An investigation on Rijkswaterstaat's approach to delivering industrial automation requirements of construction projects

Citation for published version (APA):

Document status and date:
Published: 01/01/2015

Document Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 15. May. 2020
An investigation on Rijkswaterstaat’s approach to delivering Industrial Automation requirements of construction projects

Georgia Vompiri

January, 2015
AN INVESTIGATION ON RIJKSWATERSTAAT’S APPROACH TO DELIVERING INDUSTRIAL AUTOMATION REQUIREMENTS OF CONSTRUCTION PROJECTS

By

GEORGIA VOMPIRI

A dissertation submitted in partial fulfillment of the requirements for the degree of

Professional Doctorate of Engineering

Prof. dr. ir. Bauke de Vries, university coach
Dr. ir. P.P.J.M. Paul Spierings, company coach
ir. Femke Braaksma, company coach
Dhr. Arjan Verweij, company coach

Eindhoven, the Netherlands

January, 2015

This thesis has been established in collaboration with
A catalogue record is available from the Eindhoven University of Technology Library

Contents
1 Introduction ................................................................................................................................... 12
  1.1 Problem Background ............................................................................................................. 12
    1.1.1 Industrial Automation Definition .................................................................................. 12
    1.1.2 Industrial Automation within the Construction Industry (CI) ....................................... 12
    1.1.3 Industrial Automation within RWS ................................................................................ 15
  1.2 Problem Definition ................................................................................................................ 20
  1.3 Project’s Scope and Objectives ............................................................................................. 21
    1.3.1 The Project’s Questions ................................................................................................. 22
  1.4 Methodology ......................................................................................................................... 23
    1.4.1 Project Framework ........................................................................................................ 25
2 Rijkswaterstaat’s Approach ........................................................................................................... 26
  2.1 The contracting chain ............................................................................................................ 26
    2.1.1 Rijkswaterstaat’s Approach to delivering the Industrial Automation Requirements .... 28
    2.1.2 First Identified Barriers of RWS approach of IA requirements specification ............... 29
  2.2 Industrial Automation Requirements Specification .............................................................. 30
    2.2.1 System-oriented Contract Management (SCM) in Rijkswaterstaat .............................. 31
    2.2.2 The Functional Specification Working Method (FS) in Rijkswaterstaat ........................ 31
    2.2.3 The Systems Engineering (SE) Working Method ........................................................... 34
  2.3 The external parties ............................................................................................................... 42
  2.4 Identified Problems ............................................................................................................... 44
3 Other Companies Approaches ...................................................................................................... 51
  3.1 ProRail’s Approach ................................................................................................................ 51
    3.1.1 ProRail’s Identified Problems ........................................................................................ 52
    3.1.2 ProRail’s Answer to the Problem of IA Requirements Delivering: Spoorzone Delft Project 53
    3.1.3 ProRail’s Future Direction .............................................................................................. 56
  3.2 Schiphol Group’s Approach ................................................................................................... 56
    3.2.1 Small Scale Projects ....................................................................................................... 58
    3.2.2 Medium Scale Projects ................................................................................................. 59
    3.2.3 Large Scale Projects ....................................................................................................... 61
    3.2.4 Main Differences between Schiphol Group’s and RWS’s Approaches ......................... 63
4 Conclusions .................................................................................................................................... 66
5 Recommendations and Suggestions ............................................................................................. 70
5.1 Recommendations ................................................................................................................ 70
5.2 Suggestions ............................................................................................................................ 77
6 References..................................................................................................................................... 80
Dedication

This dissertation is dedicated to my life partner Orestis and my parents Eugenia and Nikolaos. Thank you for always believing in me and encouraging me to become the best version of myself.
Preface

After my Bachelor and Master Studies in Civil Engineering at the University of Patras in Greece I decided to follow the two-year PDEng Program "Smart Energy Buildings and Cities". This decision was related to my interest in becoming a technological designer in the field of energy and sustainability within the built environment.

For my second year project I was connected to Rijkswaterstaat and this is my project’s final report. The project is an investigation on Rijkswaterstaat’s approach to the Industrial Automation Requirements specification and delivery via contracts to their external stakeholders. For the realization of this project I worked closely with a very supportive design team that consists of my University Coach and my Company Coaches. I would like to thank my University, Coach Prof. dr. ir. Bauke de Vries, for his academic advice, the useful feedback and his support during the last two years. I have also received guidance and supervision from my Company Coaches, Dr. ir. P.P.J.M. Paul Spierings, ir. Femke Braaksma and Dhr. Arjan Verweij. Therefore, I would like to thank them all for their guidance, their constructive feedback and their help during the course of this project. More specifically, I would like to thank Dr. ir. P.P.J.M. Paul Spierings for giving me the opportunity, through this project, to explore new disciplines, working methods, areas of interest and to develop myself and my personal skills.

During the last year I became part of the "Installaties and Bediening" (IB) department of Rijkswaterstaat. This is the department where my two company coaches, ir. Femke Braaksma and Dhr. Arjan Verweij, work. Subsequently, I would like to thank them, not only for the aforementioned reasons, but also for devoting their time to making me feel part of their team, for inspiring me to always look for alternatives, better ideas and solutions. At this point, I would like to give my special gratitude towards all my colleagues who work at the IB department for always being willing to help, for sharing their ideas and for making me feel an active member of their team.

In order to carry out this project a number of interviews were conducted. The interviewees either as managers or advisors in a variety of companies (Rijkswaterstaat, ProRail, Schiphol Group, Royal BAM, Royal Imtech, Covalent). Without their valuable input this project could not have been realized. I would like to thank each one of them for devoting time to be interviewed and for their willingness to help me with my investigation:

- ing. Paul Besseling, Advisor and System Designer, Covalent
- ir. T.J.A. (Theo) Boumans, Projectmanager, ProRail
- ir. Femke Braaksma, Teamleader at the Department "Installaties and Bediening", Rijkswaterstaat
• Dhr. ing. Ruud Derksen, Senior Advisor at the Department "Installaties and Bediening", Rijkswaterstaat

• Prof. dr. ir. Paul Grefen, Full Professor at the Department of Industrial Engineering and Innovation Sciences, Eindhoven University of Technology

• Prof. ir. Ger Maas, Director of Strategy Royal BAM Group and Co-chair of the group PEBE at Eindhoven University of Technology

• Dhr. ing. Patrick Maessen, Senior Advisor at the Department "Installaties and Bediening", Rijkswaterstaat

• Dhr. ing. Gert-Jan Oosterlee, Senior Advisor Specialist at the Department "Installaties and Bediening", Rijkswaterstaat

• Drs. Michel Rog, Senior Manager at Strategic (Project) Procurement & Contract Management, Schiphol Group

• ing. Bob Scholten, Consultant, NSPYRE and Advisor at the Department "Installaties and Bediening", Rijkswaterstaat

• ing. Auke Sjoukema, Projectmanager, ProRail

• Dhr. Marc Unger, Director of Corporate Procurement, Schiphol Group

• Dhr. Arjan Verweij, Head of the Department "Installaties and Bediening", Rijkswaterstaat

• ing. Jille (J.) Wedzinga, Senior Adviseur at the Department "Installaties and Bediening", Rijkswaterstaat

• ing. Hans van Zijtveld, Project Leader, Royal Imtech

It was my pleasure to carry out this project since I got the experience of working in a large construction organization and collaborating with a variety of people (people from different companies with different backgrounds, positions and mindsets). This experience helped me evolve and enhance my personal and professional skills. Moreover, I definitely learned a lot about the field of Industrial Automation and how to approach a multi-layer problem from different perspectives.
Executive Summary

Rijkswaterstaat (RWS) is a large construction organization that nowadays does not construct or purchase any components. Instead, RWS provides a set of requirements to their external stakeholders that need to be fulfilled. In RWS’s civil engineering projects, apart from the static part (civil structures), there is also the complex dynamic part (technical installations). These technical installations constitute the Industrial Automation (IA) part of construction projects.

On one hand, Rijkswaterstaat’s identity as a large construction organization with a long-history provides it with a lot of expertise on requirements specification of structural engineering components. On the other hand, when it comes to requirements specification of Industrial Automation components there is a lack of expertise and knowledge within the company. Moreover, during the last years, the company has faced several failures on their Industrial Automation projects. Thus, the aforementioned situations have strengthened the belief within the organization that there is much space for improvement in the area of Industrial Automation.

The project’s focus is on gaining insight and familiarity for further investigation on RWS’s hot issue of IA requirements specification. The project’s main question is the following one:

- Is RWS dealing well with the IA part of their civil engineering projects?

This project investigated the present practice of RWS’s IA requirements specification and delivering via contracts in order to answer the above question and to identify the most likely factors that may adversely affect the delivered project (usually in terms of quality, but also time and money). Then, in order to explore possible solutions to RWS’s approach to IA requirements specification and delivering, ProRail’s and Schiphol Group’s approaches were investigated and compared to Rijkswaterstaat’s.

The research methodology that has been followed for this project includes literature research, study of RWS’s documentation/reports and conducting of interviews. Interviews have been selected as a tool to investigate RWS’s, ProRail’s and Schiphol Group’s approaches but also the market’s (projects’ external stakeholders) point of view.

From the whole investigation the following conclusions are drawn:

1. Rijkswaterstaat does not have its IA projects under control. Thus, there is space for improvements.

2. Rijkswaterstaat suffers from lack of knowledge in the area of IA requirements specification.
3. Most of the people who work in RWS are not aware of the importance and benefits of IA in construction projects. The fact that most of the people who work in RWS are civil engineers in combination with the company’s identity as a construction organization gives to the whole problem a cultural aspect as well.

4. The strategic choice of delivering more freedom to the market is not in balance with the market’s wishes. The market requests to be delivered more details from the client (RWS).

5. The lenience of RWS towards insufficient performance of companies (contractors) and even non-functional delivered products has cultivated the following attitude in the market: "Working for Rijkswaterstaat (the government) is more beneficial. More money can be earned and in case of failure there is no danger of receiving severe penalties and future collaborations are not threatened."

6. The contract management of IA projects is weak since in case of failures contractors easily find "exit windows" in order to avoid any kind of penalties.

7. Rijkswaterstaat lacks the ability to learn from its failures and mistakes regarding to the IA part of their construction projects.

From the comparison between RWS’s and other companies’ approaches (ProRail and Schiphol Group) it was concluded that:

- ProRail’s approach seems to face more or less the same problems as Rijkswaterstaat
- Schiphol Group’s approach seems to be more effective since they do not face any problems with their projects’ IA part.

The project’s recommendations are closely interrelated and should be viewed as a set of measures for Rijkswaterstaat to adopt. Rijkswaterstaat needs to be able to define the level of its involvement in IA requirements specification, in each project. This will be achieved only by investing on bringing the knowledge and expertise about IA, within Rijkswaterstaat. Moreover, there is a need for developing a project hierarchy in terms of roles and responsibilities for RWS’s managers, in order to avoid misunderstandings. Each project’s aim must be clearly defined for everyone involved. It also seems that there is a need to redefine the contracts. For this reason, a further investigation about the type of contracts (define the optimum contract type) and their legal framework is suggested.

It should be pointed out that in order for RWS to have finally its IA projects under control and not to repeat the mistakes of the past, all the recommendations of this report should be implemented.
List of Terms

A: Automation Subcontract
CI: Construction Industry
COP: Community of Practice
F: Functionalities Subcontract
IA: Industrial Automation
ICT: Information & Communication Technology
ICAT: Information Communication & Automation Technologies
RWS: Rijkswaterstaat
SE: Systems Engineering
SEB&C: Smart Energy Buildings & Cities
T: Techniques Subcontract
1 Introduction

1.1 Problem Background

In order to better understand the problem itself and its context the problem’s background is presented in the following paragraphs. Firstly, a definition of the Industrial Automation is given. Finally, the role of IA within the construction industry and RWS is described.

1.1.1 Industrial Automation Definition

For the aim of this project it is necessary to define the IA as a term and more specifically RWS’s perspective on IA definition. As the name indicates, IA refers to the Automation that is especially related to the industry. IA is thereby related to companies and commodities processing intermediates and converting them into products. In short, it is the automation of the physical manufacturing/construction processes.

IA as a term is considered to be very broad. In the case of Rijkswaterstaat organization, it is applicable with the task of managing the physical infrastructure and complex processes, such as the operation of tunnels, bridges and locks (civil works) and the handling of traffic flow. When it comes to IA within RWS the organization defines the term as it follows: “Industrial Automation is the Information that is functionally connected to infrastructure”. The term "infrastructure" refers to the physical network. By "functionally connected" it is meant that IA does not necessarily have to be physically fitted/installed to concrete and steel [1].

The term IA also includes the center from which monitoring and operation takes place (operation of the bridges, traffic control and monitoring etc.). The more comprehensive definition of IA is: "Industrial Automation includes the ICT-related systems and components (hardware and software, both functional and technical), which are functionally interacting with the physical environment and/or user (e.g., a bridge, substation, highway, tunnel etc.)” [1]. The aforementioned includes obtaining information about the physical environment and its influence (control operation).

1.1.2 Industrial Automation within the Construction Industry (CI)

The globalization of the economy has increased the competition between all the organizations/companies in different fields. In order to gain a competitive advantage and stay in the market this trend necessitates many organizations to investigate all possible solutions in order to improve their products and/or services. The above trend has also influenced the CI by making it more integrated and efficient.
As it is illustrated in Figure 1 the global drivers that compel the CI to change come from economic, political, social, technological and environmental trends [2].

In order to understand why IA is considered important to a construction organization, such as RWS, and how it helps the organization to be more competitive and efficient, it is useful to get an insight into the importance of IA within the CI in general.

From the latter and more inclusive definition of IA it has been made totally clear that IA is closely related to the ICT systems (software) and the necessary equipment (hardware). Because of the aforementioned link, the IA benefits and main barriers within the CI will be examined from an ICT & Automation (ICAT) perspective.

