of Relatics. The creation of this model will be described in the next chapter. This model will be used to examine whether Relatics can help to create the requirements definition in a systematic way and whether Relatics can help with the implementation of the systems engineering processes. This should help the municipalities with implementing SE because they are guided into systems thinking. During the case study it will become clear whether some processes change with the use of Relatics. Again these new processes are evaluated in comparison with both the current processes and the technical processes. An evaluation through interviews with the users from the municipalities should provide the answers to the research questions described above.

7.1 Current processes of the municipality in a reconstruction project
The case study that is covered in this phase is about the Vlielandseweg. This road is situated in the municipality Pijnacker-Nootdorp. The municipality says that the Vlielandseweg needs to be reconstructed. This actually gives a solution to a problem, while the problem is not yet stated. In the context of this research the current processes in the municipality Pijnacker-Nootdorp for a reconstruction project are determined through interviews. These processes are compared to the technical processes. The following processes are included in the technical processes:
- Acquisition process;
- Stakeholder requirements definition process;
- Requirements analysis process;
- Architectural design process;
- Verification process;
- Validation process.

The first process (the acquisition process) actually belongs to the agreement processes group. But because the acquisition process is influenced by stakeholder requirements definition process, the first is included into the technical processes. The purpose of the Acquisition Process is to obtain a product or service in accordance with the acquirer’s requirements (ISO/IEC 15288, 2008).

From the goal of this research it becomes clear that the data is not needed for statistical research. Therefore the qualitative open research method, oral interview is used. The technical processes as described above form the basis for the interview questions. The interviews will be conducted on the basis of these questions. The questions can be found in Annex B Interview Processes.

7.1.2 Description of the current processes

One of the components of SE is making choices explicit so that the coupling moments between processes can be transferred better. For this purpose, it is necessary to know what processes are used. In order to find out these processes an interview is held. This interview and the response can be found in Annex B Interview Processes. This paragraph gives an overview of the processes that have been identified during the interview.

Project work

Each project in the municipality Pijnacker-Nootdorp starts with the guideline Project work (Dutch: projectmatig werken). This guideline describes the four phases of a project namely: initiative, definition, implementation and closure. For each phase a process description is given for the purpose, outcomes, activities and tasks. These processes are the overarching processes in a project.

Initiative

Start: A project starts with an idea, problem or challenge by a client
Purpose: Exploration feasibility of the project.
Outcomes: Project assignment
Activities and tasks:
- Check backgrounds;
- make strategic considerations;
- point out desired effects;
- determine boundary conditions;
- outline global financial framework;
- exploration project team composition;
- make first image intended project results.

Definition

Start: The definition phase starts with the project assignment from the previous phase
Purpose: the purpose of this process is to define the project with the project team
Outcomes: A project plan prepared by the project team with the approval of the client
Activities and tasks:
- The project team holds a collective intake with the client and submits the agreements to the project definition;
- The project team determines how the project is implemented by translating it into activities;
- The client, the project leader and the project team create a management plan for the six management aspects.
- The project team conducts a risk analysis and proposes a risk management plan.
Implementation
Start: The implementation phase starts after the approval of the project plan from the definition phase. Purpose: Implementation and control of the project and ultimately the acceptance of the project results. Outcome: an accepted project result.
Activities and tasks:
- Implementing the project plan
- Preparation of one or more progress report
- Deliver project results and prepare the transfer document

Closure
Start: The closure process starts after the accepted project result. Purpose: Completion of the transfer and a clear evaluation. Outcome: Closure document with evaluation.
Activities and tasks:
- Develop transfer
- Unwind open point
- Evaluate the project
- Formally close the project

Besides these overarching processes, the municipality also uses technical processes to guide the project. The first process after the project work is the design process for the preliminary design. This process partly replaces the implementation process above described.

Design process
Preliminary design process (see Annex C)
Start: This process starts after the definition process and is comparable with the implementation process. Purpose: the establishment of the preliminary design. Outcome: Approved preliminary design.
Activities and tasks:
- Identifying available data
- Drawing sketch design
- Verifying sketch design by Plan Toets Team
- Drawing preliminary design
- Verifying preliminary design by Plan Toets Team
- Establish preliminary design.

Final design process
For the final design, the municipality doesn't have a written guideline. Usually this process is outsourced. Yet, through the interview, the municipality has described this process for the cases that it is not outsourced.
Start: This process starts after the preliminary design process. Purpose: The establishment of the final design. Outcome: Approved final design.
Activities and tasks:
- Identify requirements from users
- Check requirements with policy and management aspects
- Establish requirements
- Draw final design
- Verify final design by council
- Establish final design.

Drawing specification (Dutch: bestek) and cost estimation process (see Annex C)
Start: This process starts after the final design process and like the preliminary design process it is comparable with the implementation process. Purpose: to establish the specification and cost estimation. Outcome: Specification and cost estimation.
Activities and tasks:
- Identifying available data
• Preparing draft specifications
• Verifying draft specification
• Preparing draft cost estimates
• Verifying draft cost estimates
• Establishing cost estimates.

7.1.3 Comparison with the system lifecycle processes

The previous section described the processes that the municipality uses in order to complete projects in a successful way. This section will be used to reflect the described processes with the system lifecycle processes from ISO/IEC15288-2008. Before this is done, the coherence of the system lifecycle processes is described. As already explained the applicable system lifecycle processes are:

• Acquisition process;
• Stakeholder requirements definition process;
• Requirements analysis process;
• Architectural design process;
• Verification process;
• Validation process.

The purpose of the acquisition process is to obtain a product or service in accordance with the acquirer's requirements. The first activity of this process is the preparation of the acquisition. The first task of this activity is the establishment of a strategy for how the acquisition will be conducted. The second and last task of this activity is the preparation of a request for the supply of a product or service that includes the definition of the requirements (ISO/IEC 15288, 2008).

The purpose and activities of the stakeholder requirements definition process, Requirements analysis process and architectural design process are already explained in paragraph 3.3.

The specified design requirements resulting from the design process forms the basis for verifying the realized system and for devising an assembly and verification strategy. The purpose of the verification process is to confirm that the specified design requirements are fulfilled by the system (ISO/IEC 15288, 2008). The coherence of the above processes can best be caught in a graphically manner as can be seen in Figure 7-1 (Rijkswaterstaat et al., 2013). The iterative nature of the processes can be seen here.

![Iterative processes](image)

Figure 7-1 Iterative processes

If the processes from the municipality are reflected with the system lifecycle processes as described above, it becomes apparent that the processes are quite familiar. Yet, in order to implement SE within the municipalities some processes have to change or should be made more explicit. One example of the process that needs to be more explicit is the definition process from project work. From the interview held with the municipality it became clear that the requirements definition is not explicit. The requirements
definition forms the basis of the entire project. The explicit requirements definition process also forms the basis of the verification process, because it needs to be clear what needs to be verified. This process also needs to be further developed. Along with the changing of this process, the verification process needs to be changed. But, this can only be done if the requirements definition is more explicit.

The next paragraph will focus on a project within the municipality Pijnacker-Nootdorp. The system lifecycle processes as described above form the basis of this case.

7.2 Vlielandseweg

In the previous paragraph the processes that the municipality goes through in a reconstruction project are described and compared with the applicable system lifecycle processes. These system lifecycle processes form now the basis for the project approach of the case Vlielandseweg. The startup of this case will be done in this paragraph with an extensive description of the project. This description will consist of a project definition, problem analysis, goal analysis and a stakeholder analysis. The needed information is gained with interviews with the initiators of the project from the municipality Pijnacker-Nootdorp, see Annex D Interview Project definition. The complete Project definition can be found in Annex E Project definition Vlielandseweg. The following subparagraphs give a short overview of the topics.

7.2.1 Project definition

The Vlielandseweg (red on Figure 7-2) is a distributor road within the urban area of the municipality Pijnacker-Nootdorp with a maximum speed of 50 km/h. In the north the road connects to the Katwijkerlaan (blue in) and in the south on the Oostlaan (green on Figure 7-2) and Klapwijkseweg (Purple on Figure 7-2). With these connections the Vlielandseweg is part of the area connecting route between Zoetermeer and Pijnacker and between Delft and Pijnacker. There are various small roads and bridges that connect the adjacent buildings directly on the road. Also several access roads connect to the Vlielandseweg like the Boezemweg and Nieuwkoopseweg (yellow on Figure 7-2). As a result the Vlielandseweg is an important road for the traffic system of Pijnacker.

Figure 7-2 Vlielandseweg and connecting roads

7.2.2 Problem analysis

Considering the age of the Vlielandseweg, the past five years only the necessary maintenance was performed. The problems surrounding the Vlielandseweg are all interrelated and therefore should be seen as one. Yet, one has tried to make a distinction between the problems. The problems can be traced to the following categories: road construction, sewer and water.

Problem: Because the Vlielandseweg is very outdated, there are major problems for residents and users in the field of construction, water management and sanitation.
7.2.3 Goal analysis
The goals for the municipality of this project is twofold. Their primary goal is to solve the problems within the budget and time schedule. In order to reach that goal they have decided to execute this project with an UAV-gc contract (dutch: Uniforme Administratieve Voorwaarden geïntegreerde contracten). Unfortunately they don’t have a lot of experience with using such a contract. Therefore their secondary goal is to learn as much as possible from this project with the UAV-GC contract.

7.2.4 Stakeholder analysis
The first process of the technical process group is the stakeholder requirements definition process. The first activity of this process is to identify the individual stakeholders who have a legitimate interest in the system throughout its lifecycle. This identification is done through a stakeholder analysis and is described in Annex E Project definition Vlielandseweg. The second step of this process is to elicit the requirements from the identified stakeholders. In the context of this study, the only stakeholder requirements considered are those from the municipality. As already explained the HOR is a guideline with requirements, assumptions and constraints for the public space. The guideline of the Municipality Pijnacker-Nootdorp will be elaborated in the next paragraph.

7.3 Current state of the HOR
The previous paragraph gave a short overview of the project definition of the Vlielandseweg. This project definition including the identified stakeholders is part of the stakeholder requirements definition process. Before proceeding with this process, first the HOR is elaborated on the current use. The content of the HOR will be elaborated in the next chapter.

7.3.1 Current use of the HOR
During the interview with the municipality the HOR was also extensively covered. This was done to find out what the current state of the HOR is and how it is used. From this interview various assumptions about the use of the HOR were confirmed.

The earlier assumption that the HOR is used for a requirements definition, was rejected by the municipality. The HOR is given to designers to serve as design principles and is not transferred into requirements definition. It is not clear for the designers how to use this document. For example, in the HOR are requirements given for several types of cycling paths. This gives the designer too much design freedom. Therefore the HOR is not used for its intended purpose.

Also in the current state it is not possible to verify the requirements from the HOR. The HOR is a continuous text that describes the requirements, but does not clearly outline them. During the verification of the preliminary design the requirements can therefore not be verified. The design needs to be in line with the HOR. If the preliminary design is drawn by the municipality, there is even less use of the HOR. Both respondents of the interview would like to see this differently and see the benefits of well written requirements.

Both respondents also see that the current HOR is not usable in projects. And they do know how to adjust their HOR to make it useable for UAV-GC contract types. “It would be an improvement if one could select the applicable objects and then get the requirements. However, this would especially be an advantage for the contractor.” For the client there is a risk occurs that requirements will be forgotten with this new approach.

As already explained in paragraph 7.1, in order to implement SE the requirements definition needs to be made more explicit. This goes hand-in-hand with the current use of the HOR. Besides changing the process also the HOR needs to be made more explicit and the additional meta-data needs to be added. This will be done in the next chapter with the use of Relatics.
8 The HOR with SE principles in Relatics

The previous chapter elaborated the current processes of the municipality and the use of the HOR in these processes. There it was made clear that in order to implement SE within the municipalities the requirements definition needs to be made more explicit. This is also necessary for the verification process.

With the current HOR however, this is not possible, but with the use of the information model Relatics this might be possible. The first paragraph of this chapter explains the creation of a workspace in Relatics that should accomplish a new HOR that is useable for the implementation of SE. In the second paragraph the current HOR will be imported into this workspace and the requirements will be evaluated and allocated. In the third and last paragraph a new process description will be given about how the workspace needs to be used in order to create a basis for the requirements definition.

As a result of this new process, the basis for the requirements definition for the case Vlielandseweg will be given. This basis requirements definition is filled with requirements of the HOR that is adapted to SE in Relatics. In order to get a complete requirements definition, the basic requirements needs to be supplemented with project specific requirements and requirements from other stakeholders. The above described structure of this chapter can also be seen in the process description of the HOR and in Figure 8-1.

![Figure 8-1 Process description of the HOR](image)

8.1 Creating a workspace in Relatics

Relatics is a semantic web-based database. If Relatics is configured it becomes an information model. Depending on what features are added, Relatics can be an information model for SE, asset management or quality health and environment, etc. This paragraph will describe the creation of a workspace for SE. The emphasis of this workspace will be on requirements management and the requirements definition process.

8.1.1 Requirements identification and analysis for the model

Before a workspace can be created, it needs to be clear which features need to be added into the workspace, i.e. the requirements need to be identified. The requirements definition for the workspace will be created in this section. The workspace that will be created can also be seen as a system. A system can be defined as a set of interrelated components working together towards some common objective (Kossiakoff et al., 2011). Therefore the creation of this model will be done with a systems engineering approach. Given the small size of the system, not all SE features will be used. Also, not all processes will be reviewed in its entirety.
The requirements definition starts with the identification of the stakeholders and their requirements. The stakeholders for this workspace are the end-users and the functional designers. In this case the developer is the researcher. To the users group belong two types of stakeholders, namely the client and the contractor.

Requirements identification

The following list gives an overview of the requirements for the workspace. This list also includes the identified requirements from other information management tools as done in chapter 5.

- The workspace shall be applicable for the use of SE
- The SE features that need to be added are:
  - Stakeholders
    - Persons
    - Organizations
    - Roles
  - Requirements management
    - Document the requirement including the metadata
    - Keep the requirements traceable by
      - Connecting it to the document, initiator and responsible person
      - Document the changes of the requirements over time
    - Validate the requirements text
  - Functional breakdown structure (FBS)
  - Object breakdown structure (OBS)
  - Work breakdown structure
    - Add the time features in the WBS
  - Verification process
- The workspace shall entail a document management system
- The workspace shall provide insight into the relationships between the objects.

Requirement analysis

The purpose of this process is to transform the stakeholder, requirement-driven view of desired services into a technical view of a required product that could deliver those services (ISO/IEC 15288, 2008). Part of this process is to define the functional boundary of the system in terms of the behavior and properties to be provided. As a result each function that the system is required to perform is defined. These functions are shown graphically in Figure 8-2.
The following step is to specify the system requirements. Here the stakeholder requirements are transformed into system requirements. These are the requirements that fulfill the functions and can be seen in Figure 8-3.

Figure 8-2 Function tree workspace
Figure 8.3 System requirements

With the above requirements, the requirements analysis process has finished and the next process can be started. This process is the architectural design process.

8.1.2 The model

The previous section described the requirements which are imposed for the intended workspace. This section will focus on the design, implementation and integration process.

Architectural design process:

In order to define the architecture, first the appropriate logical architectural design needs to be defined. Then the functions identified in the requirements analysis need to be allocated to the elements of the system architecture. Finally the interfaces between the system elements need to be defined and documented. The elements of the system architecture are shown in the object tree of Figure 8.4.
In order to create a workspace in Relatics, the interfaces or relations between the elements need to be identified. Also the direction of the relation is important because this direction determines the meaning of the relation. The so-called class-model for the to be created workspace can be seen in Figure 8-5.

Figure 8-5 Model for the workspace

After the creation of the class-model the architectural design process has finished. The next processes are the implementation process and then the integration process. The purpose of the implementation process is to realize a specified system element. The purpose of the integration process is to assemble a system
that is consistent with the architectural design. Both processes have the same process activities. First a plan needs to be developed and then the plan needs to be performed. In practice the WBS is used to plan all the activities for both processes. The WBS for the creation of the workspace can be seen in Figure 8-6.

![Work Breakdown Structure](image)

**Figure 8-6 WBS**

After the implementation and the integration process the system has been realized. The realized workspace can be seen in Annex F Template GM. The next process is the verification process. This process will be elaborated in the next section.

