Uncertainty-based project planning

An explorative study into the incorporation of risk and uncertainty in the project planning of project-based organizations that deliver complex product systems.

Thesis "Management of Technology"

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October 2013

TUDelft

Delft
University of
Technology

Master thesis information

Title:	Uncertainty-based project planning
Keywords:	projects, project management, risk and uncertainty, project planning, resource planning, complex product systems, project-based organizations
Version:	Final public thesis report
Graduation date:	October 18, 2013

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Faculty:	Technology, Policy & Management
Study program:	Master "Management of Technology"
Graduations section:	Technology, Strategy & Entrepreneurship

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Acknowledgements

Abstract

Many projects executed within organizations fail due to budget and time overruns. The goals for time and budget are often related to the planning of a project. However, due to unforeseen factors the execution often deviates from the initial project planning. These unforeseen factors can be led back to the extent to which a project is susceptible to uncertainties and risks. This thesis research has investigated to what extent it is possible to improve the front-end project planning on basis of theories on project risk and uncertainty. For this purpose a framework for assessing this risk and uncertainty is developed. This framework consists of four dimensions: novelty, technology, pace and complexity. The latter is divided into three sub-dimensions: technical, organizational and environmental complexity. The research tests this framework for a specific group of companies. These are project-based organizations (PBO) that produce complex product systems (CoPS). One such company was used in this research in a multiple case study approach in which 23 cases were selected. These individual case studies included a document analysis in which the resource hours of the project administration were studied and a semi-structured interview with the project manager. After the individual case studies were performed a cross case analysis was done for the entire group of cases.

The results have shown that each of the individual dimensions influences the execution of the project and thus should influence the planning in a different way. 1) Novelty influences the clarity of internal tasks and processes and therefore the planning of these relies more on estimations than calculations. The level of novelty therefore gives an indication of the required buffers in hours and timespan that will be required throughout the project. 2) Technology uncertainty influences the amount of technical iterations (design, build, and test). This uncertainty of the technical development phase should be incorporated in the planning in the form of buffers for the technical resources. 3) A higher degree of pace requires more priority from the project team. Also, teams should be smaller to work more efficient and to reduce bureaucracy and formalization. 4) The three dimensions of complexity were studied by collecting all factors mentioned in the interviews that have led to complexity in the studied cases. The complexity of a project can therefore be assessed by the factors that are applicable to that project. Even though specific factors have specific impact on the project, in general terms it has been found that technical complexity relates to the amount of technical development and coordination hours as well as time delays in the latter phase of the project. Organizational complexity relates to the efficiency of the work of the project team and the amount of internal coordination. Finally Environmental complexity has been found to have a severe impact on external coordination of the stakeholders by the project manager and possible time delays due to dependencies on stakeholders.

All the empirical data and results of the cross case analysis are incorporated in a planning tool. This tool enables a project manager to assess a project front-end on the level of risk and uncertainty this project is susceptible to. It also indicates in which dimension the risk and uncertainty is situated and it gives qualitative advice on how to incorporate buffers in timespan and hours in the project planning. This tool can therefore help a project manager in developing a more accurate project planning. The main conclusions of this study are therefore that by assessing the project risk and uncertainty in this way, it is possible to develop a more accurate project planning and with this possibly enhance the project success.

Keywords: projects, project management, risk and uncertainty, project planning, resource planning, complex product systems, project-based organizations

Executive summary

Many organizations organize a part of their operations in projects. Projects are temporary organizations to meet certain goals and are managed by project managers. The success of a project is often measured in terms of whether a project has stayed within the time and budget goals and if the required scope was delivered. Measured with these success criteria, many projects fail due to unrealistic goals for time and budget. An important element in setting these goals is the development of a front-end project planning. However, the execution of a project is often experienced to deviate from the planning.