During the last decades, information technology (IT) and information and communication technology (ICT) has been considered as an essential tool that enhances companies’ performance in terms of efficiency and effectiveness. Towards the aim of increasing competitiveness and cost reduction, ICT has been extensively applied in many sectors of industry [3].

The adoption and implementation of ICAT solutions within the construction industry aims to the improvement of many construction processes at each project phase. These processes indicate that the usage of ICAT technologies, take part during the whole life-cycle of a construction project in order to achieve the following main goals [4], [5]:

**Figure 1. Construction Industry Drivers of Change [2]**

- Reduction in Construction Time
- Reduction in Capital Cost
- Reduction in Defects
- Reduction in Accidents
- Increase in Predictability
- Reduction in Waste
- Increase in Productivity
- Reduction in O&M Costs
• project time reduction, (tasks and operations)
• project’s control increase
• delivered project’s quality improvement
• project’s operational efficiency improvement
• organization’s operational efficiency improvement
• profit levels raise
• client/user satisfaction improvement

This multitude of benefits has motivated many construction organizations to adopt ICT technologies and invest in them. Despite the advantages of ICT implementation in the construction industry, there are factors that limit the diffusion of ICT within construction organizations.

According to several studies, the main barriers of the proper diffusion of ICT within the construction industry seem to be related to the fact that ICT investments in construction projects usually represent only a small part of the total project’s cost [3]. ICT implementation in construction projects requires investments that need sufficient support from the managerial levels of construction organizations [3], [4]. According to several studies managers in construction organizations do not appreciate enough and do not have the necessary knowledge to evaluate correctly the benefits of ICT implementation within the different phases of each construction project [4]. Thus, the lack of understanding of ICT and its implementation into a project and into a construction organization may lead to an ICT implementation failure. This is the case where the ICT investment does not meet the managers’ requirements [6].

Apart from the barriers of high investment cost and lack of experience in ICT management that affect the adoption and implementation of ICT in CI, many studies identify the nature of the construction industry as an important barrier by itself. The construction industry has shown a weakness in absorption of new technological innovations and the entire industry has been considered as conservative and slow in adoption of ICT and Automation Technologies (ICAT). The culture by itself has its own power to enhance and guide the organization’s way of doing things. Organizations with a long history that tend to also be successful, present a stronger culture and identity [2], [6], [7]. In the case of the construction industry, the culture and the nature of the industry’s products limit technological change and implementation within construction organizations.
From all the above it is clear that IA has been identified as a priority area for the CI in order to achieve its goals and to fulfill its long-term vision of becoming more integrated, efficient and attractive to the market. At this point it should be mentioned that the "people and process issues" (e.g. training, culture change, integration of supply chain and systems, contracts) are considered to be the key factors towards the successful implementation of IA technologies and processes. It is through these key factors that the effective technological change will be brought within a construction organization.

The relative importance of People, Process and Technology is illustrated in Figure 2.

![Figure 2. The relative importance of People, Process & Technology](image)

1.1.3 Industrial Automation within RWS

As it is known Rijkswaterstaat is responsible for the smooth and safe flow of traffic, in a safe, clean and user-oriented national water system and the protection of the Netherlands from flooding. RWS manages the national road network (5,695 km), the national waterways network (1,686 km of canals, rivers and 6,165 km of inland waterways in open water) and rural water (65,250 km2) [8].

*The Importance of Industrial Automation within RWS*

Rijkswaterstaat has four enterprise objectives:

1. Sufficient dry land
2. Sufficient clean water
3. Smooth and safe traffic by road and water
4. Reliable and useful/usable information

The primary processes of Rijkswaterstaat are geared to support these objectives and aim to provide service to the citizens. Primary processes include:

- Land Traffic Managements (road traffic)
- Water Traffic Management (ship traffic) and
- Water Management (managing the quantity and quality of water).

In Figure 3 the enterprise objectives and goals of RWS are illustrated.

The primary processes are supported by networks for water, road and shipping. As part of the physical infrastructure, IA is the mean to steer and control the utilization within the networks.

The networks for water, road and shipping are interconnected by various objects such as bridges, locks and tunnels. These objects are operated and monitored from central or local stations (close to the object). Autonomous control takes also place, for example in dynamic traffic. The networks for water, road and shipping are illustrated in Figure 4.
Proper operation of IA is crucial because it allows RWS to fulfil the primary processes. Industrial automation is considered of crucial importance for flow, safety, availability, reliability, and performance of and within the networks.

As it has been mentioned before, RWS defines the term of IA as the information that is functionally connected to infrastructure. In the scope of this definition IA within RWS is related to the following systems/items and processes [1]:

<table>
<thead>
<tr>
<th>Related Systems/Items</th>
<th>Related Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>traffic centers, monitoring networks</td>
<td>specification, contract, design, realization</td>
</tr>
<tr>
<td>bridges, locks, tunnels</td>
<td>use, management and maintenance</td>
</tr>
<tr>
<td>weirs and pumping stations, mobile IA</td>
<td>demolition</td>
</tr>
</tbody>
</table>

Table 1. Industrial Automation within RWS-Related Systems & Processes [1]
Moreover, the following Table 2 shows in detail what IA is about within RWS and answers the following questions:

- "What does IA ensure?"
- "How does IA work?"
- "From which components (systems and equipment) does IA consist of?"
- "Where can IA be found?"

<table>
<thead>
<tr>
<th>Ensures/Provides</th>
<th>gathering information on the current status of the physical environment (e.g., loop), and / or change state physical environment (e.g. roadway, floodgate), and / or presenting information to the physical environment (e.g. matrix board, signaling)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Works/Operates</td>
<td>through control of man (operation), and / or autonomous systems via / machines</td>
</tr>
<tr>
<td>Consists Of</td>
<td>sensors and actuators connected to the civilian infrastructure and / or command and control systems (e.g. motor control) and / or fixed and mobile communication networks (data, video, audio) and / or operating systems (e.g. uniform operator MMI, ICT central)</td>
</tr>
<tr>
<td>Can Be Found</td>
<td>in or on structures such as bridges, tunnels and locks, and / or along roadside and waterways and / or in the center for monitoring and remote operation</td>
</tr>
</tbody>
</table>

Table 2. Industrial Automation’s role within RWS [1]

In general, there is regular automation/IV (specific and generic information) and IA. The difference between those two can be understood as the difference between planning and real-time processing. The Center that is found between IV and IA forms the boundary between them. This concept is illustrated in Figure 5.
Office

At the top of Figure 5 is the office environment with more than 8,000 employees in over 100 offices. In the office environment regular automation is being used, in the form of generic and specific information.

Center

Among them are a certain number of centers, such as the traffic control center. In the center is the interface with the generic ICT and applications/information systems. For example, planning is made by a central use of the regular information services. With the aid of IA in the Center the physical infrastructure is being controlled in real time remotely.

Physical area

Under the Center there are many objects in the physical infrastructure. The objects, additionally to remote control, may also have local control, for example, from a bridge guard house. Industrial automation in the Physical Area either reads the state (sensor, camera) or changes the state (actuator). Here, ICT affects other technologies such as civil engineering technologies (the constructions) and installation technologies.
Industrial automation can be found therefore in or on objects (bridges, locks, tunnels, etc.), in equipment along the roadway and waterway, and in the Center to monitor and control remotely.

**IA Objects**

Rijkswaterstaat manages a variety of objects such as tunnels, bridges, locks, dams, taxiways and rush-hour lanes. These objects are part of one or several networks: the main waterway network, main roads network and main water systems network.

The word "object" can refer to different things within IA. There are various types of IA-objects which can be operated or controlled. For example, a camera, a traffic light and even a bridge is an object. However, networks are regarded as objects as well. All of them are considered objects, but the scope and function of each one of them is different.

### 1.2 Problem Definition

This project is related to the wish of RWS to make a cultural transition within the company in the field of multidisciplinary approach in designing and executing building projects.

While RWS is looking towards this cultural transition, at the same time there is a sense within the organization that in the area of Industrial Automation there is much space for improvement. Nowadays, the organization does not purchase or construct any components, but provides a set of requirements to their external stakeholders that need to be fulfilled. The fact that RWS is an organization, whose manpower mainly consists of people who are not related to the field of IA (mostly civil engineers and people from related fields) and at the same time they have to make strategic decisions related to the IA part of their projects’, strengthens the belief that there is much space for improvement. Moreover, the nature of the organization, which is a construction organization with long history in the Netherlands, reinforces this belief further.

The aforementioned identity status provides RWS with a lot of expertise on requirements specification of structural engineering components, but when it comes to requirements specification of IA components there is a lack of expertise and knowledge.

In RWS’s civil engineering projects there is a variety of technical installations that have to be integrated and coordinated with the civil structures. The structural part of a construction project is characterized as static. On the other hand, the Industrial Automation part is characterized as very dynamic. The Industrial Automation part of civil engineering projects consists of hardware and software components combined with the crucial component of Operation and Control of the above. It must be pointed out that the IA components (both hardware and software) of a construction project have a much shorter lifetime (<15 years)
compared to the lifetime of the structural part (>100 years). The great complexity of a project, in terms of IA, demands a good design and smart/targeted testing. The invisibility and complexity of particular software has created the challenges in finding errors in order to demonstrate the correct operation.

On one hand, RWS always wants to control the final quality of their systems/products (tunnels, highways, bridges etc.). On the other hand, it is true and acceptable that IA becomes more and more present and essential part to construction engineering projects and this situation creates a lot of pressure and discomfort within the organization.

1.3 Project’s Scope and Objectives

The current project’s purpose is exploratory as it has been defined in its title as well: "An Investigation on RWS approach to delivering IA Requirements of construction projects".

The focus of this research is on gaining insight and familiarity for further investigation on RWS’s hot issue of IA requirements specification. This project will explore and examine the present practice and concept of RWS’s IA requirements specification and delivering via contracts and aims to reinforce the sustainable development of the organization in the area of IA.

The primary objective is to obtain an understanding of RWS’s process of IA requirements specification in order to identify the most likely factors that may adversely affect the delivered project (usually in terms of quality, but also time and money).

The second objective is to explore these factors and investigate them in order to justify either their negative or positive effect to the final quality of the delivered project/product. These factors may refer to strategies/processes on specifying the IA requirements of a project, the communication model of the parties that take part in the IA contract chain (RWS, Main Contractor, Subcontractors), the different drivers of each party that make them adopt this specific process, the responsibilities that each party has or even the whole approach of RWS in the IA requirements delivering. Moreover, possible RWS innovations (different, approaches or strategies) that took place during the last 2-3 years will be examined.

The company’s scope is strongly influenced by the need of cultural change within the organization and the need of a better performance in a more integral way. The aforementioned points are considered as the innovative part of this project. The current project could be also considered as a pioneering work in developing a business approach from an engineering perspective.

The above objectives point out what results can be expected from the research, namely:
• A better understanding of RWS approach on IA requirements specification and its main barriers/problems.

• Investigation of other companies approaches (ProRail and Schiphol Group) in order to examine similarities and differences. Perhaps there are better approaches from which lessons could be learned.

• Strategic advice on the main question: Is RWS dealing well or not with the IA requirements specification and delivery?

• Suggestions and directions for further investigation.

The academic value of this project lies in its nature that is considered as an interdisciplinary research on transition in large Construction Organizations in relation to technological change. From another perspective this project is dealing with critical problems at the interface of engineering, management and innovation and this makes it really interesting for the SEB&C PDEng (Professional Doctorate in Engineering) Program that aims to create a link between academia/innovation/engineering and business/industry. Furthermore, the project’s relevance to Sustainability and the Smart Energy concept of the SEB&C Program lies in the fact that well-managed IA systems in construction projects can reduce the energy consumption of the above.

Last but not least is the societal value of the project. Rijkswaterstaat funds the majority of the infrastructure projects and services in the Netherlands. Thus, there is an interest from the public sector’s side in whether the nation’s money is being spent efficiently and effectively. So any investigation towards the direction of improving RWS performance is considered to be of high importance.

1.3.1 The Project’s Questions

In order to better understand the current status of RWS IA requirements delivering approach and come up with some concrete conclusions, this assignment will address and try to answer the following questions:

• What is the position and hierarchy of IA in RWS projects?

• Is IA considered as a dominant element for delivering a project efficiently?

• How does RWS deliver the IA requirements of its projects to its external stakeholders (main contractor and subcontractors)?

• What are the main barriers/problems that the organization faces during the whole process of specifying and delivering requirements related to the IA part of a project?
• How do companies similar to RWS -companies that act as the client of a project and deliver requirements to external parties- deal with the IA requirements specification and delivery? Do they have same or different approach as RWS? Do they also face problems in their projects in terms of IA quality?

It should be highlighted that the initial and main question of this project is the following:

• Is RWS dealing well with the IA part of their civil engineering projects?

1.4 Methodology

An investigation might involve a literature research or conducting focus group interviews in order to identify the core subject and its key factors.

In order to gain satisfactory results and answers to the project’s main question and sub-questions a research methodology has been developed. The research methodology that has been followed for this project includes activities that vary from literature research and study of RWS documentation/reports to practical experiences in real life via the interviews. The study of RWS documents and reports mainly refers to documents related to the IA requirements’ specification processes (What kinds of tools/methods are being used in order to specify the IA requirements and finally deliver them via the contracts to the external parties?). Interviews have been selected as tools to explore the current IA requirements delivering approach of RWS. Furthermore, especially through interviews the main barriers/problems of RWS approach have been identified.