8.1.3 Verification of the requirements

The previous section explained the creation of the workspace in Relatics. This section will focus on the verification process. The purpose of the verification process is to confirm that the specified design requirements are fulfilled by the system. The process consists of the following activities:

- Plan verification.
- Perform verification.

The result of both activities can be seen in Annex F Template GM. An example for the verification plan and verification report can be seen here. In the context of the case study the workspace will now be used and goes into the operation process. Besides the case study the workspace is also used in several projects of Gebiedsmanagers B.V. This also proves the success and usability of the workspace.

8.2 Filling the workspace

The previous section described the process of making the workspace for SE. In the context of the case study, this workspace will be used for the requirements definition process and the subsequent processes. As stated earlier the HOR forms the basis for the requirements definition. However, the HOR gives requirements for all the objects of the public space, including requirements that may not apply for a certain project. According to the respondents of the municipality of Pijnacker-Noordorp, the HOR can be improved by structuring the requirements along objects. During a project, the applicable objects and relevant requirements can then be selected. Before this can be done the requirements of the HOR should be imported into the workspace. Then these requirements need to be allocated along the relevant decomposition structure. This process will be described in the next sections.
8.2.1 Requirements import

Before the workspace can be used, it should be filled with information. In this case, the information comes from the HOR. The HOR of the municipality Pijnacker-Nootdorp is in contrast to the literature about the HOR a continuous text with hidden requirements. According to the literature, all the requirements should be unique. In the following step the continuous text is subdivided into separate requirements. By doing so, the requirements can be formulated explicitly and SMART.

In order to facilitate the import of requirements, Relatics uses import definitions. Import definition uses a predefined Excel template. The continuous text from the HOR needs to be copied to the excel template before it can be imported. This also gives the possibility to cut the continuous text into separate requirements. The additional metadata can also be added in this Excel template. The information that can be imported from the Excel template is:

- Requirement group
- Requirement ID
- Requirement title
- Requirement text
- Requirement notes
- Requirement type
- Requirement nature
- Scale level
- Initiator
- Responsible person.

After the requirements including the metadata are imported, the requirements can be analyzed. This process will be described in the next section.

8.2.2 Requirements analysis

The previous section described the process to import the requirements. This section will focus on the requirements analysis. The analysis of this section has a different purpose as the analysis described in section 8.1.1, though the activities remain the same. The first activity is the analysis of the requirements itself in terms of the formulation of the requirement. The second activity is to define the functions in order to gain insight in the requirements and to be able to structure the requirements.

Analysis of the formulation

From the requirements import process, 364 requirements were identified. During this import it became apparent that parts of the continuous text of the HOR aren’t requirements, but a description of an object (see Figure 8-7), function (see Figure 8-8) or lifecycle phase (see Figure 8-9). These descriptions need to be filtered out to remain with only a list of requirements.

![Figure 8-7 Description of an object](image-url)
After this first step 37 requirements were filtered out and 327 requirements remained. The following step of this analysis is the check whether the requirement is SMART. In order to manage this process and to keep the requirement and the changes traceable, another feature is added in Relatics. In Relatics one can indicate whether or not the requirement text if SMART. If this is not the case, the requirements text needs to be adapted. To ensure the traceability the expired requirement text is kept including who, when and why the requirement is expired. By doing so, the changes that have been made are explicit and traceable, as can be seen in Figure 8-10.

### Figure 8-10 Requirement text analysis

**Analysis of the required functions**

Besides the analysis of the requirement text, the set of requirements needs to be analyzed in order to identify the functional boundary. This needs to be done in order to create structure in the requirements. The functional boundary is identified by performing a functional analysis. The strength of a functional analysis is that one can find alternative solutions to the design problem. The identified functions are decomposed into a FBS. A portion of the FBS can be seen in Figure 8-11.
After the identification of the functions, the requirements have been properly analyzed. The next process is the architectural design process.

### 8.2.3 Architectural design process

As already explained in the previous section, after the requirements analysis process, the architectural design process needs to be performed. The purpose of this process is to identify the objects that the system should fulfill. In this case the functions need to be converted to objects in an object tree. Part of the object tree for the requirements from the HOR can be seen in Figure 8-12.

**Figure 8-11 Functional Breakdown Structure**

After the identification of the functions, the requirements have been properly analyzed. The next process is the architectural design process.

**Figure 8-12 Object tree**
Process requirements
The next step in this process is the allocation of the requirements over the identified objects. In Relatics, this allocation can be done by selecting the function and object it belongs to. After the first allocation round, 260 of the 327 requirements were allocated. The remaining 67 requirements were process requirements. In order to allocate these requirements, another decomposition structure was used namely a process management object tree. This decomposition structure consists of a decomposition of project and process management objects that need to be made to enable the realization of a successful system but is not an object of the system. This separation of objects and process requirements can also be seen in the requirements definitions of Rijkswaterstaat (RWS). This requirements definition, which is part of the contract, contains the same separation of requirements for objects and requirements for processes. As a basis for the project management object tree, the standardized process requirements of RWS where converted into project management objects. The result of this decomposition can be seen in Figure 8-13. After the creation of the Project management object tree, the remaining 67 requirements were allocated along this decomposition.

![Figure 8-13 Project management object tree](image)

After the allocation process the workspace is filled with information and is ready to use. The old HOR is now transformed into a SE-HOR. The next paragraph will give an overview of the use of the workspace for the case "Vlielandseweg" with the new stakeholder requirements definition process.
8.3 Using the workspace (new process)

The requirements definition consists of two different types of requirements. First, the requirements from the HOR. Second, the project specific requirements. This paragraph will focus on using the workspace for retrieving the applicable requirements for the case “Vlielandseweg” from the SE-HOR. The workspace is filled with information and requirements from the old HOR of the municipality Pijnacker-Nootdorp and is now ready to use for the new process. Before this process is actually performed, first this process will be described in the next section 8.3.1. The following section 8.3.2. will give the results of the process.

8.3.1 Process description

In this section the process description will be given of the process for selecting the applicable functions, objects and requirements from the SE-HOR for a project, from the predefined decomposition structures.

Purpose:
The purpose of the stakeholder requirements definition process is to select the applicable requirements for a system that can provide the services needed by users and other stakeholders in a defined environment.

Input:
The input of this process is the new SE-HOR, allocated along the FBS, SBS and PMBS.

Output:
As a result of the successful implementation of the stakeholder requirements definition process the applicable requirements for the system remain.

Activities and Tasks:

- Functional analysis
  - Define the functional boundary of the system from the predefined FBS
  - Remove the functions that are not applicable.
- System analysis
  - Define the objects that need to be included in the system from the predefined SBS
  - Check the objects that don’t fulfill a function anymore.
  - Check whether these objects are superfluous
  - Remove the objects that are not applicable.
- Requirement analysis
  - Check the requirements that are not linked anymore with objects.
  - Check whether these requirements are superfluous
  - Remove the requirements that are not applicable to the system.

8.3.2 Results of the use of the SE-HOR process

The previous section described the process to select the relevant requirements from the HOR for the requirements definition. This section describes the result of this process and how to export these results. The context in which this process is completed is the case “Vlielandseweg”, therefore this process is completed with the users of the municipality Pijnacker-Nootdorp.

At the beginning of the process the workspace was filled with 60 functions, 77 objects and 327 requirements. After following the process 48 functions, 65 objects and 303 requirements remained. Most requirements were removed because of the fact that some objects have multiple requirements e.g. a single and double cycling lane. Other requirements were removed because some objects were redundant and the requirements were not applicable for the system anymore. During the analysis these became apparent because of the allocation of the requirements along objects. Also the contradictions in requirements can easily be found.
In order to use these requirements it would be useful if these requirements can be exported to Word or Excel. In Relatics it’s possible to create reports with the information needed, in this case the requirements allocated along the SBS. For the creation of reports, Relatics offers an additional training. This training wasn’t followed by the researcher, yet he did manage to create such report export file. Part of the resulting applicable requirements for the case Vlielandseweg can be found in Annex G Requirements from Relatics.

The requirements analysis process is passed through several times. When analyzing the result of the requirements definition several problems occur for the use of SE. These problems should have been identified in earlier analysis processes. However, because of the iterative nature, the requirements are considered several times. This gives more understanding about the requirements. Therefore the problems are identified here and not earlier. The identified problems are:

- A lot of requirements are not formulated in the correct way. The requirements were derived from a continuous text and have to be made SMART.
- The requirements that describe what functions the object needs to fulfill are missing. The requirements have to be complete.
- The analyzed requirements are mainly requirements imposed on objects that occur at a low level of the object tree. The requirements definition should be solution free.
- A number of crucial requirements are missing, e.g. lifespan requirements, settlement requirements and traffic related requirements, weight, etc.
- Requirements are imposed on objects that belong to other stakeholders. E.g. there are requirements for the waterways while the Water Board is responsible. The same goes for a number of requirements for cables and pipes. It’s important that there is consensus with the stakeholder about responsibilities and the requirements for those responsibilities.

In paragraph 10.2 recommendation will be given about how these problems should be solved.

### 8.3.3 Stakeholder requirements definition process

There is an important distinction between the HOR and the requirements definition for a specific project. The making of the requirements definition consists of selecting the requirements from the HOR that apply to the project plus the discussion on project specific requirements (CROW, 2008). The project specific requirements also include the requirements of the other stakeholders.

The stakeholders requirements definition process is after performing the use process far from ended. The requirements from the HOR only provide the basis for the requirements definition. These requirements need to be supplemented with project specific requirements and requirements from other stakeholders, see Figure 8-14.

![Figure 8-14 Use of the SE-HOR](image-url)
It is very likely that contradictions occur if the requirements definition is supplemented with project specific requirements, but because the majority of the requirements are standardized more time remains for the discussion about project specific and unique requirements. These contradictions can then easily be detected with the use of Relatics but only if the requirements is stated to the same object. If the requirements are stated to different objects it becomes more difficult to detect them.

In the example can be seen how SE offers room for discussion about contradictions. This reduces the development effort because the contradictions are known early in the process, therefore less rework is required.

Example 1:

HOR: The bricks of the cycling path shall be grey.

Architect: The bricks of the cycling path shall be red.
9 Evaluating the Relatics model and processes

The previous chapter focused on Relatics. The process of the creation of a workspace in Relatics, the filling of the workspace and the use of the workspace was addressed here. This chapter will evaluate this workspace in terms of the processes that might have changed, the use of this workspace and the factors that have affected the implementation will be discussed.

The processes will be compared with the system lifecycle processes as already described in this research. The use of the workspace will be evaluated with the users of the municipality Pijnacker-Nootdorp through interviews. The topics that will be addressed during the interview will be the usability, potential benefits and potential risks. The factors that have affected the implementation will be discussed in the last paragraph.

9.1 Reflection of the processes

As already mentioned in chapter 8, with the use of an information model the processes for developing a project might change. This paragraph will reflect the processes that were introduced in the previous chapter with the system lifecycle processes from ISO15288. In this reflection the filling of the workspace is also taken into account.

The system lifecycle processes are the processes that need to be followed during the various lifecycle phases. In this research these processes where delineated to the processes needed for the development of a system (the yellow border in Figure 9-1). This figure also shows the V-model in which the development phase has an iterative top-down nature. Top-down, because first the top requirements and functions of the system need to be identified which are then decomposed to lower level functions and requirements. The iterative nature ensures that the processes are followed multiple times. After each process cycle the system will be developed to the next level.

If the processes for filling and using the workspace of Relatics are reflected with the system lifecycle processes as described above, it becomes clear that these processes are comparable. During the filling of the workspace the same processes are followed. The filling process is the process for redefining the HOR into a SE-HOR.
First the requirements are identified and imported into the workspace (stakeholder requirements definition process). The identified requirements come from the current HOR of the municipality Pijnacker-Nootdorp. The second process step is the requirements analysis so that the functional boundary and the FBS can be determined (requirements analysis process). The third and last step is the identification of objects that should fulfill these functions and the allocation of the requirements along this SBS. This process cycle is exactly the same as described by the system lifecycle processes. The difference is that during the filling of the workspace, requirements are identified of a much broader system, namely the public space.

During the next process the broad requirements for the entire public space will be narrowed down to the system applicable requirements. This process starts with the filled workspace with requirements from the HOR. The next process is to identify the functional boundary from the predefined FBS. The third and last step is the identification of the applicable objects needed for the system to fulfill the functions. Again this can be done from a predefined SBS. From here the applicable requirements remain and are already allocated. The broad public space requirements are now narrowed down to system applicable requirements.

These process courses are very much alike with the system lifecycle processes. During the top-down development also the solution space of the system is narrowed down. This is comparable with the processes during the use of Relatics. Also the iterative nature returns with the use of Relatics, because both process cycles follow the same processes. However, the process course for filling the workspace only needs to be performed once. Hereafter this workspace can be used for multiple projects.

9.2 Evaluation of the workspace

This paragraph will focus on the evaluation of the workspace. This is different from the verification of the requirements, which is already done in section 8.1.3. The evaluation that will be performed in this paragraph will be the verification and validation of the workspace.

For both verification and validation there are, depending on the lifecycle phase, different methods. Besides the method it’s important to determine the criteria that need to be evaluated. Without criteria that can be verified and validated, the objective evidence lacks its effectiveness (Rijkswaterstaat, 2009). It is important to choose the proper criteria to make the verification and validation practical and effective. The criteria that will be evaluated are the functional criteria determined during the requirements analysis process of section 8.1.1.

In order to verify these functions the method of demonstration is used. A demonstration is a qualitative representation of functional performances. Demonstrations provide an impression of the operation and characteristics of the system (Rijkswaterstaat, 2009).

In order to validate the entire system use is made of a user satisfaction evaluation. The goal of this survey is determining, by investigating the experience of users of the system, if the system meets the required needs (Rijkswaterstaat, 2009). The evaluation will be done through interviews with the users from the municipality Pijnacker-Nootdorp. Before this interview is held, the users from the municipality had the opportunity to work with Relatics and the processes as described in the previous paragraph were followed. The interview questions and answers can be found in Annex H Interview Relatics. The interview can be summarized as follows:

The first impression of Relatics and the workspace was that it is a great program with a lot of features. Basically, it is a database where you could also accommodate processes. After seeing and using the program, one user has become very enthusiastic. He immediately sees the benefits for using the program in small projects, despite it’s generally being applied in larger projects. The users believe that Relatics and a systematic approach can reduce the duration and thereby the costs of a project. The HOR could also be accommodated therein. This can lead to unambiguous results in terms of quality and maintenance.
Currently the HOR is very outdated and it needs a major update before it can be used effectively in Relatics. The greatest risk for Relatics or any other information model is that the organization can cause problems for the implementation. The majority of the employees have difficulties with changes, especially when it comes to IT solutions. The respondents are not sufficiently versed in the area of SE that they can determine whether Relatics can assist with the implementation of SE. However, they see that this tool can help to save all project information in a clear and organized way. They also see the opportunity to use Relatics for the preparation of the requirements definition.

Besides the users of the municipality, also the researcher has used the workspace. The researcher has used Relatics to track the information for the development of the workspace. The development of the workspace was done using SE processes. For each of the used processes, Relatics offers a way to record that information. E.g. the requirements from the requirements definition process can be recorded in the requirements section of the workspace. The functional boundary of the system can be recorded in FBS. The system objects and the project management object can be recorded in the respectively SBS and PMS. With the use of Relatics this information was recorded and structured. The WBS structured the different objects that needed to be developed. The WBS was also used for the verification process of the requirements. All this gave insight in the developed system. So, Relatics can help with recording the information that is gained during the different processes. However, the user needs to know how these processes are performed.

The owners of the workspace have also evaluated the use of the workspace in relation with their potential clients. They want to use the workspace in two ways. The first manner is to use the template in their own projects. For those cases the workspace is now being used so they don’t have an opinion about that yet. The second manner is to use the template to help the municipalities with the setting up of their HOR for the use of SE. The processes that they go through are the same as the processes of the HOR as can be seen in Figure 8-1. The setting up of the SE-HOR is already done in paragraph 8.1 with the creation of the workspace. The filling of the SE-HOR is done in paragraph 8.2 with the old HOR of Pijnacker-Nootdorp. The use of the SE-HOR is done is paragraph 8.3 with the case Vlielandseweg, this can also be seen in Figure 9-2.

Figure 9-2 Use of the Workspace by Gebiedsmanagers B.V.