This deviation can be led back to unforeseen factors that have influenced the project execution. The amount and severity in which the factors influence the execution differs among projects. The reason for this is that some projects are more susceptible to risk and uncertainty than other projects. This research focuses on using this project risk and uncertainty and relating this to the front-end project planning. The research objective is therefore to investigate to what extent it is possible for a project manager to use theories on project risk and uncertainty to develop a more accurate project planning which in turn enhances the success of a project. The central question of the research is:

"How could a project manager of a project-based organisation that develops complex product systems use theories on project risk and uncertainty to develop a more accurate project planning?"

The research has been conducted for a specific research domain. This domain consists of project-based organizations (PBO) that deliver complex product systems (CoPS) to businesses and governments. This is an interesting research domain since the projects are often high-cost, tailor-made and developed in a large web of stakeholders. This makes these projects very susceptible to uncertainties and risks. The research will be executed in one such organization. This company is a medium-sized organization that develops intelligent transport systems.

On the basis of a literature study a framework for assessing project risk and uncertainty is proposed. This framework is developed by combining two theories on risk and uncertainty: the 'diamond model' by Shenhar & Dvir (2007) and the TOE-framework for complexity by Bosch-Rekveldt (2011). The developed framework consists of the four dimensions: novelty, technology, pace and complexity. The latter is again divided in three sub-dimensions: technical, organizational and environmental complexity. These dimensions are studied on the extent to which they should influence the resource capacity planning. Resource capacity planning consists of the elements time and resource hours.

The research has been performed by means of a multiple case study approach. On the basis of observations, and several selection criteria, 23 cases of the external company's projects were selected. The cases were divided in five case groups and studied individually. This has been done in two phases. First, information on the utilization of resource hours and time was derived from the project administration. This data was made insightful by developing graphs and analysing the patterns. This information was than used in semi-structured interviews with the project managers. In these interviews, among other things, information was gathered on which factors influenced the project execution and how they influenced the execution. This led to detailed insight on how certain factors influence the resource hours and time for specific function groups at specific stages.

The explained framework constructed from the literature study, was a general framework that could be used for any project regardless of the context. To be able to relate this framework to the specific research domain new definitions for the dimensions of the framework and the levels within each dimension are proposed. These definitions and levels were developed on the basis of the results of the case studies. For novelty, technology and pace 4 levels were defined and for all sub-dimensions of complexity 3 levels were defined.

All results of the case studies have been analysed together in a cross case analysis. The objective of this cross case analysis was to study how an increased level in each of the dimensions affects the planning. The results of the cross case analysis will be shortly summarized:

- Novelty: This dimension has been found to influence the clarity of internal tasks and processes. The planning of novel projects therefore relies more on estimations than calculations. Depending on the degree of novelty a buffer should be incorporated both in time and hours for all functions throughout the project.
- Technology: The dimension of technology has primarily an influence on the technical functions. It has been found that technology influences the amount of iterations (design-build-test) required for the development, and thus the time needed. It will also be visible in a larger front-end design phase (hours) and a longer client acceptation phase (primarily time).
- Pace: It has been found that higher paced projects require more priority from the project team (or even a dedicated team) and less team members and bureaucracy to enhance the efficiency. It has also been found that smaller, dedicated, teams have a larger feeling of responsibility towards the end-goal. In turn, this feeling of responsibility leads to more commitment among the team and with this more project success. On the other hand, very low paced projects will require some degree of pressure, because otherwise projects will drag along too long.
- Complexity: This dimension has been studied by gathering all factors that were mentioned in the semi-structured interviews to have led to complexity in each of the 3 sub-dimensions. The most significant factors will be named and the overall impact of the sub-dimensions on the planning will be summarized:
  - Technical complexity: 16 factors have been found in this sub-dimension. The most significant factors were the size of the project, possible scope changes, need for on-site presence, the amount of interrelating parts and if tasks are outsourced; the clarity of the task and experience of the team. In general terms a high degree of technical complexity will have an impact on the amount of technical development and technical coordination hours as well as time delays in the latter phase of the project.
  - Organizational complexity: 11 factors have been found. The most significant were: experience of the project manager, possible changes in project management, the size of project team and availability of the team. A high degree of organizational complexity will have an impact on the efficiency of the work of the project team (more hours required) and the amount of internal coordination required.
  - Environmental complexity: 10 factors have been found. The most significant: outsourced project management (client), managerial attention demand by the client and the number of stakeholders. Environmental complexity has been found to have a severe impact on external coordination of the stakeholders by the project manager and possible time delays due to dependencies on stakeholders