In order to better understand the above approach there was the need of getting information and feedback from the different parties that take part in the whole process (RWS managers and contractors, Main Contractors, IA Suppliers). Apart from that, it has been considered very useful for the project itself but also for RWS to acquire insight on how other organizations/companies that are related to the field of the Built Environment deal with the same problem. For this reason, several interviews with Managers and Consultants from ProRail and Schiphol Group have been conducted. The basic idea is to identify their approach and process of specifying and delivering the IA requirements to their external stakeholders and its barriers as well. Therefore a comparison between different approaches/processes has been made and conclusions, such as strategic advice or direction for future investigation have been drawn. Furthermore, the market’s point of view on the topic of IA requirements specification and delivery at RWS’s construction projects is considered important as well. For this reason, a number of interviews have been conducted with people who work as managers or consultants at companies that act either as the Main Contractor or the Subcontractor in RWS projects. The selected companies from the market’s side are Royal Bam and Royal Imtech.
The type of interviews that has been followed is semi-structured interviews and the form of interviewing is face-to-face. A structured guide with a combination of specific questions and with more general questions designed to open up conversation about the topic has been developed. The information gathered from the interviews proved particularly useful in the following areas:

- Rijkswaterstaat’s approach to specifying and delivering the IA requirements of their construction projects
- Identification of related problems to RWS’s approach
- Investigation of ProRail’s and Schiphol’s Group approach to specifying and delivering the IA requirements of their construction projects
- Identification of similarities and/or differences between the above different approaches
- Getting an insight to the market’s (Main Contractors and Subcontractors) point of view on the investigated topic

In the scope of this project, a series of case studies and researches related to the topic of IA within the construction industry have been studied in order to get a more global view on the topic.

In Figure 6 the Research Model that has been developed and followed is visualized and the main steps that were followed during the project are illustrated. The project’s purpose is exploratory and that provides it with a dynamic nature.
1.4.1 Project Framework

The focus of this project is on gaining insights and familiarity for further investigation to RWS hot issue of IA requirements’ specification and delivery. It’s beyond the scope of this project to examine the topic in specific projects and to delve deep into each and every aspect of them (e.g. examination of all the different external stakeholders of RWS) but rather an overall view of the topic is needed to get the required insight.

This project has been carried out from a fresh and independent viewpoint to identify the nature of the problem and come up with concrete conclusions and recommendations.
2 Rijkswaterstaat’s Approach

Globally, there is an increasing trend in the percentage of the part of IA in construction projects, which makes the need to investigate the current status of RWS approach to IA requirements specification and delivering absolutely necessary. Industrial Automation has penetrated the construction industry and looking towards the future of constructions one thing can be stated with high certainty: IA will get a higher position at the hierarchy of the construction value chain.

Up until now RWS has developed and followed a specific strategic model related to IA requirements specification and delivering. The organization’s approach to IA requirements specification and delivering is explained and presented in the following paragraphs. It should be mentioned that the company’s approach has been investigated through documentation and report study but mostly via interviews with a variety of RWS’s managers, consultants and external partners.

2.1 The contracting chain

RWS acts as the principal of a construction project, who at the same time is also the client of the project, the one who sets and specifies the project’s requirements and deliverables. As the principal of the project RWS is the responsible party that guarantees its final quality.

It must be pointed out that RWS does not take part during the design and construction phase of a project and does not purchase any sort of components (building components, ICT, IA etc.). Instead, it cooperates with external stakeholders and delivers a specific working package to each of them with specific requirements as well.

When it comes to RWS’s requirements delivery we refer to the process of contracts. A client such as RWS signs a contract with its main contractor(s) that could be either a specific company (it usually is a Civil Engineering Company) or a Consortium (its composition may be different from project to project) that is willing to undertake the construction project. Then, the main contractor(s) deliver(s) the subcontracts to the third parties, the subcontractors. This master contract is the tool for RWS to deliver its requirements to its main contractors. Moreover, from this contract, which is essentially an agreement between two or more parties, responsibilities are originated. The process of delivering project requirements through contracts is visualized in Figure 7.
This master/main contract could be either a DBFM or a D&C contract. DBFM stands for "Design, Build, Finance and Maintain-" contract and this type of contract has been applied by the Dutch government since 1999 [9]. D&C stands for "Design & Construct-" contract.

The so-called master contracts (DBFM/ D&C) are considered as an integrated and innovative type of contracts that require a different method to deliver a project’s requirements to the contractors. Shifting the responsibilities and the risks of the design and building phase more towards the market, were reasons to introduce integrated contracts.

Before putting a project in the market a system definition is created and from it the so called "Systemontwerp/System Design Paper" is formed. From that System Design Paper (SDP) the basic requirements that describe the functionalities of the system/project are obtained and with these requirements the Basic Design Paper (BDP) is prepared. Those two papers (SDP and BDP) are the input for the formation of the VSE (VraagspecificatieEisendeel). VSE is part of the master contract (DBFM/D&C) and contains the Structural Engineering Requirements Contract and the Industrial Automation Requirements Contract. VSE looks different in each case as it is completely dependent on the main contract’s type and project’s type and complexity. The above procedure is shown in Figure 8.
2.1.1 Rijkswaterstaat’s Approach to delivering the Industrial Automation Requirements

The IA requirements are delivered from RWS to the main contractor via the Industrial Automation Contract. The IA Contrast consists of the following three subcontracts:

1. **Functionalities (F)** is the mainly asked contract and is delivered directly from the client (RWS) to the main contractor. It is the subcontract that asks for the automation; it includes the requirements on the type of automation that is required to be in a project (e.g. Lighting in the tunnel is required).

2. **Automation (A)** is the Process Subcontract. In order to reach the desired Functionality a specific process should be followed which includes an input, a throughput and an output. This subcontract refers to that process and up until now it is mainly delivered from the main contractor to the subcontractors.

3. **Techniques (T)** is the Subcontract that refers to the needed IA equipment (hardware) that is required for a specific IA Functionality. The Techniques (T) subcontract is also mainly delivered from the main contractor to the subcontractors.
RWS approach to delivering the IA requirements via the contracts is being visualized in the following Diagram, Figure 9.

![Diagram of RWS Industrial Automation Requirements Delivery via Contracts](image)

**Figure 9. RWS Industrial Automation Requirements Delivery via Contracts**

### 2.1.2 First Identified Barriers of RWS approach of IA requirements specification

Until approximately fifteen years ago RWS was very much involved in technical specification as they used to write down everything in the contracts. After that period it was decided to put more responsibility and design freedom on the market.

At first RWS used to deliver the (F) part of the IA contract only to the main contractor, who was -and still is in a lower percentage- the responsible party for translating it to the (A) and (T) subcontracts before delivering them to the subcontractors (IA software and hardware suppliers). During this process there was a high level of abstraction from the main contractor in the translation and transformation of the (F) subcontract to the (A) and (T) subcontracts. The level of abstraction was so high that in many cases at the end of a project the project’s functionalities (F) and main requirements weren’t fulfilled. The aforesaid means that in such cases the delivered final project does not reach the client’s (RWS) requirements and the desired final quality.
It was after facing such problems when RWS decided to try a different approach on IA requirements specification and delivering. So it was decided to deliver not only the (F) part of the IA contract to the main contractor but also the (A) and (T) parts of it. During this procedure the organization identified its weakness on the specification of IA requirements. Because of that lack of knowledge (A) and (T) subcontracts aren’t being delivered in detail to the main contractor. This means that there is still an important responsibility of the main contractor to translate, form and deliver the (A) and (T) subcontracts and their included requirements to the subcontractors (IA Suppliers).

Rijkswaterstaat in this case, through the contracts delivers not only requirements and responsibility to its main contractor, but also the problem. However, the problem cannot be solved efficiently this way, as the main contractor is also a Civil/Construction Engineering company that also has a lack of knowledge on IA requirements specification and delivering.

Moreover, the main contractor is not the IA supplier, which means that the communication with the suppliers always takes place through the main contractor. The fact that the contract standardization does not include anything about the IA part of a project is considered to be one of the main problems that the organization is trying to deal with.

The wide spectrum of RWS construction projects increases the problem’s complexity as at the moment there is almost no uniformity in IA requirements specification. There are many different kinds of projects (tunnels, bridges, highways etc.) and each has different requirements.

Last but not least is the fact that it is a matter of money as well. The IA part of a construction project usually takes place at the final phase of a project before its delivery to the client (RWS). The main contractor, who is usually a Civil/Construction Engineering Company profits mainly from the design and the construction of a project. Thus, it is assumed that for this reason the main contractor is not motivated enough to deliver a final product that meets the client’s desired IA standards. In the following chapters the problems and their nature are analyzed and presented in more details.

### 2.2 Industrial Automation Requirements Specification

After having explained the main approach of RWS to delivering the IA requirements of their construction projects to the external parties it is useful to see what kind of tools and/or methods are being used for the requirements’ formation and delivery. The investigation of these tools and/or methods aims to the acquisition of an insight into possible problems by implementing those methods. These problems are related to a low quality level of the IA in RWS’s civil engineering projects.
2.2.1 System-oriented Contract Management (SCM) in Rijkswaterstaat

Around 10 years ago the political and social pressure on RWS has formed one of the organization’s prior ambitions: RWS has the ambition of being the “Leading Client”. Working with innovative contracts leads to a different interpretation of the roles of client and contractor. Rijkswaterstaat is committed since January 2003 to renew its working relationships with the market participants [10].

Quality plays an important role on RWS’s projects. Rijkswaterstaat wants the knowledge and ideas of the market being used optimally in its projects and aims to excite the market to come up with creative solutions by providing it with more freedom. This leads to a different interpretation of the roles of client and contractor. The contractor has a greater input and responsibility in the development and design of products. Rijkswaterstaat as a client oversees the projects in a less involved manner. The result is that the contractor must be able to demonstrate compliance with quality standards, both during and after completion of the work. This method is called external quality assurance. If the client uses the Quality Management System (QMS) of the contractor for the management of a contract, then we are dealing with system-oriented contract management (SCM) [10].

Effective cooperation between client and contractor is needed in order to achieve the best result. It is noteworthy that effective cooperation between client and contractor is based on reciprocal trust and respect for each other’s interests. It is expected that everyone follows the following motto: “Say what you do and do what you say”.

2.2.2 The Functional Specification Working Method (FS) in Rijkswaterstaat

During the last years there is the tendency within RWS to outsource more working packages of the construction process to the market. This is related to the desire of the organization to work more effectively and efficiently. This tendency also applies to the design process, where it can be combined with (parts of) the implementation activities to Design & Construct Contracts (D&C). It is considered to be beneficial for RWS to deliver large parts of the design process to the contractors, mainly because of their extensive knowledge and expertise in the area of implementation. This strategy may also accelerate innovation and can possibly lead to more cost-effective solutions.

As it was mentioned before, the use of integrated contracts requires a different method by the client for the drafting of the demands. Rijkswaterstaat has developed the method of "Functional Specification (FS)‖, which has been increasingly applied during the last years. The specification of requirements consists as much as possible of functional requirements. Requirements are made in as little detail as possible so that the largest possible space for solution-oriented innovation and creativity is left to the market.
Rijkswaterstaat’s decision to apply increasingly more innovative contracts to its projects includes a shift of tasks, responsibilities and risks from RWS to the market. This occurs because the contractors are involved earlier in the construction process. This happens as long as the market is able to carry out its delivered tasks. If not, then Rijkswaterstaat is responsible to carry them out. The Functional Specification (FS) method aims to improve the price/quality ratio of the construction projects.

Officially, Rijkswaterstaat defines the Functional Specification (FS) as the capture of the desired performance of a system in terms of requirements that are based as much as possible on the function(s) that the system should fulfill [1]. It is the -as much as possible- functional and solution-free description of the required performance that the end product has to meet. The Functional Specification Method (FS), as it is introduced by Rijkswaterstaat, is based on the specification of requirements by using the Systems Engineering Method (SE) as a tool. The Systems Engineering Method (SE) is thoroughly described in section 2.2.3. The term functional is to emphasize that the specification is related to the functions that an object needs to have. In Table 3 the goals and the important aspects and results of the Functional Specification Method (FS) in combination with those of the Systems Engineering Method (SE) are shown.

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>GOAL</th>
<th>DESIRED RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROJECT</strong></td>
<td>solve a problem or fulfill a need</td>
<td>a product that best solves a problem or fulfill a need</td>
</tr>
<tr>
<td><strong>SE</strong></td>
<td>control and structure the design process for (large-scale &amp; complex) projects on aspects of price, time and quality</td>
<td>a design that best solves a problem or fulfil a need</td>
</tr>
<tr>
<td><strong>SPECIFICATION</strong></td>
<td>communication of interrogator and solver</td>
<td>VSE that best describes the requirements</td>
</tr>
<tr>
<td><strong>FS in RWS</strong></td>
<td>communication of interrogator and solver focused as much as possible on the functionalities</td>
<td>VSE that best describes the requirements in terms of functionalities as much as possible</td>
</tr>
<tr>
<td><strong>FS in RWS in a wider perspective</strong></td>
<td>creating of design freedom for market participants to make use of their knowledge and experience</td>
<td>Better price/quality ratio in RWS projects</td>
</tr>
</tbody>
</table>

Table 3. Overview of the goals and results of the Functional Specification (FS) and the Systems Engineering (SE) Working Methods [11]
The implementation of the Functional Specification Method (FS) by RWS aims to the following:

- Solution-Free Specification
- Provide the market with optimum design freedom
- Improve the competitive Dutch contractors by encouraging innovation
- Better quality/price ratio
- Use the expertise of the market
- Accelerate Innovation
- Better solutions
- Cheaper projects
- Application of structure in the process
- Obtain clarity in the process by thinking in terms of functions
- Smaller civil service

In Figure 10 the inter-relationships between the different objectives of the Functional Specification (FS) method are visualized.
2.2.3 The Systems Engineering (SE) Working Method

Rijkswaterstaat uses the Functional Specification Method (FS) for Functional Requirements Specification. As mentioned in section 2.2.2, the Functional Specification Method (FS) uses the Systems Engineering Method as a tool to define those requirements.

Moreover, the implementation of integrated contracts has forced the usage of SE since it plays a major role. So, when RWS delivers their projects’ IA requirements via contracts to each project’s Main Contractor, the mainly delivered subcontract is the one about Functionalities. In the Functionalities subcontract, the use of Systems Engineering (SE) is always required in order to secure the quality of the delivered project and that all the requirements will be fulfilled in terms of time and money.

The Systems Engineering Working Method (SE): Definition and Scope

The International Council of Systems Engineering (INCOSE) defines Systems Engineering as it follows:

"Systems Engineering (SE) 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: Operations, Cost and Schedule, Performance, Training and Support, Test, Manufacturing and Disposal. Systems
engineering (SE) integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering (SE) considers both the business and the technical needs of all customers with the goal of providing quality product that meets the user’s needs." [12].