After seeing and using the workspace in the case study Vlielandseweg, they are very pleased with the result. They expect that the application of the SE-HOR to other projects within Pijnacker-Nootdorp will costs significantly less time. An indication of this time reduction can be seen in Figure 9-3.
By using and updating the SE-HOR in multiple projects, it will also become possible to create a generic SE-HOR. This generic SE-HOR can then easily be used for the transition of other HORs from other municipalities. In addition to the gains that can be achieved by a generic HOR there is the benefit that the creation of the workspace is already done. Gebiedsmanagers can now use this workspace to help multiple municipalities with the transition towards a SE-HOR.

9.3 Success and failure factors for implementing SE

The previous paragraphs have given an evaluation on the processes and the use surrounding the workspace. This paragraph will focus on why the implementation of SE in the case Vlielandseweg was a success and what were the blockages of this implementation.

9.3.1 Success factors for implementing SE

This section will elaborate the factors that affected the implementation of SE into the municipality.

The most important factor for the implementation is that the municipality want to learn about SE. They know the benefits about SE in theory and now want to find out if this is also the case in practice. Therefore, they have chosen to do the case study with the use of SE. This approach is supported by the higher management of the municipality because the manager was always present at the interviews. He also involved individual project employees in the meetings and interviews. After seeing Relatics and hearing the explanation of SE they were also very interested. The manager also reserved financial resources for this project.

The fact that the municipality use the processes from project work made the implementation a bit easier. They are already familiar with supporting processes for project management, contract management and risk management. This makes the cooperation between the different disciplines better.

Another important factor is the project itself. There are many involved disciplines in the case "Vlielandseweg", it also has many interfaces with external objects and many involved stakeholders. This
makes this case perfect for the use of SE. The organization has already been divided into the different disciplines that know how to collaborate.

The case “Vlielandseweg” has been appointed as a pilot project by the municipality. Therefore the project has the freedom to take as much time as needed to understand all the ins and outs about SE. Besides the learning effect of this freedom there is also the benefit that all the processes can be gone through in its full potential to gain as much benefit from SE as possible.

The last important factor that played a major role in the successful implementation was the presence of the researcher who functioned as the SE manager. He explained all the processes and explained the systems thinking. Besides the learning effect of the presence of a SE manager, they also learned a lot by actually doing all the processes in practice. Because of his presence and the freedom in the project arrangements the implementation was a success.

9.3.2 Blockages of the implementation
This section will elaborate the factors that blocked the implementation or have caused a delay.

The most important factor that delayed the implementation of SE within the municipality was their insufficient knowledge of SE. This factor can be subdivided into several sub-factors. A sub-factor that blocked the implementation rate was their insufficient knowledge of the SE processes. This had also an influence in the filling of the workspace process. Initially we wanted to draw up the FBS and SBS together but because the municipality is not familiar with systems thinking and drawing up functional specifications it was done by the researcher. This predefined FBS and SBS was then a benefit for the use of the workspace process, because the people of the municipality were guided into systems thinking. Also during the use process we were able to discuss both decomposition structures. By doing so they learned a lot about SE, the processes and systems thinking.

It is a benefit that the municipality uses the processes from project work (see paragraph 7.1.2) because it supports the coordination with the supporting processes. However, they do need to change some of their current processes. Most processes and their results are not explicit, which is needed for the transfer between the client and contractor. Besides making the processes explicit some SE processes need to be incorporated in their processes e.g. the verification and validation process. Relatics offers a standardization and a workflow for these processes.

Another blocking factor was their current HOR which is not usable for SE. Before SE can be used it’s important to have requirements formulated according to the rules as stated in paragraph 3.3. This problem became apparent with the use of Relatics. Also with Relatics it was possible to update their HOR and to keep the changes traceable, so the municipality could learn from the made changes. i.e. Relatics was a tremendous help with the requirements analysis process.

9.3.3 Comparing factors from the research to the literature
This section will compare the success and blockading factors with the factors found in the literature. The considered literature is from Van den Houdt and Rijkswaterstaat. In Table 9-1 the comparison can be seen. From this comparison it can be concluded that the identified factors are comparable with the factors found in the literature, this substantiates the identified factors.
9.4 Implementing strategies

From the previous paragraph we learned about the factors that could affect the implementation of SE. Knowing these factors and knowing how to deal with them, an implementing strategy can be determined. Before the strategies are determined it is suggested to classify the municipalities according to the will-skill matrix as can be seen in Figure 9-4. This matrix also provides strategies for implementing SE.

![Will-Skill matrix](image)

In the above matrix a separation is made between the will (motivation) and the skill (knowledge). This is also applicable to the municipalities regarding SE. This matrix also gives four strategies about how to deal with each group. With the determined factors from the previous section the municipalities can be classified to a group with the applicable strategies. The strategies will be further elaborated below:

**High will, low skill / Guide strategy:** This group is probably the largest group and the municipality Pijnacker-Nootdorp also belongs to this group. They want to use SE but don't have the acquired knowledge to do so. For this group it's important that they gain the required knowledge. This knowledge
can be gained by following courses on SE and then apply this knowledge in a project. In addition, a SE expert is needed for the alignment of SE theory with the application in practice. This expert can train both the theoretical as the practical knowledge are therefore guide the municipality into SE. The implementation should be done step-by-step according to the CMMI-model (Table 2-1). After the first level of the CMMI-model the municipality should be able to perform requirements management. Therefore, first the HOR should be transformed into a SE-HOR, which can best be done with the use of Relatics. This transition is a one-time effort after which the time and effort for creating a requirements definition is reduced, as seen in Figure 9-3.

High will, high skill / Delegate strategy: The municipalities in this group are the leaders in terms of implementing capabilities of SE. This group doesn’t need guidance or motivation from an SE expert. However, they can be helped with project capacity if they don’t have enough available personnel.

Low will, high skill / Excite strategy: This group only needs the motivation for the implementation of SE. They need to be convinced of the benefits of SE. They need intrinsic motivation, incentives and value alignment. Recognizable examples with the benefits should help to motivate them. According to Gebiedsmanagers and the researcher this group (if they exist) is really small.

Low will, low skill / Direct strategy: This group needs, in contrast to the previous, both the knowledge as the motivation for the implementation of SE. The benefit for the implementation is that they don’t have wrong expectations or wrong knowledge. This implementation needs a combination of a task-oriented and people-centered approach. Just as with the guide strategy it’s important to implement it step-by-step according to the CMMI-model. For the gain in motivation the strategy as described with Exite should be followed.

9.5 Intermediate conclusion
In this chapter the following sub-question was addressed:

Which problems arise when setting the HOR up for SE and Relatics?

In the first paragraph, the process for using Relatics is compared with the system lifecycle processes. Here it becomes apparent that there are hardly any differences between both process cycles. So the processes itself don’t give any problems.

In the second paragraph the workspace is evaluated by the users of the municipality and by the researcher. The initial problem that occurred was that the process requirements couldn’t be allocated to a decomposition structure to create insight in the requirements. This was solved by introducing another decomposition structure named the Project Management Object tree.

The third paragraph discussed the factors that influenced the implementation of SE. The complete list of factors that have an influence on the implementation of SE and a comparison with factors found in the literature can be seen in Table 9-1. A separation can be made between will (motivation) and skill (knowledge) factors. Within the municipality Pijnacker-Nootdorp there is the will to implement SE. However the skill or knowledge how to implement SE is lacking. In order to determine what skills the municipalities have they can be classified according to the CMMI-model as can be seen in Table 2-1. According to the will and the skill of the municipality a strategy from the will skill matrix (see Figure 9-4) can be chosen for the implementation of SE.

In addition, according to the theory about the HOR, the requirements and the set up should already be useable for SE. However, during the case study an investigation was done about the HOR of the municipality Pijnacker-Nootdorp and the following problems about the HOR became apparent:

- The HOR is a continuous text while the requirements should be unique
- The current HOR is very outdated and is no longer in line with the current policies
• A lot of requirements are not formulated in the correct way. The requirements were derived from a continuous text and have to be made SMART
• The requirements that describe what functions the object needs to fulfill are missing. The requirements have to be complete
• The analyzed requirements are mainly requirements imposed on objects that occur at a low level of the object tree. The requirements definition should be solution free
• A number of crucial requirements are missing. E.g. lifespan requirements, settlement requirements, traffic volume, traffic weight, etc. The requirements have to be complete
• Requirements are imposed on objects belong to other stakeholders. E.g. there are requirements for the waterways while the Water Board is responsible here. The same goes for a number of requirements for cables and pipes. It’s important for the use of the HOR that there is consensus with the stakeholders about who is responsible for what object. The responsible stakeholder should then formulate the correct requirements.

The above stated problems were identified from the HOR of the municipality Pijnacker-Nootdorp. It is therefore not known if these problems also occur in the HOR of different municipalities.
Phase D: Conclusion and Recommendations

10 Conclusions and recommendations
This report contains an investigation about how municipalities should adjust their HOR in order to implement Systems Engineering in their projects. In addition, it is investigated whether Relatics can help with this adjustment and implementation. The first paragraph provides the answer to the main research questions, as posed in the introduction of this report.

10.1 Conclusions
In paragraph 2.3 the main research questions were presented:

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<th>Research Question 1:</th>
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<td>How can the HOR be set up for the use of Systems Engineering?</td>
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<th>Research Question 2:</th>
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<td>How can Relatics help with the implementation of Systems Engineering at municipalities?</td>
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The answer on the first research question is based on the literature about SE and the HOR. During this literature study sub-questions were used for both SE and HOR.

- How are requirements formulated for the use in Systems Engineering?
- How are requirements formulated in the HOR?

The combination of both questions provides the answer of the first research question:

Research question 1:

How can the HOR be set up for the use of Systems Engineering
In order to set up the HOR for SE first of all the requirements need to be formulated according to specifications from paragraph 3.3 and 4.2. Both paragraphs state the same requirements to the formulation, the traceability and the allocation of the requirements. The requirements should fulfill the demands Complete, Current, Clear, SMART.

“The HOR is a collection of knowledge, experiences, requirements and conditions for the public space imposed by the municipality. The guideline is a kind of database out of which the customer requirements specifications can be composed.”

Such a database can be hardcopy or digital. From the gained experience of the performed transition of the old HOR of Pijnacker-Nootdorp into the SE-HOR, it can be concluded that the HOR can be set up for the use of SE with Relatics. This transition to Relatics should be seen as a single action which costs a lot of effort. After that transition, the time and effort will drastically reduce, as can be seen in Figure 9-3.

The main benefit of creating a HOR according to the SE principles is that consistency is created in the standardized requirements. There is an important distinction between the HOR and the requirements definition for a specific project. The making of the requirements definition consists of selecting the requirements from the HOR that apply to the project plus the discussion on project specific and unique requirements. It is very likely that contradictions occur if the requirements definition is supplemented with project specific requirements, but because the majority of the requirements are standardized more time remains for the discussion about project specific and unique requirements.
According to the theory about the HOR, the requirements should already meet the demands to the requirements as stated in chapter 6. During the case study an investigation was done about the HOR of the municipality Pijnacker-Nootdorp and the following problems about their HOR became apparent:

- The HOR is a continuous text while the requirements should be unique
- The current HOR is very outdated and is no longer in line with the current policies
- A lot of requirements are not formulated in the correct way. The requirements were derived from a continuous text and have to be made SMART
- The requirements that describe what functions the object needs to fulfill are missing. The requirements have to be complete
- The analyzed requirements are mainly requirements imposed on objects that occur at a low level of the object tree. The requirements definition should be solution free
- A number of crucial requirements are missing. E.g. lifespan requirements, settlement requirements, traffic volume, traffic weight, etc. the requirements have to be complete
- Requirements are imposed on objects belong to other stakeholders. E.g. there are requirements for the waterways while the Water Board is responsible here. The same goes for a number of requirements for cables and pipes. It’s important for the use of the HOR that there is consensus with the stakeholders about who is responsible for what object. The responsible stakeholder should then formulate the correct requirements.

Research question 2:

How can Relatics help with the implementation of Systems Engineering at municipalities?
Based on the research about Relatics in a practical manner it can be concluded that Relatics can help with the implementation of SE in the following ways:

- The results of the system lifecycle processes can easily be stored and managed
- Project members have explicit and unambiguous project information
- By using Relatics in combination with an SE expert one learns about the system lifecycle processes in practice
- Project information from documents can be stored through the document management system
- Supporting processes can be accommodated in Relatics (Project planning, Project assessment and control, Risk management and Configuration management)
- It supports the decision making process.
- Changes to the requirements can be made traceable and explicit
- The requirements formulation can be checked
- The requirements analysis becomes easier
- The requirements can be structured to gain insight
- The verification process will be standardized

Besides the above mentioned conclusion and answering the two main research questions other conclusions can be draw up because of this research. In this research a workspace for Relatics is created. Creating a workspace gave the researcher more insight into SE because all the relations between the different decomposition structures needed to be clear. Therefore, a lot of theoretical knowledge about the system lifecycle processes was gained. Especially the verification process, which is accommodated into the workspace, has given more insight into the different relations. The creation of the workspace process has been described in paragraph 8.1.

The researcher has also given a description on how to use to workspace in order to retrieve the applicable requirements from the SE-HOR for the first set of requirements of the requirements definition in paragraph 8.3.1. The second set of requirements for the requirements definition (project specific
requirements) can be found in paragraph 8.3.3. During the case study “Vlielandseweg” the processes as described in 8.3.1 have been gone through. In the comparison with the system lifecycle processes (from ISO 15288) it became clear that the processes are very alike. Therefore Relatics can help to gain insight into the system life cycle processes.

The SE processes that occur during the development of a system are stakeholder requirements definition process, requirements analysis process, architectural design process, verification and validation process. In order to implement SE, the users need to know how these processes are performed. The results of the different SE processes can easily be stored in Relatics. The user however still needs to know how these processes are performed. The implementation of SE is more than only the implementation of an information model based on systems engineering. Even though, some processes can be accommodated in Relatics this doesn't mean it fully contributes to the implementation of SE. It can help with the management of the result of the different processes of SE, but not with the implementation of the processes within the organization.

The requirements analysis process is a factor that might affect the implementation of SE. In Relatics the requirements analysis process can fully be accommodated. By allocating the requirements insight is gained in the factor if the set of requirements are complete. Also the feature for checking whether the requirement is SMART can be added. In order to check whether the requirement is current, a start and end date can be added to each requirement. However, this all depends on how the user uses Relatics. The correct use of Relatics depends on the knowledge of SE of the end user.

Within Relatics a feature is added for the Verification process. Here both activities of this process are accommodated. First the verification plan can be made and after the verification is performed, a verification report can be created. The verification of the requirements is performed from the WBS. Therefore each requirement can be verified in the applicable lifecycle phase.

Besides these implementation factors Relatics also helps to capture the project information in an explicit way. The requirements, changes, decisions, documents and other project related information can be captured in Relatics in an unambiguous way. This is needed when the project is transferred between the client and the contractor.

The gained experience in SE, the HOR and Relatics have also led to a list of factors that affect the implementation of SE. These factors are comparable with factors found in the literature of Van den Houdt and Rijkswaterstaat. The factors that affect the implementation of SE are:

- Want to learn (they have the motivation)
- Know the benefits
- Supported by higher management
- Supported by individual project employees
- Available Resources
- Supporting processes
- Explicit processes
- Many involved disciplines
- Many involved stakeholders
- Freedom in project arrangements
- Presence of the SE manager
- Doing all the processes in practice
- Knowledge of SE
- Knowledge of SE processes
- Knowledge of systems thinking
- Knowledge of functional specifications
• Verification and validation process
• Requirements formulation
• Requirements analysis

Furthermore, during this research it became apparent that it was difficult to create insight into the process requirements. The other requirements can be allocated along to SBS. The process requirements couldn’t. Therefore another decomposition structure was added for the allocation of the process requirements. The decomposition structure contains objects to control the process to realize the system in a successful way. The process requirements can be decomposed to the WBS but the client is not allowed to define the WBS for the contractor. In addition, by adding a simple decomposition structure the same separation is created as in the requirements definition of RWS. They use two types of requirements definitions, one for the system requirements and one for the process requirements. Usually SE is prescribed in a project with an UAV-GC contract type, but SE can also be used in other contract types. It’s important however to always consider whether it is relevant to use SE, given the complexity, for that specific project.