The empirical data gathered by the individual case studies as well as the results of the cross case analysis just presented were used to develop a planning tool. This planning tool is an MS Excel based questionnaire in which a project manager is asked to assess the project in the front-end stage on the characteristics of the project. For the dimensions of novelty, technology and pace the project manager is asked to assess the project on one of the defined levels within each of these dimensions. For the three sublevels of complexity questions are asked on all factors found in the research. The project manager is asked for each of these factors if they are applicable to the project at hand and to what extent they are applicable. On the basis of the questions given a qualitative advice appears on how to adapt the project planning to the risk and uncertainty profile of the project. This advice includes the extent to which hour and time buffers need to be incorporated in specific phases of the project. Additionally an overview appears in which both graphical and textual is explained in which dimensions the most uncertainty in the project is situated. The outcome of the tool is an aid for the project manager in making a realistic project planning. Furthermore, the tool forces the project manager to consider all aspects of the project. This can be of aid in other processes in the initiation phase of the project. The tool was tested internally in the case study company and the project managers experienced the practical implication of the tool as positive.

Finally two interviews have been conducted with project managers from other organizations (InteSping and Damen Shipyards) to check if the results would be generalizable for the research domain. These interviews have shown that the framework, including the newly proposed definitions for the dimensions and the levels, indeed is applicable for a larger range of organizations. However, the factors leading to complexity found in this research do not apply to all organizations. To develop a generic list of factors leading to complexity additional research is required. This can be seen as one of the recommendations for future research. Additionally recommendations are provided for future research to further exploit the potential possibilities of the provided framework. Future research can for instance focus on the potential of the framework on other project management process besides project planning and also the potential for other research domains. As example of a different research domain the field of innovation projects is proposed.

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1   Introduction and description of the research

This chapter will provide an introduction to the research and a description of the research. It will focus on the research problem, the conceptual framework, the objective and research question(s), the relevance and finally the design of the research.

1.1   Introduction to the research

Many of the organizations organize a part of their business operations in projects. These projects are a temporary organization set up to achieve a certain goal within certain time and budget constraints. These restraining resources, time and budget, are often used to measure the success of projects. Therefore budget overrun and time delays often lead to project failure. Setting a realistic goal for the time and budget can therefore be considered a vital element for projects. In many industries the amount of human resources needed for a certain project have a large influence on the execution time and, through the labour rate, on the budget. Making a realistic estimation on the amount of human resource hours, and required timespan, and using this to develop a realistic project planning can therefore be considered a very important element in projects.

Developing a project planning is one of the key activities of a project manager during initiation. However, in many organizations large fluctuations from the project planning are experienced during the execution of the project. These fluctuations can often be led back to unforeseen factors that have occurred during the project. The amount and severity of these factors can give an indication on the level of risk and uncertainty a project is susceptible to. This thesis will therefore investigate if it is possible to use theories on project risk and uncertainty to develop a more accurate project planning.

This thesis will proceed as follows. The second chapter will provide an extensive literature study to the topics introduced in the conceptual framework in this chapter. This literature study will result in a theoretical framework that will form the basis for the research. Chapter 3 will provide more information on the research domain. This research domain is the group of companies for which this research applies. This chapter will also give an introduction to the company that is used in the case study set up. The fourth chapter will introduce and give the results of a multiple case study consisting of 23 cases in five different case groups. This chapter will provide the results of the individual cases as well as general conclusions per case group. Chapter 5 will use the results of the case studies in a cross case analysis. This analysis will develop overall results for the entire set of cases. To make it possible to relate the results of the cross case analysis to the project planning of future projects a planning tool is constructed. This tool will be described in chapter 6. Also this chapter will focus on how the results of the research are generalizable for the research domain. In chapter 7,8 and 9 this thesis will present discussions, conclusions and recommendations.