According to RWS Systems Engineering is:

"A systematic and structured design process that gradually develops feasible solutions from requirements or goals." [13].

The scope of SE is to provide control and structure in (large and complex) construction projects in terms of price, time, and quality. This includes the following [1]:

- Structured requirements specification
- Structured design of a suitable solution to the requirements
- Implementation of the proper approach to develop and manage the solution
- Implementation of the proper verification and validation approach
- Use of a controlled approach to manage the total system during its entire life cycle

Systems Engineering Method is considered as a life-cycle approach. It focuses on the customer’s needs during the entire life-cycle. This is the reason why all the processes of SE aim to the optimization of a system for its total life-cycle.

The desired outcome of Systems engineering is a design that solves a problem or fulfills a need in the best possible way. A project where Systems Engineering is applied as a process aims to the delivery of an end-product that solves a problem or fulfills a need in the optimum way as well.

Why Systems Engineering (SE)?

Before the implementation of the Systems Engineering (SE) Method the traditional way to deliver a project’s requirements was more solution oriented. The client used to clarify his demands and then a solution was proposed and specifications were made. The client used to continue with the specification process going in more details. At some point this process reached the Final Design (FD) stage and only then the very detailed requirements (drawings and calculations) were handed over to the contractor. Rijkswaterstaat used to operate in this manner. This did not leave almost any space for creativity and innovation to the contractors. The above procedure is visualized in Figure 11:
Nowadays, the construction industry globally finds itself in a transition phase in the sense of efficiency and effectiveness. Moreover, in the construction industry it is also desirable that the clients set their requirements and the market comes up with creative and innovative solutions. The market must always focus on the problem and the client’s wishes.

Rijkswaterstaat is also in a transition phase, both cultural and functional. Rijkswaterstaat, during the last years, has faced a political and social demand to increase its efficiency and effectiveness. This means that the organization must be less involved in the projects and leave space to the market sector for greater participation in the civil engineering projects. All these facts, in combination with the need of process control and the fact that more and more information has to be transmitted during the construction process, make the use of the Systems Engineering Method (SE) essential.

The new way of working is more functional oriented. The client in order to provide the market with more design freedom delivers the requirements in a clear way but not in such high level of detail. The contractor is responsible to specify them further and come up with a proposed solution. This approach has been visualized in Figure 12.
In the development of a system/object everything starts with the identification of the client’s needs and wishes. Then the client’s needs are specified in the form of requirements (CRS).

The Client’s Requirements Specification (CRS) is the input for the development of the system, System Specification. The System Specification includes everything that defines the system (available solution space, description of the desired functionalities, the context of the system etc.). By using the System Specification, RWS translates the client’s requirements (CRS) into Requirements Specification that contains the Functional Specifications and the Aspects Specifications.

Then the client’s requirements specification (CRS) and the System Specification is used for the Contract Specification (formation of contracts).

Figure 13 shows the information stream from the client’s requirements to contract specification.
The engineering process of the Systems Engineering Method consists of three sub-processes: the Requirements Analysis, the Functional Analysis and the Design Synthesis. Between two consecutive sub-processes there is a loop. At the end of each process, the Design Synthesis is always compared to specified requirements.

The input for the Requirements Analysis is the output from the Client’s Requirements Specification (CRS). The Requirements Analysis aims to the transformation of the client’s requirements to system requirements (System Specification). As it was mentioned before, System Specification consists of the Functional Specifications and the Aspects Specifications. The Functional Specifications determine the functional requirements that the system to be designed must fulfil. The Aspects Specifications are related to other requirements that the system must satisfy (reliability, availability, maintainability, safety etc.).

Then, the Functional Analysis process aims to two things. The first goal is the transformation of a system’s functions into subsystems. The second goal is the specification of the relevant subsystems’ requirements.

During the design phase the subsystems are developed in order to meet all the requirements that have been determined in the Functional Analysis.

During the aforementioned process and before moving to the next step a Verification process should also take place. The aim of the Verification process is to demonstrate that the design meets the requirements.

The Systems Engineering (SE) Process Model of RWS is visualized in Figure 14.
Nowadays the client’s needs are characterized as very dynamic and highly complex. This means that a problem’s solution cannot be found at once. Systems Engineering (SE) uses an iterative specification process for the development of a system’s functions, requirements and solutions.

This iterative process is repeated in several levels of detail and every single system can be split into subsystems and then into components in order to reduce the complexity of the system to be developed. "The result of going through this iterative process, in connection with the Verification and Validation processes, is a specified system with associated requirements and design. These iterative steps can be depicted in a V-model." [15]

The V-model with its iterative steps is illustrated in Figure 15.

This iterative process of Systems Engineering includes a top-down system specification and a bottom-up realization. The top-down design process has as its staring point the system level and goes downwards in more detail to the element level (decomposition). At each level the design must be verified to the requirements specification. After the design phase has been completed we move on to the realization phase. The design must be executed. The realization process starts from the element level and moves upwards to the system level (composition).
The realization phase, apart from the integration of all the elements to components, subsystems and to the final system, also includes the inspection and testing of the above and their validation.

Verification and Validation processes go hand in hand, but a definition of them is required in order to distinguish their roles.

Verification is the process of determining that a designed system meets its specifications and represents the developer’s conceptual description. It ensures that a system is well-designed and error-free. It answers the following question: "Are we building the system right?"

Validation is the process of determining how well a system addresses a real-world need. It is the process of checking whether the specification and the designed system capture the customer’s actual needs. It answers the following question: "Are we building the right system?"

In Figure 16 a more detailed V-model is visualized.
Testing [1][15]

During the realization phase, a number of acceptance tests are performed. Testing is considered as a form of Verification but sometimes it could also be a type of Validation. The results of all the following tests are used as proof in the V&V reports. In Figure 16, in the V-model the different tests are indicated by the green arrows.

The acceptance tests that should take place are the following:

- **FAT**: refers to the Factory Acceptance Test and it is about the testing of the equipment (components/units) in order to determine if it meets the requirements and whether it is functional or not. It occurs at the supplier’s location.

- **SAT**: refers to the Site Acceptance Test and tests if each subsystem works properly after its installation to the project’s site (e.g. is the ventilator in this tunnel doing what it is supposed to do?).
• **ISAT:** refers to Integral Site Acceptance Test and tests if each subsystem works properly with the system as a whole (e.g. is the ventilator in this tunnel coordinates properly with the Environmental Control Platform?).

• **SIT:** refers to Site Integration Test. Once SAT or ISAT has been completed the integration of all the systems (components) is being tested in order to ensure that the product as a whole functions properly.

After having analysed the basic tools (FS and SE) that Rijkswaterstaat uses in order to form and deliver its projects’ IA requirements to their stakeholders, the procedure of delivering the requirements by the aforementioned tools is presented briefly in the following paragraphs.

So, the client, RWS delivers the Functionalities requirements (Client requirements in the V-model of Figure 16) via a contract to the Main Contractor. Then the Main Contractor has to prepare the main design (System level) and check it before they deliver the Automation (Subsystem level) and the Techniques requirements to the Subcontractors through the IA subcontracts. Afterwards, a more detailed design (Component level) and the realization design (Element level) have to be prepared by the Subcontractors in order to continue with realization phase of the V-model.

At this point it should be mentioned that in the case that FAT is not acceptable Rijkswaterstaat has a "blocking possibility" for the project. For the Main Contractor this means that they cannot continue with the project if they do not fix the problem in order to fulfil the client’s requirements. If the problem has not been fixed the Main Contractor is not going to get paid. The above "blocking possibility" is always mentioned in the contract that RWS delivers to the Main Contractor (Functionalities contract).

The final step before the delivery of the project to the client and the user is a Validation process that must take place. As it was mentioned before, Validation is simply the activity of demonstrating that all the implemented systems meet, in all respects, the desired functional requirements (Functionalities contract). The Validation consists of two different types, the Technical Validation and the Functional Validation. The Technical Validation is conducted by the Main Contractor and it ensures that everything works properly. The Functional Validation is conducted by the client, RWS, and it ensures that the final product fulfil its initial purpose of use.

### 2.3 The external parties

The external parties, the Main Contractor and the Subcontractors, play an important role in the formation, delivery and fulfilment of the IA requirements of RWS construction projects. In order to acquire an insight into their point of view on this topic some interviews with a few
selected companies were conducted. The contact persons work as managers, consultants and/or directors of strategy in the companies that are mentioned in the following paragraph.

Royal Bam Group is a construction group company and it is one of the basic Main Contractors of Rijkswaterstaat. From the Subcontractors side Royal Imtech was selected. Royal Imtech is an Industrial Automation provider that collaborates often with RWS, acting as a subcontractor.

The market (both the Main Contractor and the Subcontractors) seems to prefer to work with less design freedom. The level of detail of the IA requirements that is provided from RWS to the market is considered to be very low. Rijkswaterstaat forms and delivers their IA requirements with a high level of abstraction. Such a high level of abstraction is not desired from the market since it almost always leads to misunderstandings and failures. It is worth mentioning that the interviewees from both sides, Royal Bam and Royal Imtech, place importance on the fact that RWS should be able to specify exactly what they want to have delivered to them. Moreover, they indicate the existence of a lack of knowledge and expertise in the field of IA within RWS.

Royal Imtech is a company that also collaborates with ProRail and Schiphol Group. ProRail and Schiphol Group are companies that act similarly to RWS, as the client of their projects, and their approach to IA requirements specification and delivery via the contracts has been investigated and is presented (see Chapter 3). The fact that RWS is a governmental company seems to influence the way the external parties act. There is a sense within RWS that whenever an external party collaborates with RWS they do not perform the best they could, but when the same party collaborates with a private company like Schiphol Group they perform much better. From the market’s side the thing that holds true is that there is a different attitude working for the government than working for private companies. A private company like Schiphol Group finances their projects by using their own funds. In this case, no delays or failures are acceptable. If a company like Imtech fails to deliver successfully what e.g. Schiphol Group has requested within the budget and time limit, they will not get compensated for their work. This situation indicates a big loss for companies like Imtech, because they not only lose money, but also exclude themselves from future collaborations with the same client.

On the other hand, working for the government seems to be more beneficial for the market since the government is not so strict with the deadlines. Thus, whenever there is a delay for any reason the external parties can ask for more time, which means that they can also earn more. Furthermore, the fact that RWS lacks the knowledge to specify the IA requirements in more details seems to provide the external parties with an "exit window", which they can use to avoid any penalties in case something goes wrong with the fulfillment of the IA requirements. In short, if the client does not specify his wishes in enough detail, the market
gets the freedom to deliver and end product that is more likely not to fulfil the client’s needs, with an increased final project cost.

### 2.4 Identified Problems

In the first part of this chapter the main approach of RWS to specifying and delivering the IA requirements of its construction projects is investigated and presented. Through the description of the IA contracting chain, the main actors and their relationships are analyzed. Moreover, the most commonly used tools and/or methods that are used for the requirements formation and delivery are also presented.

The above actions both aim to provide a better understanding of the company’s approach and an insight to the most frequently faced problems.

The identification of the main problems and barriers of RWS approach to IA requirements specification and delivering have been mainly recognized through various of interviews with RWS managers, external partners and/or consultants of RWS and last but not least managers from the market’s side. Furthermore, in the following paragraphs an effort has been put in identifying, as much as possible, the inner reasons that cause those problems.

The main identified problems are related to the communication among all parties, some strategic choices of RWS, the lack of knowledge and expertise in the area of IA and the company’s nature itself. At this point it should be mentioned that the majority of the problems occur at several levels. The nature of each problem type has been analyzed in the following paragraphs.

#### Lack of Communication

A highly significant factor that influences the delivered project in terms of quality, time and money is the communication model between all parties of the IA requirements contracting chain (Client - Main Contractor - Subcontractors). A good communication is always required in order to achieve the best possible result.

Several communication problems between different parties that influence the delivered project have been noticed within the IA requirements contracting chain of RWS. Often, there is a lack of communication and a lot of misunderstandings between the client (RWS) and the Main Contractor. Also, communication problems appear within a consortium that forms the Main Contractor party; there are also cases that communication problems occur between a Main Contractor and Sub-contractor(s).

In order to better understand what kind of problems could result from lack of communication a real case example is briefly presented. It has been mentioned before, that there are projects where the Functionalities contract has been delivered to a consortium. In these cases the
consortium is the project’s Main Contractor. But even in the case of a consortium there is always a Civil Engineering Company that is mostly in charge of the project. There was a project where the Main Contractor was a consortium and at some point the Civil Engineering Company decided to change the project’s construction but did not inform the Electrical Engineering Company about the change. The communication was lost between the above stakeholders. In this case, the lack of communication led to the project not being realized. Apart from the aforementioned types of communication problems, sometimes there are problems because of the lack of communication within RWS. In order to understand the reasons that cause this we have to understand the key actors that form each project’s RWS team. Moreover, we should understand each actor’s role and goals about the project.

A Rijkswaterstaat’s project team mainly consists of the Contract Manager (CM), the Surroundings Manager (SM), the Project Manager (PM) and the Technical Manager (TM). The main concern of the Contract Manager is the budget and the timeline of the project. Simply put, the delivered project should be within the initial budget and deadline. The Surroundings Manager has to ensure a good communication and collaboration with the external stakeholders. A Project Manager is the person who is responsible for the final project in all respects. The Project Manager is responsible for making sure a project is completed within a certain set of restraints. These restraints usually involve time, money, people and materials. The project must then be completed to a certain level of quality. His goal is to deliver a good project in the end. Last but not least, the Technical Manager wants to ensure that in the end, the delivered project is going to be a good product as well. He wants to secure that the final product as a whole functions properly and fulfils its purpose of use.