10.2 Recommendations

The topics of this research were SE in general, HOR of the municipalities and Relatics, while this research was conducted at Gebiedsmanagers B.V. Therefore this paragraph will give recommendations for all the stakeholders.

General SE recommendations

Structure process requirements: The requirement allocation is used to create insight into the requirements. Some requirements however are process requirements and couldn’t be allocated along the SBS. These are requirements used to control the process to realize the system in a successful way. When making use of an integrated contract type these processes need to be fulfilled by the contractor. In order to create insight into these process requirements, it’s recommended to use another object tree for the management of the project, Project Management Object tree (PMO). So, the problem that arose during the setting up of the HOR into Relatics was that the process requirements could be allocated to a decomposition structure. The solution was the introduction of another so-called PMO.

Any form of contract: In general SE is used and prescribed by a UAV-GC contract. Even with a contract with RAW-system, SE can offer many benefits. It’s important however to always consider whether it is relevant to use SE, given the complexity, for that specific project.

Recommendations for Gebiedsmanagers B.V.

Determine the strategy: For the successful implementation of SE Gebiedsmanagers B.V. should use the different strategies that are determined in chapter 9. It’s up to Gebiedsmanagers whether they focus on all the groups of municipalities. For the municipalities who have a low skill it’s recommended to start with the transition of the HOR into a SE-HOR. this transition provides the required knowledge for the requirements management, which is needed to grow to the second level of the CMMI-Model, as can be seen in Table 2-1. If this transition is done with the use of Relatics, the users are also guided into the systems thinking and the system lifecycle processes. The knowledge on the system lifecycle processes can be learned through the ISO15288 document. Along with the V-model this should create a basis for the required knowledge in the field of SE. The municipalities who don’t have the will can probably be motivated with the graph seen in Figure 9-3. This graph shows the time and effort needed to create a requirements definition for each project. The transition will is a one-time effort, after which the time and effort is drastically reduced.

Train SE Experts and increase their skills: During the case study “Vlielandseweg” the importance of the presence of an SE expert became apparent. This project would have certainly failed if the researcher was not present. Therefore Gebiedsmanagers B.V. should train all of their employees in the field of SE. This can be done by following courses or involving the employees in their SE based projects. The CMMI-model
indicates 5 levels of maturity. The employees and the municipalities should be trained step-by-step according to the model. A good way to teach people about SE is by using Relatics in actual projects. In the created workspace a lot of processes are accommodated. By using Relatics to store the results of a process of an actual project, the user is guided into the systems thinking and system lifecycle processes. These system lifecycle processes are described and elaborated in the ISO15288. It is recommended to start using this document in a project. If the system lifecycle processes in combination with the V-model are understood, a big part of the theoretical knowledge of SE is gained. The next step is to apply this in practice.

**Train a functional designer:** In this research, Relatics formed the basis for storing the project information. The created workspace was also used for the transition of the old HOR towards the SE-HOR. The creation of the workspace is done by the researcher and can now be used in multiple projects. The workspace however requires maintenance and modifications for each project. For this maintenance and modifications several trainings can be followed. The researcher has only followed the basic functional design training. In the workspace however, more advanced features are implemented which normally requires other trainings. The researcher has created these features mainly because of his interest in computer science. In addition the knowledgebase and the helpdesk was also a support for adding those features. Still, the feature for creating reports needs a major update. Therefore it's recommended an employee of Gebiedsmanagers follows the basic functional design training to keep the workspace up-to-date and the adjust minor modifications. The larger modifications and the update of the report feature should be done with a consultant of Relatics.

**Recommendations for Gebiedsmanagers and Relatics**

**Provide a workspace:** The creation of a workspace is a lot of work. In addition, the basic functional design training needs to be followed. There are a lot of small companies or organizations who would like to use Relatics but don't want to invest a lot of time and money in the creation of a workspace. Therefore it's recommended to provide a small and simple workspace for those small companies and organizations. Relatics already offers a workspace based on SE but this workspace is really large and contains a lot of features which are not always necessary. This makes it a large transition and deters many potential users. The small workspace for SE should include the basic SE elements for requirements and the features for importing and exporting the project information.

**Cooperate towards potential users:** Gebiedsmanagers has a lot of theoretical and practical knowledge about SE. Relatics know best how to create a workspace and can best explain all the benefits of the program. If both companies cooperate and create a simple workspace based on SE, a very huge market can be accessed, namely the municipalities. Relatics can benefit by providing licenses and by modifying the workspace to the client specific needs. Gebiedsmanagers can benefit by support in the field of SE. This research has proven that both specialties can offer a huge benefit for municipalities. Therefore, Relatics and Gebiedsmanagers should cooperate and provide a full package for the municipalities.

**Recommendations for municipalities**

**Learn from each other:** During this research the municipality Pijnacker-Nootdorp saw several benefits and risks in the use of Relatics. After seeing and using Relatics they have become very enthusiastic about it. They immediately see the benefits for using the program in small projects, despite that it's generally being applied in larger projects. The users believe that Relatics and a systematic approach can reduce the duration and thereby the costs of a project. The HOR could also be accommodated therein. This can lead to unambiguous results in terms of quality and maintenance.

**Gain skills:** In order to implement SE at municipalities more is needed than only Relatics. Relatics can help to store and manage the results of the different process, not with the implementation of the processes. Therefore it is recommended that the municipalities gain knowledge on the SE processes. This knowledge can be gained in several ways. The best way for the municipalities to gain knowledge is from practical experience. It is recommended to start a pilot project with the use of SE. Gebiedsmanagers can
provide the needed SE expert to explain the system lifecycle processes and the V-model in both theory as in practice.

Adjust processes: During the evaluation of the processes of the municipality Pijnacker-Nootdorp, it became apparent that their processes need to be adjusted for the use of SE. The main problem with the current processes is that both their processes and the results of their processes are not recorded explicitly. With the use of an integrated contract type, the transfer point between client and contractor is of major importance.

Create a new HOR: Even though the literature states how requirements should be formulated in the HOR, the HOR of the municipality Pijnacker-Nootdorp needs a major update and the requirements should be Complete, Current, Clear and SMART. In order to create insight into the stated requirements, the municipality should use Relatics. By allocation the requirements along the decomposition structures contradictions and redundancies can be identified. Gebiedsmanagers can provide the workspace needed for the transition of the HOR towards the SE-HOR. In addition they already have experience in this transition process and can therefore provide the needed assistance.

10.3 Limitations:
In this paragraph the limitations of the research are presented, following from the assumptions made and the scope chosen in 0. This research was performed by a specific qualitative practical research as explained in paragraph 2.5. The followed approach was to start with a literature study to elaborate and gain knowledge in the scientific literature, followed by a case study to gain insight from practical experiences.

During the literature study it became apparent that there is little scientific literature about the HOR and Relatics available. Although in the researcher’s opinion the literature seems very reliable, these results are less underpinned then if there were more sources available.

In the scope of this research it was chosen to do only one case study. Therefore, within this study also only one HOR is reviewed namely the HOR of municipality Pijnacker-Nootdorp. This means that the identified problems of the HOR are only applicable for this municipality. It is plausible that the HOR other municipality vary and therefore also contain other problems. This also effects the recommendations from the previous section. These recommendations are only applicable for the municipality Pijnacker-Nootdorp.

Due to the scope this research is delineated for municipalities. Therefore only the technical processes that are applicable to the development of a system are considered. The other process groups have therefore not been studied. Also, the processes of the other process groups are not accounted for in Relatics. These include the risk management process and planning process.

The evaluation of the developed workspace is in addition to interviewing the municipality done by the researcher. The researcher has developed the workspace, therefore it might be possible that his personal prejudices have effected this evaluation. Yet he has tried to carry out the evaluation as objectively as possible.

During this research, and in particular during the case study, use was made of a qualitative approach. This has the drawback that subjective results have been acquired. Although the researcher has tried not to influence the interview with his prejudice, it is possible that the results are influenced.

10.4 Future work
The execution of the research and part of its conclusions and recommendations led to a series of new questions. Furthermore, due to time constraints, a number of issues and research tasks were left out of
scope that need to be addressed by future research. Some of the recommendations for future research have a more general character.

Because this study was conducted in collaboration with only one municipality, the results can partly be generalized. To understand the issues surrounding the various HOR's more case studies need to be carried out. Besides case studies at other municipalities more case studies need to be performed at Pijnacker-Nootdorp. It can be then be reviewed if a HOR that is transformed into Relatics can help with a better and faster requirements definition process as presented in Figure 9-3.

In the current approach, the evaluation is done through interviews with the municipality. Future research should focus on quantifiable criteria to determine whether Relatics can help with the implementation of SE. This should be done so the reliability and comparability of the case studies is increased. This enables the development of industry-wide best practices. As mentioned before, this research assumes that further implementation of SE is desired on the basis of the assumption that good application of SE will result in better project results and thus project success. However, this assumption is not proven to be true under all circumstances. It seems very hard to determine the exact increases in profits for applying or not applying SE. Conducting cost benefit analysis of multiple smaller and larger civil construction project, carried out with and without the application of the SE and Relatics, might provide this insight. However, this requires the quantification of the benefits of SE. Future research should prove if such quantification is possible and how it should be implemented within the civil construction industry. Only then the questions can be answered how Relatics is related to project success and if the implementation of Relatics and SE actually drives the success of construction projects.

10.5 Scientific contribution
The point of departure for this research was the practical need of improving the HOR for the use of Systems Engineering with Relatics. The software tool for SE is already widely applied in the civil construction industry in the Netherlands. The scientific research and insight, however, is missing. This formed the basis of this research.

This graduation research can be considered as a valuable contribution about both Relatics as the HOR. This is motivated by the fact that the findings are based on the available relevant literature, a case study and the amount of interviews with the users involved. The execution of the verification and validation with the users ensures the justification of the ideas in this field of research.

Drawing up broader conclusions on an abstract level however turned out to be difficult, as the findings about combining the HOR and SE in Relatics result from a limited amount of literature, projects and personal opinions. Although findings have been validated by a group of users, this field of knowledge clearly is still evolving, so the lessons of this study are therefore context-specific and time-specific.

By studying the limited literature and to combine this with the practice I have taken a position on the use of Relatics at municipalities. This is a wonderful base for further evaluating the actual use of Relatics for a project and the (positive) results in the long term. This can be done through a more objective assessment.

As the respondents replied during the interviews, the municipality does want to implement SE. They foresee problems however with the implementation of another it-solution. They say that these problems are mainly associated with older people. The younger respondent was very enthusiastic to start using Relatics and saw the potential benefits. The older respondent mainly foresaw the problems. This does confirms the hypothesis that older people have more difficulties with changes in their project approach than younger people.

Lohman identified five bottlenecks that caused an unsuccessful attempt to improve the quality of the information, as can be seen in paragraph 5.1). The first bottleneck (Quality of data does not meet the
specified requirements) has also been identified at the municipality. This was identified with the use of Relatics. The other bottlenecks are:

- Data cannot be transformed into requested information and
- Provided and requested information was unrelated
- Discrepancy between the information requested and required
- Information use does not contribute to organizational performance

The researcher can confirm through this research that Relatics offers a solution to these bottlenecks.
11 Epilogue and reflection

This chapter contains my personal reflection on the process and results of the graduation project, including this thesis. I will start by explaining how my Master’s degree course at Delft University of Technology has led to this particular graduation project. Then, I go into a number of practical do’s and don’ts, which I realized in retrospect.

After completing my bachelors degree program on civil engineering at the Hogeschool Zuyd, I started with my masters degree course: Construction Management and Engineering (CME). This master program educates and develops besides engineering, problems solving and communication skills also how to achieve desired changes in the building industry and assess the consequences for the construction process and its organization. The curriculum is built on five compulsory courses, namely: Project Management, Process management, Legal & Governance aspects, Collaborative Design & Engineering and Integration & Orientation (I&O). During this research the theoretical knowledge has put into practice. This research has a lot of interfaces with I&O and Process management.

Several months before finding a graduation project, I grew increasingly worried about my future profession. I considered my graduation project to be the first step toward a possible future occupation. Therefore I applied at several companies for a thesis project. Only a handful replied but none with interesting topics. Then a recruitment agency brought me in contact with Gebiedsmanagers B.V. This new consultancy firm is engaged in the development of “Dijkpolder”. As in any project, they also had to deal with many stakeholders and their requirements and they sought a way to organize and structure this information.

The company Gebiedsmanagers B.V. is a really nice company to work at. Because it’s a new and small company, you get to know everybody very well. Working with friendly colleagues makes the daily grind of graduation tolerable. If I had any questions they always freed time for me. Working at a small and new company can also have its downsides. Some questions for instances could not be answered by my colleagues. Like me, they were still learning in the field of Systems Engineering and integrated contract types. For the development of the workspace of Relatics, I was completely on my own. Luckily, halfway my graduation they hired a new colleague with a lot more experience in the field of SE and Relatics. This was a tremendous help. When I first applied for this thesis project both the company as myself had the ambition to work for both my graduation as for the company. Looking back, I must admit that this ambition was too elaborate.

Conducting my graduation research and writing this thesis proved to be very challenging in multiple aspects. First of all I found it difficult to maintain the scientific rigor. I think this has two causes. First during my childhood my parents had a mechanization company. In the weekends and holidays I worked at that company and was always busy with practical matters. Second, before my masters at the TU delft I've done by bachelor’s degree at a HBO. These studies are also focused on the practice. Luckily, my graduation committee guided me in the right way. They asked the right questions, especially during the mid-term meeting, and got my back on track. Professor

Something I have always had a lot of problems with during my studies, is the long term focus on the same subject. What I’ve noticed is that working at an external company really helped me to keep the focus. Also working at an external company gave me the unique opportunity to investigate whether the sector you think is interesting, really is. The regular contact with colleagues will provide me a smooth transition from student life to working life, while making mistakes have fewer consequences. Furthermore, the practical requirements from the company have added practical usability and insight to my research.

During my graduation project I made digital audio recordings of almost all meetings with my committee, supervisors, interviewees and other seemingly random conversations with colleagues. This enabled me to be very focused during these conversations, not having to worry about making notations. Back at my desk,
the recording formed the bases for a thorough processing of all relevant information, with the ability to listen back multiple of times.

Something I could really recommend to everybody who is going to start with their graduation is make sure you have a good workstation, both at home and at work. I would recommend using an external display, keyboard and mouse if you work with a laptop. A good place to work helps to stay concentrated for longer periods of time. Gebiedsmanagers provided me with an excellent working place at their office.

I want to conclude this reflection by stating that if I had to choose to do my graduation project all over again, I would choose to do my graduation project with Gebiedsmanagers again. However, I would have put less focus on perfecting the workspace of Relatics. It's better to use an already existing workspace designed for SE so that more time remains for the actual case studies. This would certainly have had a huge benefit for the scientific contribution of my research.
Literature


Wikipedia. from http://en.wikipedia.org/wiki/Main_Page
Annexes

Annex A: Interview Professionals

Datum: 10-06-2014
Tijd: 08:00 uur
Locatie: Weverskade 110, Maassluis
Aanwezig: Berwich Sluer
Karel Ossewaarde
Camille Huijnen

Berwich Sluer werkzaam bij Boskalis Nederland afdeling QRS

Tijdens het gesprek met Berwich die in eerste instantie zou gaan over het opstellen van een objecten bibliotheek kwamen meerdere onderwerpen aanbod. Een van deze onderwerpen ging over Systems Engineering.

Vraag: Is een projectaanpak met Systems engineering gemeengoed?

Berwich ziet bijna alleen nog maar projecten die op een systematische manier benaderd zijn. Bij bijna alle projecten wordt gekozen voor geïntegreerde contracten waarbij Systems engineering een uitgangspunt is. Op de vraag of hij onderscheid kan maken tussen welke opdrachtgevers wel en welke niet met geïntegreerde contracten werken zegt hij: over alle lagen van de opdrachtgevers gaat tegenwoordig de voorkeur uit naar geïntegreerde contracten Rijkswaterstaat, provincies, en gemeentes. Zelfs bij kleine werken van tussen de 50.000 en 100.000 euro wordt bijna alleen nog maar voor geïntegreerde contracten gekozen. Ook hierbij is Systems engineering een uitgangspunt.