All the aforesaid indicate that the mainly involved managers from RWS’s side in a project do not share the same goals and sometimes the communication among them is not the best. For example, in a lot of cases the Technical Manager delivers comments to the Main Contractor about things of the IA part of a project that need to be changed. However, the latter refuses to change them. The reason for this is that RWS Contract Manager strictly requires from the Main Contractor to deliver the project on time and within a specific budget. So, if there is no good communication among the RWS team, the Main Contractor will follow the instructions of the person who does not request any kind of changes and perhaps has more power on decisions related to the project. Changes cost time and money for the Main Contractor.

All the aforementioned indicate the importance of a good communication among all the parties of the IA requirements contracting chain. A bad communication may lead to a lower final product quality, a higher project cost, a waste of essential time or even to the non-realization of a project. All of the interviewees agree that an improved communication will definitely raise all stakeholders’ satisfaction regarding both to the process and the quality of the end product. Moreover, a better communication would probably lead to less delays and lower project’s costs.
Communication problems between the various stakeholders within the construction industry are not something new. This fact indicates the relationship between the existence of communication problems and the industry’s nature. The construction industry is characterized as a very dynamic and fragmented sector. Every project is unique, in terms of requirements and stakeholders. This means that there is a frequent change of stakeholders’ relationships which is contractually driven. So, it is a cultural issue as well since the nature of the industry itself shows a reality of conflicts and lack of mutual respect and trust.

**Lack of knowledge**

**IA Importance on a civil engineering project**

Based on the interviews’ outcomes and on the observation of many projects’ low quality end product, it can be said with certainty that within RWS there is a lack of knowledge about Industrial Automation and its importance in construction projects. Civil Engineers are not aware of the Industrial Automation part of their construction projects (What is it? Why do they need it? etc.). They feel insecure working with it and the great majority of them do not understand that nowadays Industrial Automation is an essential part of all construction projects. This occurs partly because of RWS’s nature and culture; a civil engineering organization with a long history. The great majority of RWS people are civil engineers who do not have knowledge related to Industrial Automation and do not understand its importance in construction projects. In addition, nowadays there are no experts in the field of Industrial Automation within the company. It is noteworthy that, the last observation has been supported from every external partner/consultant of RWS that has been interviewed.

The participation of Industrial Automation in construction projects has been increased since the 70’s and it is going to increase further in the following years. As in many other construction companies, RWS civil engineers must stop working as they were used to back in the 70’s. All the interviewees agree that RWS managers must learn how to deal and work effectively with the IA part of their construction projects.

**Systems Engineering Working Method**

Lack of knowledge is one of those problems that occur at several levels. The organization in order to increase the efficiency and effectiveness of their projects has decided to implement and work with tools such as the Systems Engineering Working Method. Tools as the aforementioned are considered very useful if they are implemented properly.

Also, in this case there is a lack of knowledge within RWS to work effectively with such methods. Nevertheless, this problem does not only refer to RWS. Many of the external stakeholders of RWS, especially the Civil Engineering companies, are not mature enough to implement the Systems Engineering Process properly. Often, many steps of the V-model of
Systems Engineering are being skipped. This can lead to huge problems, such as time delays of the project, increase of the total cost or even a non-functional final product.

The reality is that in the majority of RWS projects, the Systems Engineering Process is supposed to be followed but it is not. The environment within RWS as in other construction companies is not mature enough to support the implementation of such methods.

More specifically, most of the problems appear during the Development (design) Phase of the V-model (see figure). This happens because of the fact that the Main Contractor usually wants to go directly to the Realization Phase of the project and skip the intermediate steps, despite the fact that SE process is required to be followed in the main contract.

In order to understand the reason why the Main Contractor usually prefers not to follow the whole V-model process we have to look at the identity of the Main Contractor. The Main Contractor, who is usually a construction engineering company, does not thoroughly understand either the importance of IA in construction projects or the fact that IA needs time in order to be implemented in a project and to fulfil the desired requirements. It is also a problem that RWS usually only delivers the Functional Requirements (Functionalities contract) to the Main Contractor. After delivery of the Functional Requirements the Main Contractor is free to act as he pleases. Furthermore, the decisions of the Main Contractor are always driven by profit.

Moreover, the Verification and Validation Process of the V-model is considered to be a very important and crucial procedure. A very important remark that comes from several external Managers and/or external Senior Advisors of RWS in the field of IA requirements of the construction projects is that RWS sometimes underestimates the importance of the designs during the Verification process. In order to secure that the final product meets its deadline, while having fulfilled all its requirements and that the project’s initial budget is not going to be overdrawn, a really good Verification team is needed. Such a team consists of people who are able to see beyond the delivered designs and reports. They must be able to visualize what all the above (designs and reports) mean for the final product. An engineer who works in a Verification team should be able to foresee a problem at an early stage of a project (during the Development Phase). So, if something goes wrong it must be able to be fixed as soon as possible with the least possible cost. In other words a good Verification team could save time and money and that makes it really useful in a project.

**System-Oriented Contract Management Method**

System-oriented Contract Management (SCM) process is a risk based check of deliverables. This process can only work if one has the knowledge of the risk in a project. People in RWS do not have the knowledge within IA and therefore this SCM method does not work effectively.
This conclusion is derived mainly from people who work for RWS as external Technical Managers and/or Advisors.

**Strategic Choice of providing the market with more design freedom**

Another significant factor that seems to influence the delivered project in terms of Industrial Automation is the last years’ decision of RWS to deliver less detailed requirements to the market. The organization has made this choice because they are willing to provide the market with more freedom to come up with innovative solutions. Nevertheless, it should be mentioned that by making this choice, more responsibility is being delivered to the market as well.

Despite the willingness of RWS to give more freedom to the market to act, the market (especially the Main Contractors) seems to prefer the delivery of more detailed requirements. Rijkswaterstaat at the moment mainly delivers the F subcontract (Functionalities subcontract) of Industrial Automation that refers to the desired functionalities of a project/product. They do not deliver to the Main Contractor the A subcontract that refers to the needed automation (processes/software), so the Main Contractor is responsible and free to form and define it.

Rijkswaterstaat used to have the knowledge to form and deliver more details in terms of the Industrial Automation requirements of their projects, but nowadays that knowledge does not exist anymore. So, one reason that they insist on delivering less details to the market is because they do not know how to define and deliver more detailed requirements. As mentioned earlier another reason is the drive of the organization to give more freedom to the market to come up with innovative solutions.

In the case of RWS, the freedom and the responsibility to define and form more detailed requirements in terms of Industrial Automation is being delivered to the Main Contractor which is always a civil engineering company. This indicates that the problem is being transferred because a civil engineering company does not feel comfortable with Industrial Automation requirements specification either. They also do not have the needed knowledge.

Some of the interviewees, especially the external consultants of RWS, support that RWS has to be able to identify the level of detail that should be delivered to the market in each case. When they know exactly what they need for a project they have to be able to deliver more detailed requirements to the market.

**Governmental Influence**

One main difference between RWS and other companies of the Building Industry that act like RWS, as the client of their projects (Schiphol Group etc.), is that RWS is a governmental company. This means that the company must comply with some special regulations that are related to the market and are being formed by the European Union. For instance, RWS cannot
specify what kind of components/elements/systems they need for their projects by their brand-names. It is forbidden by law to request e.g. a SIEMENS Automation System even if they know that this is the exact system they need! They are only allowed to describe the function they need without mentioning any specific brand or company name, since the Dutch Government should not deprive any company of the opportunity to be a stakeholder of a RWS project. The Government’s policy is to work with as little internal recourses as possible. The lesson learned from previous projects is that RWS should check and audit more. Their policy is to reduce recourses and this is conflicting.

This is the reason why Main Contractors or even Subcontractors are not afraid of performing poorly in a RWS project. They are confident that a poor performance will not exclude them from future collaborations with RWS. There are many project examples where an external stakeholder company has delivered a non-functional product, yet they were permitted to start working at another RWS project immediately. The external stakeholder companies always get paid by RWS no matter what they deliver. So, it seems like there is a need for a stakeholders control process.

It should be mentioned that the above situation does not hold true with private companies that operate in a similar manner to RWS e.g. Schiphol Group.

Subcontractors’ Involvement

The Industrial Automation companies act as a project’s subcontractors almost in every case. They are usually delivered a project’s IA requirements at a later phase, which deprives them of addressing any suggestions or concerns regarding to a project’s design. For example, an IA subcontractor might have an idea of integrating an ICT system better into a construction project that could save time and money; but because of the fact that the IA subcontractors usually get involved at a later phase of a project their collaboration with the Civil Engineering companies is lacking. This situation does not provide the IA subcontractors with the opportunity to perform at their best.

Lack of Standardization

Standardization is defined as "A framework of agreements to which all relevant parties in an industry or organization must adhere, in order to ensure that all processes associated with the creation of a good or performance of a service are performed within set guidelines. This is done to ensure the end product has consistent quality, and that any conclusions made drawn are comparable with all other equivalent items in the same class."[16]

It is commonly accepted that standardization has always played a crucial role in the construction industry. For instance, there are technical standards referring to the structural parts of a project and classification standards referring to the functional building elements such as windows, doors etc. Moreover, in the past few years there has been a higher demand
for CAD (Computer Aided Design) standardization in the construction industry since building
information modeling seems to be more essential than ever.

All the above indicate the importance of standardization within the construction industry. When it comes to IA in construction projects there is a high need of having standardized processes and requirements. Perhaps this need is even higher because of the fact that IA in constructions is something relatively new and dynamic compared to the constructions themselves. The lack of IA standardization within RWS creates a lot of problems related to the IA requirements specification. In other words, when what is needed is not known and well-specified it cannot be properly requested from the contractors. An IA standardization in terms of requirements and processes will benefit the projects in terms of time, cost and of course quality.

In Table 4 all the aforementioned identified problems are summarized and presented.

<table>
<thead>
<tr>
<th>IDENTIFIED PROBLEM</th>
<th>PROBLEM’S NATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Communication</td>
<td>between client (RWS) and Main Contractor (MC) within a project’s consortium</td>
</tr>
<tr>
<td>Lack of Knowledge</td>
<td>about IA within RWS about tools/methods as Systems Engineering</td>
</tr>
<tr>
<td>Freedom to the market</td>
<td>delivery of the problem of IA requirements specification the market requires more details</td>
</tr>
<tr>
<td>Governmental Influence</td>
<td>compliance with special market regulations RWS too lenient on external parties that fail to deliver</td>
</tr>
<tr>
<td>Subcontractors’ Involvement</td>
<td>IA suppliers (subcontractors) are involved at a later project’s phase</td>
</tr>
<tr>
<td>Lack of Standardization</td>
<td>no standardized processes and IA requirements</td>
</tr>
</tbody>
</table>

Table 4. Identified Problems related to the Industrial Automation Requirements Specification and Delivery of RWS
3 Other Companies Approaches

The acquisition of an insight into other companies’ approaches to the Industrial Automation requirements specification and delivery is considered an important part of this project. Through this acquisition similarities and differences among the various approaches have been identified and are presented in the following paragraphs.

The selected companies, whose approaches are presented, are ProRail and Schiphol Group. The selection of the companies was made after careful consideration. Both ProRail and Schiphol Group are big construction companies that act as the client of their projects; they deliver their projects’ requirements to their external stakeholders. Especially, Schiphol Group has been selected because there is a sense within Rijkswaterstaat that Schiphol Group has its IA projects under control. It is believed that Schiphol Group performs better than RWS in terms of the IA part of their construction projects. This feeling needed to be investigated.

In this chapter, ProRail’s and Schiphol Group’s approaches are presented. Moreover, the similarities and/or differences between these approaches and RWS’s approach are discussed. The focus is more on Schiphol Group’s approach since this is the one that is different to RWS’s and it seems to be successful.

In order to acquire the needed information a number of interviews were conducted. The interviewees work at ProRail or Schiphol Group as Technical Managers, ICT Consultants, Project Managers, Procurement and Contract Managers or Directors of Corporate Procurement.

3.1 ProRail’s Approach

ProRail is a young, professional organization with years of experience in the management of the Dutch railway network. ProRail is responsible for the rail network of the Netherlands in terms of construction, maintenance, management and security. It is an independent organization with a clear goal: a reliable and safe rail network with sufficient capacity for passengers and freight. They work closely with the government and carriers.[17]

ProRail acts also as the client of their projects. They don’t construct their projects but they deliver each project’s requirements to the main contractors via the contracts. Their usual approach to requirements delivering looks a lot like RWS’s approach. One difference is that ProRail instead of one Main Contractor or a Consortium has always as their Main Contractor a CCL (Combinatie Crommelijn) Consortium. The CCL is the responsible party for enabling various subcontractors. In Figure 17 the usual ProRail’s contracting model of IA requirements is visualized. So, in general ProRail is the responsible party for the formation and delivery of
the Functionalities (F) subcontract to the CCL. Then, the CCL Consortium is usually the main responsible party for the specification and delivery of the Automation (A) and the Techniques (T) subcontracts to the various subcontractors.

Every project has a different CCL consortium. ProRail puts the project in the market and different CCL consortiums apply for undertaking the project. Then, ProRail decides on the best fitted CCL for each project. It should be mentioned that ProRail does not form any CCL.

3.1.1 ProRail’s Identified Problems

As Rijkswaterstaat, ProRail also faces problems with the specification and delivering of IA requirements via contracts. The main identified problems are the following:

1. **Lack of Communication**: Communication problems between the client (ProRail) and the main contractor (CCL) but also between the main contractor and the subcontractors. There is lack of communication within the company as well, since different departments and people are responsible for the construction phase of a project and for its maintenance. A project’s IA requirements refer also to its maintenance phase. This means that in the case that different departments are responsible for different phases of a project’s life cycle they should collaborate effectively, otherwise there are a lot of problems during the maintenance phase and that costs more money and time.
2. **Lack of knowledge**: The same problems as in RWS’s case seems to take also place in ProRail’s one. There is a lack of knowledge and expertise within ProRail on IA requirements specification and delivering.

3. **Freedom to the market**: ProRail has also taken the strategic choice to provide the market with more freedom. As in RWS’s case this means that the main responsibility of the IA requirements’ specification is delivered to the market and more specifically to the Main Contractor. This creates the same problems as in RWS’s case (see 2.4).

4. **Governmental Influence**: ProRail also has to follow specific regulations related to the market since it is a government task organization.

5. **Lack of Standardization**: ProRail faces also the problem of no standardization in terms of IA requirements and processes.

It is worth mentioning that both ProRail’s approach and RWS’s approach to delivering the IA requirements share more or less the same barriers.

At this point it should be highlighted that IA requirements’ specification and delivery via contracts refers to the whole life-cycle of a project. This includes not only the requirements that are related to the realization of a project (Construction Phase), but also the requirements related to the maintenance phase of a project.

ProRail faces many problems during the maintenance phase of their projects, in terms of the IA part. Lack of knowledge and expertise on the specification of a project’s IA requirements combined with the absence of any contracts’ and requirements’ standardization are the source of the above problems. For instance, when a problem occurs during the operating and maintenance phase of a project, in the majority of the cases it takes much more time to fix it. This has negative effects in terms of time, cost and the provided service.

3.1.2 **ProRail’s Answer to the Problem of IA Requirements Delivering: Spoorzone Delft Project**

In an effort to solve the problem, ProRail decided to assign the task of IA requirements specification and delivering to a consultancy office/company that has the required knowledge to provide them with solutions and/or different approaches.

So, in the Spoorzone Delft Project (Railway Zone Project in Delft), Covalent was involved as the external consultancy office. Covalent had to take care that the delivered project, in terms of IA, would have the desired quality.

In the Spoorzone Delft Project the following approach was followed. ProRail as the client formed and delivered the Functionalities (F) subcontract to the already chosen CCL (project’s
main contractor) consortium. For instance, one (F) that could have been asked is: "I need to have this quality of air inside the tunnel". After the (F) subcontract was delivered to the CCL consortium, the CCL through a "high level design" translated the (F) into the needed technical installations (e.g. for the above (F) I will need 40 ventilators).

Up until this point of the new procedure nothing new has been introduced to the usual procedure of delivering the IA requirements. In order to better define the required installations and to better control the IA requirements delivery to the subcontractors, the so-called "Alliantie" was formed. Alliantie is a collaborative team that consists of two parties, the CCL (main contractor) and ProRail (the client). ProRail was represented by Covalent. The first thing that Alliantie did was to work on the "high level design" that had been prepared by the CCL in order to improve it in terms of IA (e.g. It is better to use 35 bigger ventilators instead of 40 smaller ones). Afterwards the Automation (A) and Techniques (T) subcontracts were formed and delivered to the subcontractors (IA suppliers) by the Alliantie. In this case it can be noticed that Alliantie acted as the client of the subcontractors.

So ProRail created and delivered the Functional Requirements of the project (F) and Alliantie was the main responsible party for the formation and delivery of the Automation (A) and Techniques (T) subcontracts. Moreover, Alliantie took care of the interaction and integration of the IA systems. This procedure is shown in Figure 18.

Through this approach ProRail (the client) takes part in the whole process of delivering the IA requirements to all their external stakeholders. The added value is that the client can better control the main contractor in terms of specifying and delivering the (A) and (T) requirements to the subcontractors. Subsequently, there is less room for mistakes and misunderstandings from the contractor’s side. In the end, ProRail can be sure that their actual IA requirements have reached their subcontractors. Last but not least is the fact that via the above approach the communication between all parties is also being improved. Good communication between all parties could prove really important in crucial moments.

In the Spoorzone Delft Project, in order to secure the quality of the delivered project, another innovative action took place. After having delivered the (A) and (T) requirements to the subcontractors and before implementing and integrating them into the final project, Covalent suggested and introduced a real situation model test. The IA components (ICT and technical equipment) that the subcontractors suggested in order to fulfil the (A) and (T) requirements were tested under real operational conditions using models that had been created inside a room (small-scale models) and not at the project’s site. They actually conducted an IFAT (Integration Factory Acceptance Test), which is also called FIT (Factory Integration Test).

Through the above intervention the delivered components can be tested before their final implementation into the project. So, if there are any mistakes, or the delivered components do not fulfil the client’s requirements, the shortcomings can be identified and corrected
before the delivery of the project. These integration tests via models may cost some additional money in the beginning but in the end they save more money and time as well.

ProRail’s choice, to hire advisors from an external company (Covalent), raises the following questions:

- Is ProRail going to cooperate with external knowledge holders for every project in order to solve their IA requirements delivering problems?

- Is it better for the company to invest in the creation of a specialized team in the IA requirements delivering and IA components testing?

The above questions are proposed for future investigation from managers that work in ProRail, in order to determine whether hiring external advisors is the most cost-effective method.
3.1.3 ProRail’s Future Direction

ProRail has also recognized the problems they face in the area of IA and that there is a need to change. Furthermore, hiring external advisors or companies in order to deal with the IA part of their projects is not considered as a long-term solution. They are also in a transition phase trying to achieve the following basic goals:

- Acquire knowledge and expertise in the area of IA requirements’ specification and delivery via contracts to the market
- IA Contract Standardization (including also Requirements Standardization)
- More control over the end result of their products

They also want to be able to deliver requirements via contracts directly to the ICT companies, which are usually the subcontractors. This leads to a problem; the ICT external stakeholders are usually small companies. So, in case that something goes wrong and they do not perform well, they cannot afford any kind of penalties. The aforementioned is the reason why the ICT companies usually act as a project’s subcontractor and not main contractor.

A solution could be for the client (ProRail in this case) to also deliver subcontracts to the market. This way the ICT companies are still a project’s subcontractor but they have a contract directly with the client. On the other hand, this indicates a larger involvement of the client in the project and a more detailed requirements specification.

It is clear enough that this is a strategic choice of a company and must be analyzed and evaluated properly before its implementation.

All the aforementioned goals need time to be achieved successfully. A Standardization of projects’ requirements according to their type is required in order to control and guarantee a high level quality, in terms of IA, during the whole life-cycle of a project. ProRail has started working towards this direction. The development of Tunnel’s Standardization is just the starting point of this effort. The idea is to develop the Basic Specifications of an ideal tunnel. This will provide a well-structured Tunnel Requirements Specification archive that will be used as the reference for the development of any future tunnel. Moreover, through this effort the required knowledge and expertise will be developed within the company.

3.2 Schiphol Group’s Approach

Schiphol Group is an airport company and its main activity area is the operation of Amsterdam Airport Schiphol. It is a company related to the Built Environment with a range of construction projects from terminals, gates, runways to office buildings and hotels that are located in the greater area of the airport.
In Schiphol Group’s construction projects there is a lot of Industrial Automation involved (Lighting Systems, Safety and Security Systems etc.). The company also acts as the client of their projects, like RWS does. They define and deliver their projects’ requirements to their external stakeholders via the contracts. This means that the company does not purchase or construct any kind of components (building components, ICT, Industrial Automation etc.). Instead, they cooperate with external stakeholders and deliver their projects’ requirements to each one of them.

In comparison to RWS, Schiphol Group does not face the problem of being delivered a final product poor in quality in terms of Industrial Automation. It seems like Schiphol Group has developed a robust contracting chain system in order to specify and deliver their projects’ IA requirements to their external stakeholders. Through that approach they have managed to secure that every project is delivered with the desired quality in terms of Industrial Automation.

Schiphol Group’s approach to IA requirements specification and delivering is characterized by modularity since the followed approach differs every time according to the project’s cost. The projects are divided into small scale (cost less than 5.000.000 €), medium scale (cost between 5.000.000 € and 10.000.000 €) and large scale (cost more than 10.000.000 €) projects. The different IA project categories of Schiphol Group according to the cost are shown in Figure 19.

Before analyzing Schiphol Group’s modular approach to IA requirements specification and delivery some important information about the company’s structure should be mentioned. Schiphol Group has developed an internal procedure to specify in the best possible way the Industrial Automation requirements before they deliver them to the Contractors.

Schiphol Group has developed very robust teams within the company. Among them are PLUS, the ICT Team and the Procurement Department. PLUS is a civil engineering company owned by Schiphol Group and in general, PLUS is the responsible party for the static part of the projects. They take care of the civil engineering requirements of the projects. The ICT Team is one of the most robust teams within the company since Schiphol Group has identified the importance of IA in their projects and they have decided to invest a lot on ICT knowledge and expertise. They always take care that they have the right people with the needed expertise within this team. The ICT Team is the responsible party for the dynamic part -the IA part- of Schiphol Group’s projects. Moreover, there is also the Procurement Department that consists of very specialized people, who have the knowledge to run projects -especially the large scale ones- successfully.
In the following paragraphs Schiphol Group’s working methods according to the cost scale of a project are presented.

### 3.2.1 Small Scale Projects

In cases of projects that cost less than 5,000,000 € the fulfillment of the project’s Industrial Automation requirements is undertaken by the company’s ICT Team. They only form and deliver some contracts to IA equipment companies (ICT hardware suppliers) in order to get the needed equipment (hardware). Thus, in this case only the Techniques (T) subcontract is delivered. The contracting chain of this case is shown in Figure 20. This situation indicates the capability of Schiphol Group to not only specify and deliver the Industrial Automation requirements successfully, but also to fulfill those requirements in smaller scale projects.
3.2.2 Medium Scale Projects

Medium scale projects are those whose cost ranges between 5,000,000 € and 10,000,000 €. It has been mentioned that Schiphol Group has its own Civil Engineering Company, named PLUS. In medium scale projects PLUS has a dual-purpose. PLUS is the responsible party to deliver all kinds of requirements to the market and at the same time takes care of the coordination and the management of the whole project. They have to secure that in the end, all of the project’s requirements have been fulfilled.

PLUS is a Civil Engineering Company, thus they do not have the required knowledge to specify correctly the Industrial Automation requirements of a project. In order to solve this issue Schiphol Group has formed an internal ICT Team, which is responsible to form these requirements and deliver them to PLUS. Only then, PLUS can deliver the Industrial Automation requirements to the Main Contractor.

Moreover, Schiphol Group has decided to be more involved in the Industrial Automation requirements specification and not leave too much freedom to the market. They came up with this decision in order to better control and secure the final quality of their products. This explains why Schiphol Group forms and delivers to their external stakeholders not only the F (Functionalities) subcontract but also the A (Automation/needed software) subcontract.

So, as we can see in Figure 21, Schiphol Group delivers the project’s Basic Requirements to the ICT Team. Then, the ICT Team specifies the Industrial Automation requirements of the project—both the Functionalities and the needed software/processes—and they deliver them to PLUS. Finally, PLUS delivers all kind of requirements to the Main Contractors including the ones of Industrial Automation.

Furthermore, Schiphol’s Group policy is that for projects with a cost ranging from 5,000,000 € to 10,000,000 € they collaborate with standard external stakeholders. The Main Contractor of a project is a Consortium that usually consists of two companies. One Construction Company, which is always the VolkerWessels Bouw (VWBouw), is responsible for the project’s structural components. VWBouw is the party of the Consortium that is in charge of the project. The second company that is part of the Consortium is the Automation Company. There is a small list of possible companies. It could be Cofely, Siemens or Imtech.

So, as illustrated in Figure 21 and Figure 22, PLUS delivers the F (Functionalities) and the A (Automation) subcontracts directly to the Automation Company. Then, if needed, the Automation Company forms and delivers the T (Techniques: refers to the needed Hardware/ the IA equipment) subcontract to the Subcontractor/s.

At this point it should be mentioned that Schiphol Group have contracts with all the external parties. Thus, there is no need to communicate with the Automation Company through the VWBouw (the Civil Engineering Company).
Figure 21. Schiphol’s Group Industrial Automation Contracting Chain of Medium Scale Projects

Figure 22. Schiphol’s Group Industrial Automation Contracting Chain for medium scale projects
3.2.3 Large Scale Projects

For projects with a cost higher than 10.000.000 € (large scale projects) Schiphol Group put the project in the market in order to get the best fitted solution from every point of view. In these cases the formed Consortiums -the external stakeholders- differ from project to project. The specification and delivery of the IA requirements of large scale projects has two phases:

1. Consortium Selection Phase
2. Contracts Realization Phase

Consortium Selection Phase

During the first phase the project, along with its Functional Requirements, is put in the market in order to select the best fitted consortium. The best fitted consortium is the one that seems to meet the client’s -Schiphol Group- needs better. Before putting a project in the market the project’s requirements must be specified. PLUS, the civil engineering company, within Schiphol Group, takes care of the requirements specification of the project’s static part. Schiphol Group’s ICT Team takes care of the requirements specification of the project’s dynamic part (the IA requirements). In this phase the ICT Team specifies the project’s Functional Requirements (F). Thus, Schiphol Group, in cases of large scale projects, they first put the project in the market having delivered only the Functionalities (F) subcontract. Apart from the IA Functional Requirements, Schiphol Group also delivers a case to the market and asks for the following:

- What kind of ICT equipment and Architecture is needed in order to fulfill the case’s requirements?
- What is the best type of logistics system to be used in this case?

Afterwards, the market replies. The market consists of four different consortiums. Each consortium comes up with its proposal and solutions. In order to decide which the best fitted
consortium for a specific project is, Schiphol Group evaluates and scores its consortium according to the presentation, the proposed design solutions and the pricing. In the end, the best score wins and the project’s external stakeholders are selected. In Figure 23, the aforementioned procedure is presented.

It is worth mentioning that Schiphol Group triggers the market to come up with innovative ideas through the delivered case. The ICT Team has the knowledge to specify in more detail what they want and almost in every case they know which the best design solution is for them. Nevertheless, they choose to ask the market to come up with their ideas in order to better evaluate them and select the optimal party out of the four. After the selection of the best fitted consortium, Schiphol Group follows the same approach as in medium scale projects; they deliver the Functionalities (F) and the Automation (A) subcontracts to the IA Main Contractors. Then, the IA Main Contractors, that in case of Schiphol Group are always ICT companies, form and deliver -if needed- the Techniques (T) subcontract to the Subcontractors. In Figure 24, Schiphol Group’s approach to delivering the IA requirements of their construction projects is summarized and presented. It includes the approach to small and large scale projects.