Vraag: Boskalis werkt met Ticon en bij mijn afstuderen richt ik me voornamelijk op Relatics. Wat is uw mening over deze programma's?

Tijdens het gesprek is ook naar de mening gevraagd over Relatics. Bij Boskalis wordt gewerkt met Ticon. Dit programma is gemaakt door van Meijel en richtte zich in eerste instantie op accountancy software. Naderhand zijn ze begonnen met het maken van project management software inclusief Systems engineering toepassingen. Berwich zegt verder over Ticon dat hij liever een ander systeem zou zien omdat Ticon niet dynamisch en flexibel genoeg is. Telkens wanneer er iets veranderd moet worden aan het programma moet een hele procedure doorlopen worden en door de drukte kan het vaak wel 4 maanden duren voordat je aan de beurt bent. Berwich zou liever met Relatics werken. Hij geeft ook aan dat eigenlijk alle grote aannemers werken met Relatics behalve Boskalis. Als Boskalis een samenwerkingsverband aangaat met andere aannemers wordt eigenlijk altijd gekozen voor Relatics, dus waarom zouden ze er zelf niet mee beginnen.
Annex B Interview Processes

Interview: Processen

datum 30 juni 2014
plaats Pijnacker
opsteller Camille Huijnen
onderwerp Interview huidige processen Gemeente Pijnacker-Nootdorp

Introductie
Momenteel ben ik aan het onderzoeken of het gebruik van Relatics gemeenten kan helpen bij het standaardiseren van het opstellen van een programma van eisen (PvE). Het proces van het opstellen van een PvE zal door het gebruik van Relatics gaan veranderen. Daarnaast is de aanname dat naast het opstellen van een PvE proces ook andere processen veranderen. In het kader van een reconstructie project zijn vanuit de literatuur de volgende processen geïdentificeerd:

- Aanbestedingsproces
- Projectdefinitie
- Opstellen programma van eisen van de stakeholders
- Eisen analyse
- Ontwerpproces
- Verificatie proces
- Validatie proces

Om te kunnen zien of deze processen veranderen dient eerst in kaart gebracht te worden hoe de huidige processen gaan. Vandaar dit interview om erachter te komen hoe jullie processen lopen en daarnaast of en hoe deze beschreven zijn.

Processen algemeen
Maken jullie gebruik van gestandaardiseerde bouwprocessen?
Zijn deze processen beschreven in een document of op een andere manier?
Zou u het fijn vinden als de processen meer expliciet gemaakt zouden zijn?

Het benoemen van de processen
Als we een denkbeeldig project doorlopen, welke processen moeten dan allemaal doorlopen worden om tot een realisatie te komen?

Kunnen we de net benoemde processen verder uitwerken en waar nodig toelichten?
Hierbij is het van belang om de volgende zaken duidelijk te krijgen:
- doel van het proces;
- welke activiteiten in welke volgorde worden uitgevoerd;
- wie de eindverantwoordelijk is voor het proces (proceseigenaar);
- op basis van welke informatie het proces wordt aangestuurd;
- de aanleiding voor het uitvoeren van het proces;
- welke informatiebronnen (ICT-systemen, documenten) bij welke activiteiten worden gebruikt;
- welke documenten in welke activiteiten ontstaan en welke formulieren hierbij worden gebruikt en waar die documenten worden bewaard (archieven);
- welke relaties (interfaces) er zijn met andere processen.

Initiatie fase
Door welke personen/instanties/afdelingen/politiek kunnen projecten geïnitieerd worden?
Worden daar documenten voor opgesteld met bijvoorbeeld een duidelijke projectdefinitie, probleem stelling, doelstellingen, Stakeholder analyse?
Denkt u dat er verbeterpunten liggen binnen dit proces? Zo ja welke?

Aanbestedingsproces
Hoe wordt bepaald in welke contractvorm het project uitgevoerd gaat worden?
Hoe staat de gemeente Pijnacker tegenover de “nieuwe” geïntegreerde contractvormen?
Denkt u dat er verbeterpunten liggen binnen dit proces? Zo ja welke?
**Opstellen Programma van eisen**

Hoe gaat het proces van het opstellen van het programma van eisen?
Wie zijn er verantwoordelijk voor dit proces? (Initiator, andere?)
Wordt het HOR gebruikt bij het opstellen van het programma van eisen?
Denkt u dat er verbeterpunten liggen binnen dit proces? Zo ja welke?
Kan het LIOR geoptimaliseerd worden en hoe?

**Ontwerpproces**

Hebben jullie een gestandaardiseerd ontwerpproces?
Wordt het ontwerp over het algemeen binnen de gemeente opgesteld of wordt dit uitbesteed?
Wordt voor het ontwerp ook een programma van eisen opgesteld?
Wordt dit PvE ook daadwerkelijk gebruikt bij het ontwerpen?
Worden ontwerpkewes vastgelegd?
Denkt u dat er verbeterpunten liggen binnen dit proces? Zo ja welke?

**Verificatieproces**

Hebben jullie een gestandaardiseerd verificatieproces?
Denkt u dat er verbeterpunten liggen binnen dit proces? Zo ja welke?

**Scenario**

Er wordt in het kader van het scenario door mij het volgende aangenomen:
- Elke gemeente heeft meerdere projecten lopen.
- Deze projecten zijn allemaal verschillend qua grote, soort project (nieuwbouw, reconstructie), en in welke fase zich bevinden
- Voor elke project is een PvE opgesteld.
- Er is een wettelijke eis die in elk PvE terug komt
- Stel dat deze wet en daardoor ook de eis wijzigt tijdens het project

Hoe wordt er dan omgegaan met deze eis? Wordt deze eis in elk project gewijzigd? Heeft het wijzigen te maken met in welke fase het project zich bevindt? (reeds aanbesteed of niet)
Maken jullie gebruik van gestandaardiseerde bouwprocessen?
Ja, we maken gebruik van Projectmatig werken. Daarnaast hebben we voor VO, DO besteksfase, aanbestedingsfase, toezicht processen beschreven met Rollen en verantwoordelijkheden.

In chronologische volgorde:
Er wordt begonnen met de opdracht vanuit projectmatig werken. Dit is een standaard aanpak die door de hele organisatie wordt gebruikt. Vanuit de afdeling BOR wordt dan de civieltechnische procedure gestart. Daarna wordt gestart met de processen om te komen tot een VO, DO, bestek aanbesteding en toezicht.

Zijn de ontwerpprocessen expliciet gemaakt?
Hier is geen geschreven leidraad voor maar vanuit de civiele voorbereiding is er een lijst waarin staat waaraan je rekening moet houden. Dit zijn een aantal standaard aspecten die van invloed zijn op je VO. Afhankelijk van het project wordt het VO uitbesteed of zelf gedaan. In je VO zitten de randvoorwaarden over wat je moet doen:
- Binnen je beheerbudget blijven;
- Een wijk weer laten voldoen aan de parkeernorm;

Wordt er voor het maken van een VO een PvE opgesteld?
Er is geen expliciet proces voor het opstellen van een PvE. Wel is er een lijstje (kladbladje) waarop staat beschreven waaraan een VO dient te voldoen. De eisen waaraan het VO dient te voldoen wordt voorzien aan het plantoets team. Dit team toetst of het VO voldoet aan het beleid en de uitgangspunten. Er wordt dan ook gekeken naar de beheerbaarheid. Er wordt getracht niet te sturen op of iets mooi of lelijk gevonden wordt. De hoofdzaak van de afdeling BOR is om te kijken of hetgeen dat aangelegd wordt in de toekomst te beheren is. Ze kunnen dan advies geven aan het plantoets team omtrent het beheer. Als onderlegger voor de advisering heeft de afdeling BOR beheerplannen en het LIOR.

Geldt het LIOR als basis voor het VO?
Ja (beide zeggen ja)

Wordt het LIOR expliciet getoetst?
Het wordt wel getoetst, maar niet elke eis wordt expliciet getoetst. Het VO moet in lijn zijn met het LIOR. Het is een leidraad, geen wet. Je mag er, onderbouw, van afwijken met toestemming.

Zouden jullie het fijn vinden als het LIOR zou gelden als basis voor het programma van eisen?
Tim, in feite doen we dit al. Wanneer het ontwerp wordt uitbesteed wordt het LIOR meegegeven als ontwerp uitgangspunten. Dan wordt er kritischer op getoetst.

Zou het beter zijn als dit ook intern zou gebeuren?
Ja, het zou beter zijn als het ook intern expliciet zou zijn.

Van VO naar DO
Wordt het DO getoetst?

Van DO naar UO
Dit wordt hoofdzakelijk uitbesteed. Na het DO is de eerste opdracht afgerond. En vervolgens kan een andere partij de opdracht krijgen om het DO om te zetten naar een uitvoeringsproject. Dit is een afgesloten geheel, zo kan het bijvoorbeeld dat er daarna een andere project leider op komt te zitten. Na het DO heeft je afronding en evaluatie.

Het project team blijft compleet maar de rollen kunnen veranderen.

Hoe wordt bepaald in welke contractvorm het project wordt uitgevoerd?
Dit is afhankelijk van de scope van het project. Capaciteit(niveau) men hoopt dat de markt innovatieve houdt. Er is geen richtlijn voor opgesteld.

Het is een positieve ontwikkeling omdat je meer innovaties binnenhaalt. De traditionele aanbestedingsvorm werkt heel goed bij het vervangen en her-straten van een wijk. Bij complexe contructies, civiele kunstwerken,
kades, zettingsproblemen dan is het makkelijker die kennis uit de markt te halen want wij hebben die kennis niet. Zo lang wij denken dat we de kennis zelf in huis hebben doen we het traditioneel, als we denken dat we de kennis niet hebben besteden we het uit.

Op termijn moeten ze meer een regie gemeente worden.
Op dit moment heeft de gemeente wel genoeg capaciteit, omdat de projecten terug lopen alleen de kennis is misschien niet altijd op het juiste niveau. Het probleem van een vergrijzende organisatie is om de kennis op het niveau te houden.

De afdeling BOR is eigenlijk een redelijk eenvoudige afdeling want de werkzaamheden die zij verrichten is het doorlopen van continue cyclische processen. Elk jaar worden straten opgebroken en opnieuw aangelegd. Ook riolering wordt weggehaald en opnieuw teruggebracht. Wat dat betreft zijn er weinig vernieuwingen. De wereld er omheen veranderd wel dus de manier waarop je dat organiseert veranderd wel. Bij sommige projecten komen wel meer andere aspecten erbij kijken zoals bijvoorbeeld een faseringsplan of verkeersplan voor wegomleggingen waar vroeger de weg kon worden afgesloten. Of een communicatieplan dient te worden opgesteld. Kortom er zijn andere vaardigheden nodig terwijl de aard van de projecten hetzelfde blijven.

Wat is voor de afdeling BOR het verschil tussen een traditioneel contract en een UAV-GC contract als uiteindelijk toch alles door de maak wordt gedaan? Bij een geïntegreerde contractvorm zul je als ON ontzettend goed je vraagstelling moeten definiëren. Vaak kunnen ze dit zelf ook onvoldoende dus dan zal de VS ook door de marktpartij gemaakt worden. Dan zet je dus eigenlijk je hele project buiten terwijl bij de traditionele vorm blijft het wel nog binnenhuis.

Stel jullie willen een geïntegreerd contract hoe willen jullie het dan aanpakken, vanaf welke fase?
Vanaf het VO laten maken. Met enkele topeisen en de LIOR eisen. En eventueel 5 of 10 jaar garantie op de weg. De eisen die gesteld worden aan het VO dienen dan wel expliciet gemaakt te worden. Dit kan momenteel niet met het LIOR. Er is geen ervaring met het uitvoeren van een dergelijk contract bij een wegreconstructie incl. riolering. Bij een brug is die ervaring wel. Het zou een mooie proef zijn om een project een op deze manier te doen.

Waarom kan het LIOR momenteel niet gebruikt worden voor een dergelijk project?
Om dat in het LIOR bijvoorbeeld de eisen staan van meerdere soorten fietspaden (enkel, dubbel) en dan krijg je dus een niet goed gerichte opdracht met te veel vrijheden. Het gaat dan met name om de project specifieke eisen. De overige eisen kunnen aangevuld worden met het LIOR.

Verbeterpunten omtrent het bouwproces
We hebben wel alle processen en deze dienen we ook inzichtelijk te maken en op elkaar af te stemmen. Maar we zouden nog effectiever werken als we een project omgeving zouden hebben. Het gevoel bestaat dat mensen nogal eens dingen voor zichzelf willen houden. Wanneer iedereen transparant zou werken kunnen collega’s elkaar helpen. De angst bestaat dat men elkaar zal beoordelen.

Hoe denken jullie dit voor elkaar te krijgen want dit vraagt een grote cultuur omslag?

Dragen de nieuwe contractvormen bij aan het transparanter werken?
Ja, door deze contractvormen dien je meer gegevens aan te leveren en dus ook meer te delen. De nieuwe contractvormen dwingen mensen om vooraf er beter over na te denken.

Hoe denken andere afdelingen tegenover de ontwikkelingen met de nieuwe contractvormen?
Ook binnen de afdeling zijn tegenstrijdigheden. Andere afdelingen, zoals bijvoorbeeld ontwikkeling die doen juist al heel veel met deze nieuwe vormen. Ook binnen deze afdeling heeft de civiele kant vaak de voorkeur voor traditionele contracten.

Hoe wordt het programma van eisen opgesteld bij een GC?
Het projectteam zou dan het PvE opstellen. Het projectteam wordt samengesteld in de initiatief fase en bestaat uit een persoon die verantwoordelijk is voor een discipline. Zo kan een projectteam bestaan uit een of meerdere personen, afhankelijk van de disciplines en complexiteit van het project. Hier kunnen ook externe partijen in zitten zoals hoogheemraadschap, nutsbedrijven. Dit project team stelt het PvE op.

**Worden deze eisen ook nog op elkaar afgestemd?**
Ja, bijvoorbeeld het hoogheemraadschap heeft beleid vanuit de CUR dat is wetgeving die gevolgd moet worden. Het LIOR komt ook terug in het opstellen van het PvE. Echter, deze eisen worden niet specifiek behandeld.

**Wat kan verbeterd worden aan het opstellen van een PVE proces?**
Het LIOR is eerder bij een opdracht aan de ON gegeven en deze wist eigenlijk niet goed hiermee om te gaan. Omdat het zoveel en zo groot is. Als de eisen uit het LIOR vooraf geselecteerd zouden zijn, zou dit vooral een voordeel zijn voor de ON. Voor de OG bestaat namelijk het gevaar dat er eisen vergeten worden.

**Kan het LIOR geoptimaliseerd worden en hoe?**
Ja, dat is mogelijk door het meer gericht te maken voor de uitvragen van GC-vormen. Het zou een verbeterpunt zijn om bijvoorbeeld de objecten te kunnen selecteren waarna meteen de specificaties eruit komen.

**Scenario**
Als een wet wijzigt, dan dient sowieso de eisen mee te veranderen in alle projecten. Hier is geen procedure voor maar is de verantwoordelijkheid van de deskundige.

Indien een eis niet vanuit een wet komt maar wel wijzigt dan veranderen alle projecten mee die nog niet in de uitvoeringsfase zitten.
Annex C Processes of the municipality Pijnacker-Nootdorp
Annex D Interview Project definition
Startoverleg Vlielandseweg

datum 30 juni 2014
plaats Pijnacker
opsteller Camille Huijnen
onderwerp Startoverleg Vlielandseweg

Introductie
Voor het afstudeeronderzoek zal ik onderzoeken of Relatics kan helpen bij het standaardiseren van het opstellen van het programma van eisen (PvE) en andere processen. Om te zien of dit mogelijk is wordt een casestudie uitgevoerd rondom het project de Vlielandseweg in de Gemeente Pijnacker-Nootdorp. Door het project op een systematische manier aan te pakken en de voorgeschreven processen te volgen wordt gekeken of dit voordelen kan opleveren t.a.v. tijd, geld en kwaliteit. Een systematische aanpak van het project begint bij het goed en helder definiëren van het project en haar stakeholders. Vanuit de literatuur ben ik er achter gekomen dat een project definitie bestaat uit de volgende onderwerpen:

- Project omschrijving (incl afbakening)
- Probleemstelling
- Doelstelling
- Stakeholder analyse

Dit Interview is bedoeld om deze onderwerpen verder in te vullen om zo een heldere en goede start te maken van het project.

Project omschrijving
Kunt u ons wat vertellen over de Vlielandseweg?
Wat voor een soort weg is de Vlielandseweg?
Wat is het belang van deze weg?
Is er iets bekend over het aantal verkeersbewegingen van deze weg?
Kunt u op een tekening de werkgrenzen aangeven?

Probleemstelling
Wat is volgens jullie het probleem van de weg?
Waarom is deze toestand ongewenst?
Waar speelt het probleem zich precies af?
Wanneer is het begonnen een probleem te worden?
Wanneer zou het probleem opgelost moeten zijn?
Welke middelen kan de gemeente beschikbaar stellen om het probleem op te lossen?

Doelstelling
Wat is het beoogde resultaat na uitvoering van dit project?
Wat is de beoogde belevingswaarde van deze weg? (Vormgeving)
Wat is de beoogde gebruikerswaarde van deze weg? (functies, capaciteit)
Wat is de beoogde toekomstwaarde van deze weg? (kwaliteit, betrouwbaarheid, veiligheid)
Zijn er nog bijzondere wensen voor deze weg?

Stakeholderanalyse
Welke afdelingen van de gemeente zijn betrokken bij dit project?
Welke andere instanties hebben belang bij deze weg? (Hulpdiensten, OV, andere)
Welke belangen hebben deze betrokkenen bij dit project?
Welke doelen hebben deze betrokkenen bij het project?
Welke positie hebben deze betrokkenen bij het project?
Welke waarde moet de oplossing minimaal hebben voor de verschillende betrokkenen?
Zijn er allianties tussen verschillende betrokkenen?
Wat zijn de middelen die de betrokkenen hebben voor dit project? (financieel, technisch, politiek)
Annex E Project definition Vlielandseweg

Project definitie

Vlielandseweg

projectnr. 1023
revisie C0
16 juli 2014

Opdrachtgever

Gemeente Pijnacker-Nootdorp
Oranjeplein 1
2641 EZ Pijnacker

TUDelft
1. Projectdefinietie

1.1 Bestaande situatie

De Vlielandseweg (rood op Afbeelding 0-1) is een gebiedsontsluitingsweg binnen de bebouwde kom van de gemeente Pijnacker-Nootdorp met een maximumsnelheid van 50 km/h. In noordelijke richting sluit de weg aan op de Katwijkerlaan (blauw op Afbeelding 0-1) en in zuidelijke richting op de Oostlaan (groen op Afbeelding 0-1) en de Klapwijkseweg (Paars op Afbeelding 0-1). Hiermee vormt de Vlielandseweg een onderdeel van de gebiedsontsluitende route tussen Zoetermeer en Pijnacker en tussen Delft en Pijnacker. Op de Vlielandseweg takken verschillende opritten aan die de aanliggende bebouwing direct aansluiten op de weg. Ook sluiten enkele erftoegangswegen aan op de Vlielandseweg, zoals de Boezemweg en de Nieuwkoopseweg (geel op Afbeelding 0-1). Mede hierdoor is de Vlielandseweg een drager van de verkeersstructuur van de kern Pijnacker.

Afbeelding 0-1 situatie overzicht Vlielandseweg

De Vlielandseweg en de omliggende wegen zijn conform Duurzaam Veilig gecategoriseerd. Zo hebben de erftoegangswegen binnen de bebouwde kom een maximumsnelheid van 30 km/h (zoals de Nieuwkoopseweg). De erftoegangswegen buiten de bebouwde kom hebben een maximumsnelheid van 60 km/h (zoals de Katwijkerlaan). De gebiedsontsluitingswegen binnen de bebouwde kom kennen een snelheidsregime van 50 km/h (zoals de Vlielandseweg, de Oostlaan en de Klapwijkseweg).

1.2 Probleem beschrijving

Aan de Vlielandseweg is de afgelopen vijf jaar (2009-2014) alleen nog maar het nodige onderhoud uitgevoerd. De problemen rondom de Vlielandseweg staan allen met elkaar in verband en dienen daarom als een probleem gezien te worden. Toch is getracht onderscheid in de problematiek aan te brengen. De problemen zijn te herleiden naar de volgende categorieën: wegconstructie, riolering en waterhuishouding.

De Vlielandseweg is een verouderde weg die constructief gezien aan het einde van zijn levensduur zit. Qua onderhoud wordt aan de weg de afgelopen jaren alleen nog het nodige gedaan om de weg in stand te houden. De kosten van het onderhoud zijn namelijk dermate hoog dat dit niet meer loont. De veroudering van de weg is o.a. terug te zien in het oude straatwerk, een nog niet geasfalteerd fietspad en zeer slechte...
asfaltcondities. De weg is op een aantal plekken verzakt. Op sommige plekken tot onder het niveau van de overstortdrempel van de riolering. Hierdoor blijft na een hevige regenbui of periode van veel regen, water op de weg staan. Dit zorgt er tevens voor dat een onveilige situatie ontstaat waardoor de verkeersveiligheid in het gedrang komt.

De riolering is een verouderd gemengd stelsel. Waarbij het gedeelte tussen de Boezemweg en de Katwijkerlaan bestaat uit asbestcement buizen. Sommige woningen die direct aangesloten zijn op de Vlielandseweg liggen onder het wegniveau. Deze bewoners ondervinden daarom hinder van een vollopend rioolstelsel.

Andere bewoners ondervinden hinder van grondwater. Doordat het verhard oppervlak niet goed kan afwateren stroomt het regenwater de tuinen in of dringt het de woningen binnen. De monumentale boerderij op nr 26-28, heeft vanwege de grondwaterstandverschillen problemen met scheurvorming in de woning. Voor het peilgebied waar het plangebied in ligt, geldt een maximale peilstijging van 23 cm. Dit kan problemen geven doordat er te weinig drooglegging is.

Probleemstelling: Doordat de Vlielandseweg zeer verouderd is, worden er grote problemen ondervonden voor de bewoners en gebruikers op het gebied van wegindeling, waterhuishouding en riolering.

1.3 Uit te zoeken onduidelijkheden

Naast de bovengenoemde problemen bevinden zich binnen het systeem meerdere onduidelijkheden niet bekend, deze zijn:

- Wie is de eigenaar van de bruggen naar de woningen? (gemeente, bewoner of gedeeld)
- Het is nog onbekend wie de perceel eigenaren zijn
- Op het rioleringstelsel is ook de riolering van het mandelig gebied Klein Vlieland aangesloten. Dit rioolstelsel is een vrijverval riool dat via een zinker onder de watergang doorgaat. Wat gaat er in de toekomst met deze aansluiting gebeuren?
- De weg ligt naast een primaire watergang. Welke gevolgen heeft dit voor een nieuw rioolstelsel?
- De Vlielandseweg heeft twee kruisingen met duikers waarvan de gemeente eigenaar is terwijl het Waterschap de beheerder is. De constructieve staat van de duikers is ook onbekend.
- Milieukundig worden ook nog de nodige problemen verwacht met minerale oliën, teerhoudend asfalt, PAK’s en een hoge waarschijnlijkheid van de aanwezigheid van asbest en asresten.
- Mogelijke weerstand van de omwonenden.
- Wat is de gevolgschade

1.4 Doelstellingen

De primaire doelstelling van dit project is: De problemen die door de bewoners en gebruikers van de Vlielandseweg ondervinden op het gebied van wegconstructie, riolering en waterhuishouding dienen opgelost te worden binnen het vastgestelde budget en tijdsbestek. Als eindresultaat dient er een systeem te liggen die voldoet aan alle aspecten van beheer, verkeer, riolering, gebruik, K&L, nuts, waterhuishouding en ecologie en niet eindig.

De Primaire doelstelling voor de gemeente is: Het verkrijgen van inzicht in de Systems Engineering methodiek en geïntegreerde contractvormen. Onder het verkrijgen van inzicht wordt o.a. verstaan hoe men dient om te gaan met de risico’s die zich binnen dit project bevinden.

Gezien de complexiteit van het project met de verschillende disciplines, randvoorwaarden en stakeholders is het voor de gemeente onduidelijk of ze genoeg capaciteit en kerncompetenties hebben om
het proces van dit project in goede banen te leiden. Een manier om toch de doelstellingen te halen is door gebruik te maken van een geïntegreerd contract. Deze contractvorm is voor de gemeente nog relatief nieuw en heeft daardoor nog veel onzekerheden.

### 1.5 Stakeholder analyse

De reden waarom civieltechnische vraagstukken complex zijn, is omdat er verschillende partijen bij betrokken zijn. Deze partijen worden elk op een eigen wijze door de desbetreffende situatie geraakt. De actoren die betrokken zijn bij het project de Vlielandseweg verschillen allen met elkaar wanneer het gaat om belangen, doelen en middelen. Om deze stakeholders goed in beeld te brengen worden verschillende tabellen en overzichten gebruikt. Als eerste worden de stakeholders geïdentificeerd en omschreven. Tevens zijn de belangen, doelen, probleempercepties en de middelen van elke stakeholder (indien mogelijk) bepaald. Middels deze tabel wordt meer inzicht gecreëerd in de achtergrond van de stakeholder en de positie in het project. Als tweede worden de verschillende actoren onderscheiden door middel van hun belangrijke middelen, de mate van vervangbaarheid, en afhankelijkheid. Deze aspecten bepalen of een stakeholder kritisch is of niet (Bruin de & Ernst ten, 2008).

#### Stakeholder identificatie

Tijdens een gesprek met de gemeente Pijnacker-Nootdorp zijn de volgende stakeholders geïdentificeerd.

A. Gemeente Pijnacker-Nootdorp (OG)
   a. Afdeling BOR (Beheer openbare ruimte)
      i. Taakveld ibor (inrichting beheer openbare ruimte)
         1. Riolering
         2. Wegen
         3. Civiele kunstwerken
         4. Openbare verlichting
         5. Beschoeiingen
         6. Waterloket
      ii. Taakveld Verkeer
      iii. Taakveld Milieu & handhaving
   b. Afdeling WBH (Wijkbeheer)
      i. Taakveld Groen
      ii. Taakveld Spelen
   c. Afdeling IDV (interne dienstverlening)
      i. Team Geo
      ii. Team Automatisering
      iii. Team Communicatie

B. Hoogheemraadschap van Delfland
C. Hulpdiensten, veiligheidregio Haaglanden
D. Openbaar vervoer (Veolia + andere)
E. Bedrijvenpark de Boezem
F. Bewoners Klein Vlieland
G. Bewoners monumentale boerderij
H. Bewoners verbonden via bruggen (lintbebouwing Vlielandseweg)
I. Overige bewoners
J. Weggebruikers, lokaal verkeer
K. Weggebruikers, doorgaand verkeer
L. Weggebruikers, fietsers
M. Weggebruikers voetgangers
N. Bewoners Katwijkerlaan
O. Avalex
P. Fietsnetwerk
Q. OV-verlichting
R. Nutsbedrijven
   a. Water
   b. Gas
   c. Electra
   d. Glasvezel/cai
   e. Telecom
   f. Stichting kabel televisie Pijnacker

Deze stakeholders worden in de volgende tabel besproken aan de hand van hun omschrijving, belangen, doelen, probleem perceptie en middelen.
<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Omschrijving</th>
<th>Belang</th>
<th>Doelen</th>
<th>Probleem perceptie</th>
<th>Middelen</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Afdeling BOR</td>
<td>Afdeling verantwoordelijk voor beheer en onderhoud</td>
<td>De weg valt onder het beheer areaal van de afdeling</td>
<td>Zorgen dat het projectresultaat binnen het beheerbudget blijft</td>
<td>Het is te duur geworden om de weg te onderhouden</td>
<td>Politieke middelen</td>
</tr>
<tr>
<td>1. Riolering</td>
<td>verantwoordelijk voor riolering en waterloket.</td>
<td>Projectresultaat conform GRP</td>
<td></td>
<td>Lior, kennis, Groundwaterloket Servicebedrijf</td>
<td></td>
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<td></td>
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<tr>
<td>2. Wegen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Openbare verlichting</td>
<td></td>
<td>PR: voldoen aan beheerplan verlichting</td>
<td></td>
<td>Lior/ kennis</td>
<td></td>
</tr>
<tr>
<td>5. Beschoeiing</td>
<td>Afdeling verantwoordelijk voor de Beschoeiingen</td>
<td>Pr: voldoen aan Beheerplan beschoeiingen</td>
<td>?</td>
<td>Lior, Kennis</td>
<td></td>
</tr>
<tr>
<td>6. Waterloket</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii Taakveld Verkeer</td>
<td>Afdeling verantwoordelijk voor Verkeerskundiger &amp; -technische aspecten</td>
<td>PR: voldoen aan mobiliteitsplan</td>
<td>De weg voldoet niet meer aan de verkeerskundige aspecten</td>
<td>Ontwerp kennis, lior Verkeersmodel Meetmiddelen ANWB/ Stadsgewest</td>
<td></td>
</tr>
<tr>
<td>iii Taakveld Milieu &amp; Handhaving</td>
<td>Verantwoordelijk voor toetsen en bewerken lucht, bodem, geluid en ecologie</td>
<td>PR: voldoen aan Bodemkwaliteitskaart Beleidsplan Ecologie Geluidsmetouren ...</td>
<td></td>
<td>Lior/ Kennis, Bestuursdwang/ handhaving Geluidsmetingen Erkend eco loog/ Flora Fauna kennis</td>
<td></td>
</tr>
<tr>
<td>b. Afdeling Wijkbeheer (WBH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Taakveld Groen</td>
<td>Afdeling verantwoordelijk</td>
<td>PR: voldoen aan Grip op Groen</td>
<td>Groenvoorziening is</td>
<td>Lior, Kennis,</td>
<td></td>
</tr>
</tbody>
</table>
voor aanleg en onderhoud

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<thead>
<tr>
<th>voor aanleg en onderhoud</th>
<th>niet conform Grip op Groen</th>
<th>Servicebedrijf</th>
</tr>
</thead>
<tbody>
<tr>
<td>groenvoorziening</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### i. Taakveld Spelen

C. Afdeling interne dienstverlening (IDV)

#### i. Team Geo
Afdeling verantwoordelijk voor GEO-informatie van het projectgebied

#### ii. Team automatisering

#### iii. Communicatie
Verantwoordelijk voor beleid en uitvoering van alle gemeentelijke communicatie

PR: tijdens het project alle communicatie conform eisen team Communicatie

Communicatieplan
Telstar (online media)
Twitter
Website
...

### B. Hoogheemraadschap Delfland

Waterschap verantwoordelijk voor de projectomgeving. Zorgen voor: Waterbeheer, Waterkering, Waterkwaliteit

HHD verantwoordelijk voor watergang. Beheer en onderhoud

Borgen van waterbeheer, waterkering en waterkwaliteit binnen het projectgebied

Conform KEUR

Politieke middelen, wetgeving, technische kennis

### C. Hulpdiensten, veiligheidsregio Haaglanden

Samenwerkingsverband van omringende gemeente van het projectgebied op het gebied van veiligheidszorg (brandweer, rampenbestrijding en crisisbeheersing en geneeskundige hulpverlening)

De Vlielandseweg is een aanrij route voor deze stakeholder

Borgen van de veiligheid van de omgeving van het projectgebied door de aanrij route beschikbaar te houden

Afgesproken aanrijtijden

Kennis omtrent veiligheid

Handboek Brandweer

### D. Openbaarvervoersbedrijven (Veolia)
Veolia levert personenvervoer over de weg, het water en per rail

Er loopt een Bus route over de Vlielandseweg incl

Zorgen dat de OV-verbinding in stand gehouden wordt.