Moreover, in Schiphol Group there is a hierarchy of responsibilities that really helps avoid misunderstandings between a project’s different managers. The Procurement Department is occupied with people who have the needed knowledge on how to run big projects. They are
responsible for the final decisions on a project. Nevertheless, in order to guarantee a smooth and effective collaboration with all the different internal parties of Schiphol Group, they team up with them before the delivery of any kind requirements. For instance, before delivering any kind of requirements to the market the Procurement Department communicates with PLUS and the ICT Team in order to check the cost-effectiveness of the requirements. This way a project’s requirements are specified in the best possible way. In Figure 25 the internal collaboration among Schiphol Group’s different teams and/or departments is presented.

![Diagram of internal collaboration in Schiphol Group](image)

Figure 25. Internal Collaboration of teams in Schiphol Group

### 3.2.4 Main Differences between Schiphol Group’s and RWS’s Approaches

The main differences between RWS’s and Schiphol’s Group approach to delivering Industrial Automation requirements of construction projects have been identified and are presented:

1. **Communication**: An important key factor of having a successful end product with all its requirements fulfilled and all the involved parties being satisfied, is good and constructive communication. The Systems Engineering Method is not enough by itself to guarantee the best possible quality of the delivered project. Schiphol Group knows the importance of good communication among all parties. In order to guarantee it, they make a Team Coordination Agreement with every external stakeholder. The
Team Coordination Agreement secures a good level of communication among the involved parties in a project (client, Main Contractor/s, Subcontractors). The main responsible party from the external stakeholders’ side, which secures the honoring of the above agreement, is always the Civil Engineering Company (e.g. VWBouw). Moreover, once a week or once every two weeks Schiphol Group holds meetings, where each party participates actively. The purpose of those meetings is to keep everyone informed about the project’s evolution. Every party is aware of the other stakeholders’ identities and their responsibilities and goals in the project. This creates an environment of trust among all the stakeholders that improves the collaboration and benefits the end product. A good communication and collaboration among the client, Schiphol Group, and its external stakeholders is not enough. Every project has different managers from the Schiphol Group side (Project Manager, Technical Manager, Procurement Manager etc.). Each of those managers has different goals regarding to a specific project and possibly hopes of personal advancement through his/her involvement in the project. A constructive communication among the above managers is totally essential for the success of a project. In order to avoid conflicts and misunderstandings between the different managers, Schiphol Group has decided that the Project Manager and the Procurement Manager of a project must always agree on an issue before a decision is made.

2. Schiphol Group has contracts with all of their external stakeholders. The IA companies act as Main Contractors. The Industrial Automation contracts are made among the client -Schiphol Group- and the Industrial Automation companies. There is no need to reach the IA stakeholder through the civil engineering one as it usually happens in RWS’s approach. This helps achieve an effective communication between the client and its external stakeholders.

3. Schiphol Group seems to have a long-standing cooperation with Main Contractors, companies like VWBouw, Cofely, Siemens, etc. The above situation creates an environment of trust among all the parties and makes their collaboration easier. A good collaboration and communication among different stakeholders always benefits the end result of a project.

4. **Knowledge:** There is no lack of knowledge in the area of Industrial Automation within Schiphol Group. Schiphol Group invests a lot in ICT knowledge and expertise. There is a robust ICT Team that is able to specify a project’s Industrial Automation requirements successfully. In addition, this internal ICT Team is able to fulfil the Industrial Automation requirements at small scale projects. Last but not least is the fact that this team has the required knowledge and expertise to challenge the market (the external parties) to come up with innovative ideas and design solutions.
5. Implementation of the Systems Engineering Method: Schiphol Group requests, as RWS does, from their stakeholders to apply the Systems Engineering Method to their projects (implementation of the V-model). As it is known, the Systems Engineering Method works effectively for a project only when all the steps of the method are followed. Schiphol Group knows that and this is why they control the whole procedure, taking care of the right implementation of the model in all of their projects.

6. Freedom to the market: Schiphol Group is more involved in the specification of the Industrial Automation requirements. They always form and deliver the F and A subcontracts to their external stakeholders. In order to gain better control and guarantee the final quality of their products they have decided to leave less freedom to the market.

7. Governmental Influence: Schiphol Group is a private company so they do not have to follow the same market regulation as Rijkswaterstaat has to do. They even have the freedom to request specific brand names. For instance, if they know that they want to use a specific system from SIEMENS they can simply ask for it. Rijkswaterstaat cannot do the same. Moreover, the fact that Schiphol Group is a private company makes them stricter with the market in case of failures. They do not hesitate to impose penalties to companies that do not fulfill the projects requirements or even to exclude companies from future collaborations.

8. Subcontractor’s involvement: In Schiphol Group’s approach the IA companies act always as a project’s Main Contractors. This indicates a more immediate involvement of the IA companies in a project. Nevertheless, sometimes there is a need for a Subcontractor to be involved. In these cases the Subcontractor usually is an IA hardware supplier and this does not affect the approach.

9. Standardization: Schiphol Group seems to have standardized the IA requirements and processes.

10. Schiphol Group has identified that, nowadays, Industrial Automation plays an important role in construction projects. For this reason approximately 20% of the initial budget of a project is invested on Industrial Automation. This percentage is much higher than the case of Rijkswaterstaat.
4 Conclusions

Through this investigation the project’s main objectives were fulfilled. Rijkswaterstaat’s and other companies’ approaches (ProRail and Schiphol Group) were investigated and presented in the respective chapters (see Chapter 2 and Chapter 3). The problems of RWS’s approach concerning IA requirements specification and delivering have been identified and analyzed. Moreover, similarities and differences between RWS’s approach and other companies’ approaches (ProRail and Schiphol Group) have also been presented.

In Table 5 the identified problems of RWS’s approach are summarized and presented.

<table>
<thead>
<tr>
<th>IDENTIFIED PROBLEM</th>
<th>PROBLEM’S NATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Communication</td>
<td>between client (RWS) and Main Contractor (MC)</td>
</tr>
<tr>
<td></td>
<td>within a project’s consortium</td>
</tr>
<tr>
<td></td>
<td>between Main Contractor (MC) and Subcontractor (SC)</td>
</tr>
<tr>
<td></td>
<td>among RWS managers</td>
</tr>
<tr>
<td>Lack of Knowledge</td>
<td>about IA within RWS</td>
</tr>
<tr>
<td>Freedom to the market</td>
<td>delivery of the problem of IA requirements specification</td>
</tr>
<tr>
<td>Governmental Influence</td>
<td>compliance with special market regulations</td>
</tr>
<tr>
<td>Subcontractors’ Involvement</td>
<td>IA suppliers (subcontractors) are involved at a later project’s phase</td>
</tr>
<tr>
<td>Lack of Standardization</td>
<td>no standardized processes and IA requirements</td>
</tr>
</tbody>
</table>

Table 5 Identified Problems related to the Industrial Automation Requirements Specification and Delivery of RWS

In order to compare ProRail’s and Schiphol Group’s approaches to Rijkswaterstaat’s the following tables were developed. In general, ProRail’s approach seems to face more or less
the same problems as Rijkswaterstaat, while Schiphol Group’s approach seems to be more effective since they do not face any problems with their projects’ IA part.

In Table 6 ProRail’s identified problems and their nature are presented. In order to create a common basis of comparison among the different approaches, the categories of the problems are kept the same with those that are identified in RWS’s approach and their nature has been investigated. Nevertheless, the possible existence of additional problems in other companies’ approaches was also investigated; no additional problems were identified.

<table>
<thead>
<tr>
<th>IDENTIFIED PROBLEM</th>
<th>PROBLEM’S NATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Communication</td>
<td>between client (ProRail) and Main Contractor (MC-CCL)</td>
</tr>
<tr>
<td></td>
<td>between Main Contractor (MC-CCL) and Subcontractor (SC)</td>
</tr>
<tr>
<td></td>
<td>among ProRail’s managers</td>
</tr>
<tr>
<td>Lack of Knowledge</td>
<td>about IA requirements’ specification</td>
</tr>
<tr>
<td>Freedom to the market</td>
<td>delivery of the problem of IA requirements specification</td>
</tr>
<tr>
<td></td>
<td>the market requires more details</td>
</tr>
<tr>
<td>Governmental Influence</td>
<td>compliance with special market regulations</td>
</tr>
<tr>
<td>Lack of Standardization</td>
<td>no standardized processes and IA requirements</td>
</tr>
</tbody>
</table>

Table 6. Identified Problems related to the Industrial Automation Requirements Specification and Delivery of ProRail

The reasons why the problems RWS faces in their projects are not found in Schiphol Group’s approach have been investigated. It turns out that Schiphol Group’s actions during projects, differ to those of RWS in many areas. These actions are basically the main differences between RWS’s and Schiphol Group’s approaches. In Table 7 these differences are summarized and presented as Schiphol Group’s answers to RWS’s identified problems. For more details the identified differences are analyzed in section 3.2.4.
<table>
<thead>
<tr>
<th>IDENTIFIED PROBLEMS IN RIJKSWATERSTAAT</th>
<th>SCHIPHOL GROUP’S APPROACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Communication</td>
<td>Team Coordination Agreement</td>
</tr>
<tr>
<td>Lack of Knowledge</td>
<td>invest a lot on IA/ICT knowledge</td>
</tr>
<tr>
<td>Freedom to the market</td>
<td>delivery of less freedom to the market</td>
</tr>
<tr>
<td>Governmental Influence</td>
<td>no compliance with special market regulations</td>
</tr>
<tr>
<td>Subcontractors’ Involvement</td>
<td>IA companies act as a Main Contractor</td>
</tr>
<tr>
<td>Lack of Standardization</td>
<td>standardized IA requirements and processes</td>
</tr>
</tbody>
</table>

Table 7 Schiphol Group’s Answers to Rikswaterstaat’s Identified Problems

From the whole investigation the following conclusions are drawn:

1. Rijkswaterstaat does not have its IA projects under control. Thus, there is space for improvements.

2. Rijkswaterstaat suffers from lack of knowledge in the area of IA requirements specification.

3. Most of the people who work in RWS are not aware of the importance and benefits of IA in construction projects. The fact that most of the people who work in RWS are civil engineers in combination with the company’s identity as a construction organization gives to the whole problem a cultural aspect as well.

4. The strategic choice of delivering more freedom to the market is not in balance with the market’s wishes. The market requests to be delivered more details from the client (RWS).
5. The lenience of RWS towards insufficient performance of companies (contractors) and even non-functional delivered products has cultivated the following attitude in the market: "Working for Rijkswaterstaat (the government) is more beneficial. More money can be earned and in case of failure there is no danger of receiving severe penalties and future collaborations are not threatened."

6. The contract management of IA projects is weak since in case of failures contractors easily find "exit windows" in order to avoid any kind of penalties.

7. Rijkswaterstaat lacks the ability to learn from its failures and mistakes regarding to the IA part of their construction projects.
5 Recommendations and Suggestions

It is high time that Rijkswaterstaat started learning from its mistakes and moved towards an era where its IA projects are under control. To achieve this, a set of measures is recommended in order to be implemented. The following recommendations are a result from this project’s whole investigation. Moreover, they are closely interrelated and should be viewed as a total package of measures for Rijkswaterstaat to adopt. In the author’s opinion, if the recommendations are implemented selectively and not in their entirety, the mistakes of the past will be repeated. Instead, the company would continue facing the same problems and yet more public money would be wasted.

An effort has been put into recommending realistic measures that would not cost a lot in terms of money to the company. However, it has been realized that the implementation of the following measures would cost a lot in terms of effort from RWS’s people.

5.1 Recommendations

The following measures are recommended in order to overcome the identified problems of RWS’s approach to IA requirements specification and delivering. Some of these measures help to overcome more than one problem. In the next paragraphs the recommended measures are presented, divided into categories according to which problem they mainly aim to solve.

Lack of Communication

1. **Project Hierarchy**: The roles and responsibilities of each RWS’s manager within each project must be clearly defined. There is a need of a clear project hierarchy in order to improve the communication among the different RWS’s managers. Everyone should know who the decision-maker is and what the decision is. Through this measure any kind of misunderstandings and/or even conflicts that may lead to failures will be avoided. Moreover, it will be clearer for the external parties to recognize the responsible persons in each situation.

2. **Transparent Project Culture**: There is a need of developing an environment of trust among the different parties (client, main contractor, subcontractors) that are involved in each project. In a transparent project culture there is space for trust. In order to achieve this the following measures must be taken:
• Each project has unique features. For this reason, in the beginning of each project the responsibilities of each party and the project’s aim must be clearly defined. Rijkswaterstaat’s projects share, approximately at 90%, common features. This 10% of different features provides them with uniqueness. By determining a project’s aim, the regular/common and new/unique features are defined.

• Team Coordination Agreement: We saw that there is lack of communication between a project’s different parties and this influences the end product significantly. The client, Rijkswaterstaat, has to force the dialogue among all the involved parties. As at Schiphol Group’s approach, Rijkswaterstaat has to request from all their external stakeholders to sign a Team Coordination Agreement. According to this agreement, regular -weekly- meetings will be held close to project’s location (if it’s possible, otherwise at a RWS’s central building). Each party (client, main contractor, subcontractors) will send a representative, a person who works in the project and has specific responsibilities. The aim of these meetings is to keep everybody updated about the project’s current status. In case of micro-scale changes or problems all the parties are informed and they work as a team in order to overcome any barrier and complete the work as planned. Furthermore, if any member (party) of the team is not confident that he can perform/deliver on time, he is expected to be honest and open about the situation, so the team can work on the problem and solve it. It is important to always have the meetings at the same place -or even room- with the same persons. This will help to cultivate the environment of trust and make the participants feel part of the same team.

By cultivating an environment of trust, the communication and collaboration between the different parties is improved. More specifically, by implementing a Team Coordination Agreement an information stream about a project’s activities is created. This could prove crucial for the end project’s quality and cost since it helps avoid redesigning, late discovery of errors, delays in decision-making etc.