Ongemak voor klanten vanwege de slechte

16
<table>
<thead>
<tr>
<th>E. Bedrijvenpark de Boezem Ondernemersvereniging boezem</th>
<th>twee bushaltes.</th>
<th>wegcondities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrijventerrein gevestigd in de nabijheid van het Systeem.</td>
<td>Het bedrijventerrein wordt mede ontsloten via de Vlielandseweg</td>
<td>Borgen van de bereikbaarheid van het bedrijventerrein.</td>
</tr>
<tr>
<td></td>
<td>Slechte bereikbaarheid van het bedrijventerrein</td>
<td>Bezwaarschrift tegen vergunningen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F. Bewoners Klein Vlieland</th>
<th>deze bewoners wonen in het Projectgebied. Het betreft een mandelig perceel, openbaar toegankelijk.</th>
<th>deze woonwijk wordt ontsloten via de Vlielandseweg en de riolering is aangesloten op het stelsel van de Vlielandseweg</th>
</tr>
</thead>
<tbody>
<tr>
<td>的做法</td>
<td>Het borgen van de verbindingen (weg en riolering) tussen Klein Vlieland en de Vlielandseweg</td>
<td>Slechte aansluiting van de riolering.</td>
</tr>
<tr>
<td></td>
<td>Herstel openbare (mandelige) ruimte</td>
<td>Bezwaarschrift tegen vergunningen Zienswijze</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G. Bewoners Monumentale boerderij Nagaan of dit correct is.</th>
<th>Bewoners aan de Vlielandseweg</th>
<th>Dit monumentaal pand is gelegen aan de Vlielandseweg.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Het verkomen van problemen aan het pand bij de reconstructie van de Vlielandseweg. Het borgen van de bereikbaarheid</td>
<td>Last van riolering, waterhuishouding en scheurvorming</td>
</tr>
<tr>
<td></td>
<td>Wetgeving, Bezwaarschrift tegen vergunningen</td>
<td>Bezwaarschrift tegen vergunningen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>H. Bewoners verbonden via bruggen (lintbebouwing)</th>
<th>Bewoners aan de Vlielandseweg die zijn verbonden via bruggen</th>
<th>De woningen van deze bewoners worden ontsloten via bruggetjes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Het borgen van de bereikbaarheid van hun woningen. Zorgen dat de situatie niet verslechterd</td>
<td>Last van rioleringen waterhuishouding. Wie is de eigenaar van de bruggetjes?</td>
</tr>
<tr>
<td></td>
<td>Last van riolering en waterhuishouding.</td>
<td>Bezwaarschrift tegen vergunningen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I. Overige bewoners</th>
<th>Bewoners aan de Vlielandseweg</th>
<th>Deze bewoners wonen aan de Vlielandseweg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Het borgen van de bereikbaarheid van hun woningen. Zorgen dat de situatie niet verslechterd En parkeren</td>
<td>Last van riolering en waterhuishouding.</td>
</tr>
<tr>
<td></td>
<td>Bezwaarschrift tegen vergunningen</td>
<td>Bezwaarschrift tegen vergunningen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>J. Weggebruikers lokaal verkeer</th>
<th>comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>K. Weggebruikers, doorgaand verkeer</td>
<td>Zo min mogelijk reistijd verlies door de op te verkeersomleiding.</td>
</tr>
<tr>
<td></td>
<td>Omleiding moet toegankelijk zijn voor al het verkeer.</td>
</tr>
</tbody>
</table>

| L. Weggebruikers, fietsers en fietsnetwerk | |
|---------------------------------------------| |
| M. Weggebruikers voetgangers | |
| N. Bewoners | |
**Katwijkerlaan**

| O. Nutsbedrijven | De Nutsbedrijven zijn verantwoordelijk voor de aanleg en onderhoud van alle kabels en leidingen op het gebied van water, gas, elektra, dataverkeer/cai, telecom, etc. | Ook onder de Vlielandseweg liggen kabels en leidingen die mogelijk vervangen dienen te worden tijdens dit project | Het in standhouden van het kabels en leidingen netwerk. | Mogelijk zijn ook de kabels en leidingen verouderd en dienen deze vervangen te worden. |

**P. Avalex**
**Power versus Interest Grid**

In het power vs. interest grid worden de verschillende stakeholders geplaatst aan de hand van hun belangen en hun middelen.

![Power versus Interest Grid diagram](image)

Zoals men kan zien in de bovenstaande afbeelding, heeft de gemeente het meeste belang bij en de meeste middelen voor dit project. Ook het hoogheemraadschap van Delfland heeft belangrijke middelen voor dit project, namelijk kennis en wetgeving. Verder hebben de bewoners wel veel belang bij het project echter relatief weinig middelen om hun belangen te bewerkstelligen. Deze groep van stakeholders is afhankelijk van de gemeente om hun belangen te bewerkstelligen. Bovenstaande afbeelding geeft ons al meer inzicht in de betrokken stakeholders maar bepaald nog niet welke van cruciaal belang zijn voor een succesvolle afronding van dit project, dit wordt bepaald in de volgende paragraaf.

**Kritische actoren**

Om te bepalen welke actoren van kritische waarde zijn voor een project dient naar de afhankelijkheid van de middelen van de stakeholder gekeken te worden. Een van de manieren om onderscheid te maken tussen de actoren in een netwerk, is om te kijken welke middelen ze hebben en hoe belangrijk de stakeholder is voor het totale netwerk. Meestal is financiering een belangrijke rol, maar het kan ook specifieke (technische) kennis zijn. Belangrijke middelen en of een stakeholder vervangbaar is bepalen of het gaat om een kritische stakeholder (Bruin de & Ernst ten, 2008).

Een goede manier om de afhankelijkheid van middelen te bepalen is door gebruik te maken van de middelen afhankelijkheids tabel.
Als een stakeholder middelen bezit die van groot belang zijn voor het project en er geen andere stakeholder is die hem kan vervangen, dan is het een stakeholder met een hoge afhankelijkheid voor het proces. Dit betekent dat andere stakeholders afhankelijk zijn van de middelen van deze stakeholder. Het kan o.a. bepaald worden door antwoord te geven op de volgende vragen:

- Hoe belangrijk zijn de middelen van stakeholder X?
- Zijn deze middelen vervangbaar door een andere stakeholder?
- Hoe afhankelijk zijn andere stakeholders van deze middelen?

De aspecten van belangrijkheid van middelen en vervangbaarheid worden in de volgende table verder uitgewerkt. Tevens wordt aan de hand hiervan bepaald of een stakeholder als kritisch kan worden beschouwd.

<table>
<thead>
<tr>
<th>Actor</th>
<th>Belangrijke middelen</th>
<th>Vervangbaarheid</th>
<th>Afhankelijkheid</th>
<th>Kritisch belang</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Gemeente Pijnacker-Nootdorp (OG)</td>
<td>Wetgeving, Politieke invloeden</td>
<td>Laag</td>
<td>Hoog</td>
<td>Ja</td>
</tr>
<tr>
<td>a. Afdeling Beheer</td>
<td>Politieke middelen, Kennis</td>
<td>Hoog</td>
<td>Gemiddeld</td>
<td></td>
</tr>
<tr>
<td>b. Afdeling Verkeer</td>
<td>Politieke middelen, Kennis</td>
<td>Hoog</td>
<td>Gemiddeld</td>
<td></td>
</tr>
<tr>
<td>c. Afdeling Riolering</td>
<td>Politieke middelen, Kennis</td>
<td>Hoog</td>
<td>Gemiddeld</td>
<td></td>
</tr>
<tr>
<td>d. Afdeling Waterhuishouding</td>
<td>Politieke middelen, Kennis</td>
<td>Hoog</td>
<td>Gemiddeld</td>
<td></td>
</tr>
<tr>
<td>e. Afdeling Groen</td>
<td>Politieke middelen, Kennis</td>
<td>Hoog</td>
<td>Gemiddeld</td>
<td></td>
</tr>
<tr>
<td>f. Afdeling Civiele kunstwerken</td>
<td>Politieke middelen, Kennis</td>
<td>Hoog</td>
<td>Gemiddeld</td>
<td></td>
</tr>
<tr>
<td>g. Afdeling Beschoeving en kades</td>
<td>Politieke middelen, Kennis</td>
<td>Hoog</td>
<td>Gemiddeld</td>
<td></td>
</tr>
<tr>
<td>h. Taakveld Geo</td>
<td>Kennis</td>
<td>Hoog</td>
<td>Gemiddeld</td>
<td></td>
</tr>
<tr>
<td>B. Hoogheemraadschap ap Delfland</td>
<td>Politieke middelen, wetgeving, technische kennis</td>
<td>Laag</td>
<td>Hoog</td>
<td>Ja</td>
</tr>
<tr>
<td>C. Hulpdiensten, veiligheidsregio Haaglanden</td>
<td>Kennis omtrent veiligheid</td>
<td>Laag</td>
<td>Laag</td>
<td>Nee</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------</td>
<td>------</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>D. Openbaarvervoersbedrijven (Veolia)</td>
<td></td>
<td>Laag</td>
<td>Laag</td>
<td>Nee</td>
</tr>
<tr>
<td>E. Bedrijvenpark de Boezem</td>
<td>Bezwaarschrift tegen vergunningen</td>
<td>Laag</td>
<td>Laag</td>
<td>Nee</td>
</tr>
<tr>
<td>F. Bewoners Klein Vlieland</td>
<td>Bezwaarschrift tegen vergunningen</td>
<td>Laag</td>
<td>Laag</td>
<td>Nee</td>
</tr>
<tr>
<td>G. Bewoners Monumentale boerderij</td>
<td>Wetgeving, Bezwaarschrift tegen vergunningen</td>
<td>Laag</td>
<td>Laag</td>
<td>Nee</td>
</tr>
<tr>
<td>H. Bewoners verbonden via bruggen (lintbebouwing)</td>
<td>Bezwaarschrift tegen vergunningen</td>
<td>Laag</td>
<td>Laag</td>
<td>Nee</td>
</tr>
<tr>
<td>I. Overige bewoners</td>
<td>Bezwaarschrift tegen vergunningen</td>
<td>Laag</td>
<td>Laag</td>
<td>Nee</td>
</tr>
<tr>
<td>J. Weggebruikers lokaal verkeer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K. Weggebruikers, doorgaand verkeer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. Weggebruikers, fietsers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. Weggebruikers voetgangers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N. OV-verlichting</td>
<td>Laag (niet)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O. Nutsbedrijven</td>
<td>Laag (niet)</td>
<td>Gemiddeld</td>
<td>Ja</td>
<td></td>
</tr>
</tbody>
</table>
2. risico management

Een van de doelstellingen van de initiatiefnemer (afdeling BOR van gemeente Pijnacker-Nootdorp) is om te leren van het gebruik van de nieuwe UAV-GC contractvorm. Om zo veel mogelijk te leren van deze contractvorm hebben ze het voornemen zo veel als mogelijk (binnen de grenzen van de contractvorm) aan de markt over te laten. Gezien de complexiteit van het project en de onbekendheid van deze contractvorm gaat dit gepaard met het nemen van risico’s. In dit hoofdstuk wordt een risicoanalyse uitgevoerd om deze risico’s in kaart te brengen om ze daarna te kunnen beheren. De gebruikte methode voor de risico analyse is de RISMAN methode.

![Diagram van risicoanalyse]

Een eerste stap is het inzichtelijk maken van de stand van zaken op een bepaald moment. Dit gebeurt door het uitvoeren van een integrale risicoanalyse, waarbij als eerste het doel van de analyse wordt vastgesteld. Zonder focus in de risico’s is verdere afbakening van de risicoanalyse niet mogelijk en is geen prioritering in de risico’s aan te brengen. Bij het uitvoeren van deze risicoanalyse wordt het project beschouwd vanuit de volgende invalshoeken, zodat een integraal beeld wordt verkregen:

A. politiek/bestuurlijk  
B. financieel/economisch  
C. juridisch/wettelijk  
D. technisch  
E. organisatorisch  
F. geografisch/ruimtelijk  
G. maatschappelijk

2.1 Vaststellen doel

Voor het vaststellen van het doel van de risico analyse dient eerst de ongewenste top gebeurtenis (OTG) gedefinieerd te worden. Deze OTG is hetzelfde als het niet halen van belangrijke doelstellingen. Het is een situatie die uiteindelijk zeer onwenselijk is. Hierdoor wordt het project duurder dan geraamd, heeft een latere oplevering dan gepland en/of het resultaat voldoet niet aan de kwaliteitsnormen.

Voor het project de Vlielandse weg is de OTG: Totale onbereikbaarheid van de Vlielandseweg.

Vanuit de OTG is de doelstelling voor de risicoanalyse af te leiden naar:
Het doel van deze risicoanalyse is om in kaart te brengen welke risico's door de ON genomen kunnen worden en welke risico's beter bij de OG kunnen blijven.

2.2 Risico analyse

Resultaten van de analyse

De volledige analyse is terug te vinden in Fout! Verwijzingsbron niet gevonden.

3. Eisen van stakeholders

4. Eisen analyse

5. Eisen Allocatie
Annex F Template GM

1. Personen / Rollen
2. Organisaties
3. Eisen
4. Functies
5. Objecten
6. Werkpakketten
### Work Breakdown Structure

- WP-00001 | Ontwikkeling van de template
- WPA-0001 | Ontwikkeling Gebiedsmanagers Template
- WPA-0002 | Ontwikkelde Personen aandacht
- WPA-0003 | Ontwikkelde Organisaties aandacht
- WPA-0004 | Ontwikkelde Rollen aandacht
- WPA-0005 | Ontwikkelde Zaken aandacht
- WPA-0006 | Ontwikkelde Functies aandacht
- WPA-0007 | Ontwikkelde Objecten Overzicht
- WPA-0008 | Ontwikkelde Werkpakketten aandacht
- WPA-0009 | Ontwikkelde Verifiele aandacht
- WPA-0010 | Ontwikkelde Documenten aandacht

### Werkpakket: Ontwikkeling Gebiedsmanagers Template

<table>
<thead>
<tr>
<th>Gegevens</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WP-00001</td>
<td>WPA-0001</td>
</tr>
<tr>
<td>WPA</td>
<td>Ontwikkeling Gebiedsmanagers Template</td>
</tr>
<tr>
<td>Toelicht</td>
<td>Camelia Huisman</td>
</tr>
<tr>
<td>Verantwoordelijke Persoon</td>
<td></td>
</tr>
<tr>
<td>Onderdeel van Werkpakket</td>
<td>WP-00001</td>
</tr>
<tr>
<td>Status</td>
<td>Open</td>
</tr>
</tbody>
</table>

### Object

<table>
<thead>
<tr>
<th>Object-ID</th>
<th>Object</th>
<th>PMO-ID</th>
<th>PMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obj-00001</td>
<td>Gebiedsmanagers template</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Verificaties

Er wordt geverifieerd vanuit de werkpakket activiteiten. Hier worden de verificatie aangemaakt of uitgesloten

<table>
<thead>
<tr>
<th>Object-ID</th>
<th>Object</th>
<th>Els-ID</th>
<th>Els</th>
<th>Ver-ID</th>
<th>Verificatieplicht / Uitgesloten</th>
<th>Reden uitgesloten</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obj-0001</td>
<td>Gemeente managers template</td>
<td>Els-001</td>
<td>Realisaties tussen elementen</td>
<td>V-00001</td>
<td>Verifieke</td>
<td></td>
</tr>
<tr>
<td>Els-001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Els-ID</th>
<th>Els</th>
<th>Ver-ID</th>
<th>Verificatieplicht/ Uitgesloten</th>
<th>Reden uitgesloten</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Els-ID</th>
<th>Els</th>
<th>Ver-ID</th>
<th>Verificatieplicht/ Uitgesloten</th>
<th>Reden uitgesloten</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<table>
<thead>
<tr>
<th>Els-ID</th>
<th>Els</th>
<th>Ver-ID</th>
<th>Verificatieplicht/ Uitgesloten</th>
<th>Reden uitgesloten</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Er wordt geverifieerd vanuit de werkpakket activiteiten. Hier worden de verificatie aangemaakt of uitgesloten
op bovenstaande afbeeldingen zijn alle aangemaakte verificaties te zien. Onder gegevens staat de informatie die gebruikt is voor het verificatieplan onder verificatietaak staat de informatie die nodig is voor het verificatierapport.
Het verificatieplan kan ook gemaakt worden vanuit de activiteitenboom.
Het verificatie rapport kan ook gemaakt worden vanuit de activiteitenboom.
8. Documenten
### Annex G Requirements from Relatics

**Obj-10000 Openbare ruimte**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALG-0022</td>
<td>Bevestigingsmiddelen</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>PDE-0001</td>
<td>Bepaling van Materialen eco</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>PDE-00011</td>
<td>Duurzaamveilige inrichting</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>ALG-0018</td>
<td>Duurzaambouwen maatregel</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>PDE-00004</td>
<td>Ecologisch belang</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
</tbody>
</table>

**Obj-11000 Verhardingen**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDE-00002</td>
<td>Bepaling van Materialen esthetisch</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
</tbody>
</table>
Naast het ecologisch belang dienen vanuit esthetisch oogpunt de oude materialen (zoals bijvoorbeeld gebakken klinkers dikformaat en waalformaat) aan te sluiten bij het karakter van het plangebied.