3. Integration of Disciplines: It is known that the various technology-related disciplines in construction projects such as Civil Engineering and IA historically have formed differently having their own methods and standards. It seems that nowadays there is a need for integration of the above disciplines in order to carry out more effectively today’s multidisciplinary construction projects.

This means that both RWS and the market must learn to work in a more integral way. Unfortunately, you cannot force the market to adopt a more integral working method, but you can demonstrate to the market what the benefits of working in such a way are. In order to do this you have to first start from yourself, since you cannot request anything you are not knowledgeable about. Rijkswaterstaat has to develop an integrated approach between all disciplines in the design and realization of its
products. This could be achieved through a series of workshops where people from the Civil Engineering and Installations and Operations departments will participate. The later department is the responsible one for the IA part of RWS’s projects. People who work as Technical Managers must also be involved in these workshops since they are responsible for keeping an overview of the project. Technical Management stands for quality and safety and is interconnected to other disciplines, processes and of course people.

The above process is considered as a long-term one and it is suggested to be divided in 3 phases. Every phase has its own goal:

- **Phase I**: Raise awareness about the need for working in a more integral way and obtain a better understanding of each discipline and its role in multidisciplinary projects. The above will help with making more integral choices and prevent wrong decisions and/or misunderstandings.

- **Phase II**: Develop a modular, integral working method that with small adjustments will fit to any type of project (tunnels, bridges etc.). The development of this method could be realized by a trial-and-error process in an ideal case.

- **Phase III**: Implement the previous case’s working method in a real time small-scale project in order to find any "weaknesses" and improve it.

The developed working method must not be considered as static, but as dynamic. This means that from project to project it can be slightly modified. Moreover, by its implementation into projects there is always room for improvement. Mainly responsible for organizing these series of workshops, are people who work at the relevant departments.

At this point, it should be mentioned that Rijkswaterstaat has already recognized the importance of linking the disciplines of Civil Engineering, Industrial Automation and Technical Management. The departments of Installation and Operations (Installaties en Bediening) and Civil Engineering have taken the initiative to organize a workshop that aims to raise awareness about each discipline and to create the path of working in a more integral, multidisciplinary way. The series of this workshop took place during autumn of 2014. Rijkswaterstaat’s workshop seems to be in accordance with Phase I. Thus, it is recommended to continue with Phase II and III, because just raising awareness will not lead to the desired outcome.
Lack of Knowledge

The problem of lack of knowledge about IA and working methods such as the Systems Engineering has been identified both in RWS and in the civil engineering companies that act as a Main Contractor. Here applies also the principle that you cannot request anything from the market, if firstly you do not have the proper knowledge about what you are asking for. Rijkswaterstaat does not have sufficient in-house knowledge about IA and its requirements specification and has to invest in bringing the needed knowledge in-house. It does not matter how much design freedom, how much detail is RWS willing to provide with the market; in every case the organization must have the knowledge about IA requirements specification.

4. Social Innovation: Apart from the well-known technological innovation there is also the social innovation. Social Innovation focuses attention on the ideas and solutions that create social value; it links the technology with its societal value. Most of RWS’s employees are not aware of what IA is and its importance in construction projects. Consequently, there is a need for raising awareness about IA and its economic and societal value. The benefits resulting from IA and ICT technologies in construction projects should be demonstrated within the organization. This demonstration could be achieved through various ways. Some ideas are the following:

- Informational flyers, videos and articles about IA in RWS’s projects and its importance
- Lunch lectures in different departments (one per month or every two months) with people who work closely to the IA part of RWS’s projects. The aim is to raise awareness about the above and have and open and constructive dialogue with people from different disciplines and with different mindsets.

5. Internal IA education program: Introduce an internal, well-structured IA education program for project managers and project leaders within Rijkswaterstaat. Make it compulsory for every RWS’s manager and make it permanent in RWS’s internal training program. The program could be divided in two levels as it follows:

- Level I: Provides the participants with the basics about IA, its role in RWS’s projects and its interconnection to the other disciplines. This level should be followed from every manager within Rijkswaterstaat,
- Level II: Provides the participants with knowledge and a basic traineeship about tools and/or working methods that are related to the IA part (e.g. Implementation of the V-model of Systems Engineering etc.). This level should be followed from people who work in the specific area of IA within RWS (technical managers, ICT engineers, IA specialists etc.) and have to work with such tools.
6. **Community of Practice (COP):** In the author’s opinion, hiring other parties (companies that have the needed expertise) to handle the IA requirements should not be considered as a long-term solution. Rijkswaterstaat has to invest in bringing back the needed knowledge and expertise about IA and its requirements specification in-house. The main question is how will the needed knowledge be developed within the organization in a cost-effective way?

The answer is through the establishment of a Community of Practice (COP) within Rijkswaterstaat. This COP is considered to be a robust IA team that will bring the desired change in the field of IA within Rijkswaterstaat. The persons that will form the COP are recommended to be independent experts -persons who are not permanent employees of RWS- in order to guarantee a work independent from personal goals. The best option is to hire the external advisors/consultants and technical managers, who RWS is already collaborating with, in order to form the COP. These people are the right choice, because they know RWS’s IA projects and their problems, but they also know the market and its rules. This COP will work in three phases with the ultimate goal to bring order in RWS’s IA projects. During each phase the following activities will take place:

- **Phase I: Creation of a Project Portfolio.** This consists of the identification of the most repeated mistakes that had led to failed projects. Any kind of common factors of failure between different projects will be identified and categorized. Moreover, the most problematic collaborations with external stakeholders will be identified. A stakeholders record with their performance will be developed in order to be used properly in future collaborations. From now on, an external stakeholder’s past performance should be taken into account.

- **Phase II: Development of the Freedom Matrix.** The idea is that RWS has to be able to judge the level of its involvement in IA requirements specification in every project. Every project has unique features and has to be evaluated properly in order to define the level of freedom that will be delivered to the market. By identifying those parameters that influence the level of involvement a modular matrix will be developed. For instance, one parameter could be an external partner’s past performance. If with a specific partner past collaborations were problematic this indicates that the client, RWS, has to deliver less freedom to them in order to keep under control the quality of the end product. On the other hand, in case of good record of past collaborations RWS can take the risk, which is smaller, to deliver less details (more freedom) to the market. The developed working method will be tested in real-time projects and through a project-learning procedure will be improved and finalized.
• Phase III: *Rijkswaterstaat in action*. Rijkswaterstaat’s managers will be involved in this phase, and they will be taught to work according to the working method that the COP will have developed. Rijkswaterstaat’s managers will get more and more space to work from project to project and the COP’s members will supervise and guide them. The COP will come to an end only when it has been secured that RWS’s people are able to define the company’s level of involvement in requirements specification effectively and that they have the needed knowledge to specify the IA requirements. Furthermore, RWS’s managers should also have the ability to examine the delivered products in terms of requirements fulfillment. Through this procedure there will be people who grow to understand the working methods and RWS’s philosophy. These people will become leaders and teach others to work in the same way.

7. Ensure that RWS employs an adequate number of high-quality IA experts.

**Freedom to the market**

On one hand, Rijkswaterstaat wants to deliver more design freedom to the market in order to come up with innovative ideas. On the other hand, the market wishes to be delivered with more details in terms of requirements specification. This happens because delivering more design freedom means that more responsibility is being delivered to the market and this is not desired. There is no need to go back to the past and specify everything, but RWS needs to listen to the market and to adjust. A lesson that can be learned from Schiphol Group’s approach is that they have chosen to deliver less freedom to the market in order to control and guarantee that their projects will meet their requirements.

In Rijkswaterstaat’s case what is recommended is that the company must be able to judge the level of its involvement in IA requirements specification in every project. The achievement of this is presented in measure 6.

**Governmental Influence**

The nature of RWS cannot be changed. It is a governmental company that has to comply with special market regulations. The thing that can change is the lenience of RWS towards the market. External stakeholders must not be able anymore to get advantage of the lack of action by RWS in cases of default delivered projects.

8. **Redefine the contracts**: The contracts must be redefined in order to make them more concrete for the external partners and more useful to Rijkswaterstaat. The parties that fail to perform must not be able to find "exit windows" in the contracts in order to avoid penalties.
9. **Include exit clauses in the contracts:** Exit clauses from now on should be considered as a permanent and basic element of a RWS’s contract. They aim to provide RWS with the right to stop bad collaborations that would not lead to the desired result as soon as they are identified.

10. **Value specification:** Specify what creates value as seen from RWS’s perspective. Define what it means to be a good principal and a good contractor in terms of duties and responsibilities. There is no need to put the above in a contract, but it can be written in a form of statement that will be delivered to each external stakeholder of Rijkswaterstaat. The aim of this measure is to make RWS’s perspective and mentality clear to the external stakeholders.

11. **Contracts should not be forgotten:** Contracts exist in order to be used properly. It must be secured that contracts are for the right penalties to be imposed.

**Lack of Standardization**

12. **IA Standardization:** The IA requirements and the processes must be standardized for each project type (tunnels, locks, bridges etc.) of Rijkswaterstaat.

At this point, it should be mentioned that RWS has already started working towards this direction, having selected as their starting point the Tunnels Standardization.

Some additional recommendations to the aforementioned are the following:

13. **Motivate people and companies to perform better:** There is always room for improvement both at an individual and at a company level.

   - **Individual Level:** The performance of Rijkswaterstaat’s employees should be evaluated and people who perform well should get some credit for it. For instance, when a RWS’s manager has performed really well in a project he/she could be rewarded by being involved in a more challenging future project. A person that has not performed well, in the next project he/she could be put in a position with less responsibilities.

   - **Company level:** An external stakeholder’s past performance should be taken into account for future collaborations. More specifically, when RWS is about to select contractors of a specific project, they can evaluate the companies according to their past performance as well. This can only be realized in cases where there is a performance record for all the companies that aim to be involved in a project as a contractor. In case a new company is among the above, the past performance of a company cannot be used as an evaluation criterion because the new company cannot be judged for past performance.
14. **Provide individuals and companies with feedback:** In the framework of cultivating an environment of trust within the company and with its external stakeholders, there is the idea of giving feedback about people’s and companies performances. This could prove really important for the improvement of RWS’s external collaborations (contractors, subcontractors). Through an open and constructive dialogue RWS could deliver, for instance, the reasons why a company was not selected to be a contractor of a project. Or after the end of a project, the client -RWS- could give feedback to its external stakeholders. Last but not least is the fact that RWS could also receive feedback about its performance as client and principal.

15. **Become a learning organization that from project to project shows continuous improvement.**

16. **Prioritize the quality by developing a habit of pausing an ongoing project, in order to fix problems.**

### 5.2 Suggestions

The theme of this project is considered very broad. There are many different aspects and some of them need to be further investigated. One important aspect that seems to influence a project and the relationships between the different parties is the type of contract. So, for future investigation is suggested to:

1. Investigate if the used type of contracts by RWS is the optimum one. If not, which is the best choice?

2. Examine the legal framework of RWS’s contracts.
List of Figures

Figure 1. Construction Industry Drivers of Change [2] ................................................................. 13
Figure 2. The relative importance of People, Process & Technology [2] ........................................ 15
Figure 3. RWS Enterprise Objectives [1] ...................................................................................... 16
Figure 4. Networks Cohesion [1] .................................................................................................. 17
Figure 5. The interface between IV and IA [1] ................................................................................ 19
Figure 6. Research Model .............................................................................................................. 25
Figure 7. Requirements Delivering Process via Contracts ............................................................ 27
Figure 8. RWS's Contract Formation ............................................................................................. 28
Figure 9. RWS Industrial Automation Requirements Delivery via Contracts ............................... 29
Figure 10. Interconnection of the Functional Specification's different objectives [11] ................. 34
Figure 11. The traditional way of delivering requirements [14] .................................................... 36
Figure 12. The Systems Engineering Method (SE) with Integrated Contracts [14] ...................... 37
Figure 13. Information stream from client's requirements to contract specification [15] .......... 38
Figure 14. The Systems Engineering Process Model of RWS ....................................................... 39
Figure 15. The V-model .................................................................................................................. 40
Figure 16. Detailed V-model .......................................................................................................... 41
Figure 17. ProRail's Industrial Automation Contracting Chain .................................................... 52
Figure 18. ProRail's New Industrial Automation Contracting Chain ............................................ 55
Figure 19. Schiphol Group's Project Categories .......................................................................... 58
Figure 20. Small Scale Projects' IA Contracting Chain of Schiphol Group ................................. 58
Figure 21. Schiphol's Group Industrial Automation Contracting Chain of Medium Scale Projects .. 60
Figure 22. Schiphol's Group Industrial Automation Contracting Chain for medium scale projects .. 60
Figure 23. First Phase IA Contracting Chain in Schiphol Group's Large Scale projects .......... 61
Figure 24. Schiphol Group's Contracting Chain of IA requirements ............................................ 62
Figure 25. Internal Collaboration of teams in Schiphol Group .................................................... 63
List of Tables

Table 1. Industrial Automation within RWS-Related Systems & Processes [1] ......................................... 17
Table 2. Industrial Automation’s role within RWS [1] ........................................................................... 18
Table 4. Identified Problems related to the Industrial Automation Requirements Specification and Delivery of RWS ..................................................................................................................................... 50
Table 5 Identified Problems related to the Industrial Automation Requirements Specification and Delivery of RWS ..................................................................................................................................... 66
Table 6. Identified Problems related to the Industrial Automation Requirements Specification and Delivery of ProRail ..................................................................................................................................... 67
Table 7 Schiphol Group's Answers to Rikswaterstaat's Identified Problems ........................................ 68
6 References

[1] Rijkswaterstaat Archives
[13] RWS Archives, Construction Department of RWS, Exploration of Explicit Works and Systems Engineering
[17] https://www.prorail.nl/
3TU.School for Technological Design, Stan Ackermans Institute offers two-year postgraduate technological designer programmes. This institute is a joint initiative of the three technological universities of the Netherlands: Delft University of Technology, Eindhoven University of Technology and University of Twente. For more information please visit: www.3tu.nl/sai.