<table>
<thead>
<tr>
<th>PDE-00302</th>
<th>Aspect Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontwerpeisen hekwerk 1</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Alle veebare verhardingen moeten bereikbaar zijn middels een toegang van minimaal 2,50 m. breed.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00320</th>
<th>Object Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zettingseis</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Met de aanleg van riolering, wegen etc. mag worden aangevangen nadat de resterende zetting over 30 jaar niet meer dan 10 cm bedraagt.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Obj-11500 Bushalte</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>PDE-00058</th>
<th>Functionele Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collectief personenvervoer</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Collectief personenvervoer moet voor iedereen toegankelijk zijn, voor zowel mensen met een mobiliteitshandicap als voor mensen die bijvoorbeeld koffers sjouwen. Ook met de inrichting openbare ruimte dient hier rekening mee gehouden te worden.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00057</th>
<th>Functionele Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halteplaatsen CROW publicatie</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>De halteplaatsen dienen daarom te voldoen aan de eisen uit de CROW publicatie 233 ‘handboek Halteplaatsen’.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00056</th>
<th>Functionele Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halteplaatsen en mindervaliden</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Aan de vormgeving van halteplaatsen dient speciale aandacht te worden gegeven met betrekking tot de bereikbaarheid voor invaliden.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Obj-11510 Bovenbouw bushalte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obj-11520 Onderbouw bushalte</td>
</tr>
<tr>
<td>Obj-11200 Fietspad</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00046</th>
<th>Object Eis</th>
</tr>
</thead>
</table>

Afmeting fietspaden

De afmeting van fietspaden en fietssuggestiestroken zijn in het overzicht hieronder opgenomen:
- Fietspad éézijdig = 2.40m
- Fietspad tweezijdig = < 3.50m
- Fietssuggestiestroken = 1.50m

<table>
<thead>
<tr>
<th>PDE-00049</th>
<th>Functionele Ein</th>
<th>Gemeente Pijnacker-Nootdorp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overgang fietspad-rijbaan brommers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

De overgang fietspad-rijbaan en andersom dient op een verkeersveilige wijze plaats te vinden. Geadviseerd wordt op plaatsen waar de brommer op de rijbaan komt en andersom de richtlijnen toe te passen zoals die in de brochure "Bromfiets op de rijbaan" (augustus 1999) van het infopunt Duurzaam Veilig Verkeer zijn beschreven.

<table>
<thead>
<tr>
<th>PDE-00048</th>
<th>Functionele Ein</th>
<th>Gemeente Pijnacker-Nootdorp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overgang fietspad-fietssuggestiestrook</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bij de overgang fietspad-fietssuggestiestrook/rijbaan moet (brom)fietser "rugdekking" krijgen door uitbuiging van een rijbaanafschuiving

<table>
<thead>
<tr>
<th>PDE-00029</th>
<th>Functionele Ein</th>
<th>Gemeente Pijnacker-Nootdorp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richtlijnen belijning fietspaden</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Richtlijnen met betrekking tot belijning en markering van fietspaden zijn terug te vinden in de CROW publicatie 207 "Richtlijnen voor de bebakening en markering van wegen".

Obj-11210 Bovenbouw fietspad

<table>
<thead>
<tr>
<th>PDE-00047</th>
<th>Object Ein</th>
<th>Gemeente Pijnacker-Nootdorp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kleur asfalt</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nieuw aan te leggen fietspaden binnen de bebouwde kom moeten worden uitgevoerd in rood asfalt

Obj-11220 Onderbouw fietspad

Obj-11400 Parkeer voorziening

<table>
<thead>
<tr>
<th>PDE-00042</th>
<th>Functionele Ein</th>
<th>Gemeente Pijnacker-Nootdorp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maatvoering parkeervakken</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maatvoeringen voor parkeervakken (BiBeKo) op zowel Erftoegangswegen als Gebiedsontsluitingswegen zijn terug te vinden in het ASSV.
De parkeerrnormen die binnen de gemeente Pijnacker-Nootdorp toegepast worden zijn terug te vinden in het beleidsplan parkeren.

<table>
<thead>
<tr>
<th>PDE-00043</th>
<th>Object Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parkeervakken en P-tegel</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Parkeervakken zullen voorzien moeten worden van een P-tegel.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00044</th>
<th>Raakvlak Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parkeervakken naast een groenstrook</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Parkeervakken die naast een groenstrook gesitueerd zijn dien voorzien te worden van een Rabat/uitstapstrook bestaande uit één trottoirtegel + een gazonband.</td>
<td></td>
</tr>
</tbody>
</table>

Obj-11410 Bovenbouw parkeervoorziening

Obj-11420 Onderbouw parkeervoorziening

Obj-11600 Snelheidsremmende voorzieningen

<table>
<thead>
<tr>
<th>PDE-00033</th>
<th>Aspect Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>afstand tussen snelheidsremmende maatregelen</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Door het toepassen van een snelheidsremmende maatregel om de 75 a 80 meter wordt het doorgaande karakter van deze wegen beperkt.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00036</th>
<th>Functionele Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CROW publicatie Richtlijn verkeersdrempels</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>In CROW-publicatie 172: &quot;Richtlijn verkeersdrempels” zijn de afmetingen van de drempels terug te vinden. Bij een bepaalde snelheid en hoogte hoort een vaste afmeting.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00035</th>
<th>Object Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoogte toepasbare snelheidsverlagende voorzieningen</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>In het overzicht hieronder zijn de hoogtes van de verschillende toepasbare drempels en punaises opgenomen: type - hoogte</td>
<td></td>
</tr>
<tr>
<td>Drempel - 0.08m</td>
<td></td>
</tr>
<tr>
<td>Drempel met oversteekfunctie - 0.12m</td>
<td></td>
</tr>
<tr>
<td>Plateau/traverse - 0.12m</td>
<td></td>
</tr>
</tbody>
</table>
### Over het toepassen van snelheidsremmende voorzieningen op hoofdroutes voor hulpdiensten

Over het toepassen van snelheidsremmende voorzieningen op hoofdroutes voor hulpdiensten moet eerst overeenstemming worden bereikt met hulpdiensten.

### De snelheidsremmende voorzieningen die binnen de Gemeente Pijnacker-Nootdorp in 30km-zones worden toegepast zijn:

- Punaises
- Plateaus/drempels
- Wegversmallingen

### Plaats lichtmasten in trottoir 0,30 m achter voorkant trottoirband.

### Indien een boom in het trottoir wordt geplant dient het hart van de boom minimaal 0,65 m. achter de trottoirband te liggen. Zie ook artikel 2.4.

### Voorwaarden waar infrastructuur voor gehandicapten aan moet voldoen zijn terug te vinden in het handboek aandachtspunten bij het ontwerpen voor fysiek

### Voorzieningen mindervaliden
gehandicapten, de ASVV (richtlijnen inrichting openbare ruimte tbv minder validen), en het Handboek voor Toegankelijkheid (Reed Business Information, 5e druk)

Obj-11320 Onderbouw trottoir

Obj-11100 Weg

<table>
<thead>
<tr>
<th>PDE-00025</th>
<th>Functionele Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bochtstralen bij onvoldoende breedte</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Indien de straat waarop aangetakt wordt niet voldoende breed is om een groot voertuig langs de bocht te laten rijden, kan ervoor gekozen worden om een bochtstraal van 8 meter toe te passen (r=8).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00020</th>
<th>Object Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>in en uittreten verduidelijking</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Om de in- en uittreten de verduidelijken dient binnen de Gemeente bebouwde kom een uitrit vormgeven te worden door toepassing van inritblokken.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00019</th>
<th>Object Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>in en uittreten vormgeving</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Om een duidelijk verkeersbeeld te creëren voor de weggebruiker en informele voorrangssituaties te vermijden is het noodzakelijk dat in- en uittreten naar percelen duidelijk worden vormgegeven.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00021</th>
<th>Functionele Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>in en uittreten zonder inritblokken</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Mochten inritblokken om civiele technische reden niet toegepast kunnen worden doordat een uitrit uitkomt op bijvoorbeeld een drempelplateau, zal volstaan kunnen worden met een doorgetrokken witte streep met een breedte van 20cm (klinkers) die duidelijk te onderscheiden moet zijn van een kantstreep</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00026</th>
<th>Object Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krappe bocht</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Eventueel kan een krappe bocht voorzien worden antiparkeermaatregelen.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PDE-00087</th>
<th>Functionele Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kruin van de weg</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Grid Index</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>PDE-00017</td>
<td>Functionele Eis</td>
</tr>
<tr>
<td>Maximale snelheid bibeko</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>De maximale snelheid binnen de bebouwde kom op gebiedsontsluitingswegen is 50km/h.</td>
<td></td>
</tr>
<tr>
<td>PDE-00018</td>
<td>Functionele Eis</td>
</tr>
<tr>
<td>Maximale snelheid bubeko</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Buiten de bebouwde kom is het binnen de gemeente Pijnacker-Nootdorp ook toegestaan om een maximale snelheid van 60km/h op gebiedsontsluitingswegen te voeren.</td>
<td></td>
</tr>
<tr>
<td>PDE-00024</td>
<td>Object Eis</td>
</tr>
<tr>
<td>Minimum bochtstralen</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Binnen 30km-zones dienen straathoeken een minimumstraal van 6 meter (r=6) te hebben.</td>
<td></td>
</tr>
<tr>
<td>PDE-00049</td>
<td>Functionele Eis</td>
</tr>
<tr>
<td>Overgang fietspad-rijbaan brommers</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>De overgang fietspad-rijbaan en andersom dient op een verkeersveilige wijze plaats te vinden. Geadviseerd wordt op plaatsen waar de brommer op de rijbaan komt en andersom de richtlijnen toe te passen zoals die in de brochure “Bromfiets op de rijbaan” (augustus 1999) van het infopunt Duurzaam Veilig Verkeer zijn beschreven.</td>
<td></td>
</tr>
<tr>
<td>PDE-00048</td>
<td>Functionele Eis</td>
</tr>
<tr>
<td>Overgang fietspad-fietsuggestiestroom</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Bij de overgang fietspad-fietsuggestiestroom/rijbaan moet (brom)fietsers “rugdekking” krijgen door uitbuiging van een rijbaanafscheiding</td>
<td></td>
</tr>
<tr>
<td>PDE-00030</td>
<td>Object Eis</td>
</tr>
<tr>
<td>Overgangen erftoegangswegen en gebiedsontsluitingswegen</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Overgangen tussen Erftoegangswegen (ook onderling) en Gebiedsontsluitingswegen (ook onderling) moeten goed worden vormgegeven</td>
<td></td>
</tr>
<tr>
<td>Object Eis</td>
<td>Object Eis</td>
</tr>
<tr>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>overrijdbare straathoek</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Mocht de ruimte het niet toelaten kan ervoor gekozen worden om een straathoek overrijdbaar te maken.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Object Eis</th>
<th>Object Eis</th>
</tr>
</thead>
<tbody>
<tr>
<td>snelheidremmende voorzieningen en fietsers</td>
<td>Gemeente Pijnacker-Nootdorp</td>
</tr>
<tr>
<td>Fietsers moeten indien mogelijk om snelheidsremmende maatregelen heen geleid worden</td>
<td></td>
</tr>
</tbody>
</table>

Obj-11110 Bovenbouw weg

Obj-11120 Onderbouw weg
Annex H Interview Relatics

Interview: Evaluatie Relatics

datum 4 augustus 2014
plaats Pijnacker
opsteller Camille Huijnen
onderwerp Interview t.b.v. evaluatie Relatics

Introductie
Momenteel ben ik aan het onderzoeken of het gebruik van Relatics gemeenten kan helpen bij het standaardiseren van het opstellen van een programma van eisen (PvE) en bij de implementatie van Systems Engineering. Graag wil ik middels dit interview erachter komen hoe jullie nu, na het gebruik, tegen Relatics aankijken.

Wat is jullie eerste indruk van Relatics?
Mooi programma maar zal moeilijk worden mensen ervan te gaan overtuigen. Als het goed is ingericht denk ik dat het zal leiden tot efficiënter en eenduidiger werken maar het zal moeilijk zijn mensen zo ver te krijgen het LIOR hier in op te bouwen.

Wat denken jullie dat je met Relatics kan doen?
Is nog moeilijk te zeggen, in principe is het een database maar je kan er ook processen in bouwen.

Zouden jullie Relatics nu of in de toekomst willen gaan gebruiken?
Ja, na het zien van dit programma ben ik wel enthousiast geworden. Met name voor het gebruik bij kleine projecten lijkt me dit een groot voordeel. Door eisen en informatie te standaardiseren kun je efficiënter gaan werken en de focus leggen op de complexere projectspecifieke onderdelen.

Wat willen jullie met Relactics bereiken?
Tim: kortere doorlooptijd van de projecten, doordat we in de voorbereiding alle eisen en wensen van de stakeholders verzamelen en kunnen verwerken in het ontwerp. Hierdoor hoeft het ontwerp in een later stadium niet aangepast te worden en wordt de doorlooptijd verkort.
Eenduidiger LIOR dat gebruikt kan worden voor elk project en daardoor dezelfde kwaliteit
Meer kennis en kunde uit de markt, Aangezien de Gemeente meer een regie gemeente dient te worden is er meer kennis en kunde uit de markt nodig. Tevens kan dit innovatieve en duurzame oplossingen bieden.

Hoe staat de organisatie tegenover Systems Engineering?
We gaan als gemeente toe naar een regie gemeente. Dit betekend dat we meer kennis en kunde uit de markt moeten halen om innovatieve een duurzame oplossingen te krijgen. Systems Engineering kan helpen bij het inzicht krijgen in de projecten waarbij de gemeente een regie rol zal aannemen.

Denken jullie dat de organisatie een positieve houding zal innemen omtrent het in gebruik nemen van Relatics?
Dit is moeilijk te zeggen, ik verwacht veel weerstand uit de organisatie. De opbouw van de organisatie is verstoord want het merendeel van de werknemers is rond de 50 jaar. Deze groep mensen vinden het moeilijk om met veranderingen om te gaan. We denken dat we als we binnen dit project Relatics gaan gebruiken we op die manier bij mensen interesse kunnen wekken zonder dat ze gedwongen worden het te gaan gebruiken.

Zien jullie Risico’s bij het gebruik van Relatics?
De grootste risico’s voor het gebruik van Relatics liggen binnen de organisatie zelf. Het overtuigen van de organisatie dat een informatie systeem als Relatics kan helpen bij het beheren van je projectinformatie. Daarnaast vormt het LIOR een risico. Voordat Relatics optimaal voor een project gebruikt kan worden zullen we de eisen moeten bijwerken naar het huidige beleidsniveau, richtlijnen, wetten en regelgeving. Ook hierbij zal de nodige weerstand zijn vanuit de organisatie om met Relatics te werken.
**In hoeverre zijn jullie bekend met Systems Engineering?**
We moeten nog heel veel leren omtrent SE. We zijn wel erg benieuwd of de voordelen zoals ze zijn beschreven in de theorie ook in de praktijk op deze manier zullen uitpakken. Vandaar dat we middels dit project (red. Vlielandseweg) inzicht willen krijgen in hoe SE werkt in de praktijk.

**Kan Relatics helpen bij de implementatie van SE?**
*Om deze vraag te beantwoorden dienen we eerst beter in beeld te krijgen wat SE allemaal inhoud. Wat we tot nu toe gezien hebben van Relatics is met name tot en met de ontwikkelfase. De processen en structuren voor de uitvoering kunnen we hierdoor niet beoordelen. Dit instrument kan uiteindelijk wel helpen de informatie voor SE op te slaan.*

**Kan Relatics helpen bij het opstellen van het PvE?**
*Met name voor kleine projecten zie ik momenteel de grote voordelen. De handboeken voor de kunstwerken en met name de bruggen zijn al op een ander abstractieniveau. Hierdoor kunnen deze eisen gemakkelijker in het systeem gezet worden en als basis dienen voor een PvE. Dit PVE kan dan voor meerdere contractvormen gelden.*