1.2   Research problem

This thesis research focuses on the planning of projects as an important tool in project management. More specifically it will investigate human resources planning in project-based organizations that develop complex product systems (CoPS). This research will be partly performed in one such company. This company is a medium-sized organization that delivers Intelligent Transport Systems (ITS). Within this company the experience is that the resource consumption over time within projects often deviates from the planning. The scientific literature acknowledges this as a common problem in project management and many aspects of this problem have been studied extensively in the past.

1.2.1 Theoretical problem

Many companies organize a part of their activities in projects. These projects can be defined as "a temporary organization and process set up to achieve a specified goal under the constraints of time, budget and other resources" (A. Shenhar & Dvir, 2007). The practice of managing these projects has become known as project management (PM) and its practitioners as project managers (PMs). In turn project management can be defined as "the application of knowledge, skills, tools, and techniques to project activities to meet project requirements". Furthermore, it is "accomplished through the use of processes such as: initiating, planning, executing, controlling, closing" (Project Managment Institute, 2000). Traditionally the success of a project is measured by whether or not the project stayed within budget, time and scope (or performance goals, or requirements). This theory on project success has been named "the triple constraint" (A. Shenhar & Dvir, 2007). When measuring the project success in terms of the triple constraint many projects fail (Bosch-Rekveldt, Jongkind, Mooi, Bakker, & Verbraeck, 2011). The reasons for this failure have been studied extensively in the past, but are still debated in the literature. Also it has been argued that the project success needs to be measured in broader terms and more measures (A. J. Shenhar, Dvir, Levy, & Maltz, 2001).

A very important element in setting a realistic goal for the measures of the triple constraint is the front-end planning of the human resources in the project. To make a realistic planning it is important to assess the degree of uncertainty and risk and incorporate this in the project planning. Project risk in project management can be defined as "an uncertain event or condition that, if occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality'' (Project Managment Institute, 2000). Project uncertainty on the other hand is a context for project risk and therefore project risk can be considered a subset of project uncertainty (Perminova, Gustafsson, & Wikström, 2008). The degree to which a project is subjected to uncertainty and risk defers from project to project. The characteristics of a project play an important role in measuring the degree of project uncertainty and risk. Shenhar and Dvir (2007) argue that projects differ among each other in four dimensions: technology, complexity, novelty and pace (A. Shenhar & Dvir, 2007). These dimensions can be used to study the risk and uncertainty of a project. To date not a lot of research is done on how the project uncertainty and risk, and the characteristics of a project leading to these, should influence the front-end project planning. Research on this could have a positive impact to the project success of a large range of different projects. However, to make such a study feasible a focus for the research needs to be chosen.

A previously studied category of companies are project-based organizations (PBOs) that deliver complex product systems (CoPS) (Hobday, 2000). In a project-based organization (PBO) the projects are the main business mechanism and these projects embody most of the business functions normally carried out by departments of functional or matrix organizations. The PBO "creates and recreates new organizational structures around the needs of each product and each customer" (Hobday, 2000). CoPS are high-tech, business-to-business goods used to produce goods and services for consumers and producers. Each CoPS is high-cost and consists of many interconnected and customized parts, tailor-made for specific customers. Often CoPS are produced in projects that incorporate many different stakeholders (contractors, system integrators, suppliers, buyers, SMEs, governmental agencies, regulators and users) (Hobday, 2000). Researching project planning in such companies is interesting because the CoPS projects range from high to low on all four characteristics of projects presented by Shenhar & Dvir (2007).

1.2.2 Practical problem

This research will be partly executed in a project-based organization that develops intelligent transport systems, which can be considered complex product systems. For confidentiality reasons the name of the company is undisclosed and this thesis will refer to this organization as the studied company. For the last couple of years the studied company has been growing steadily both in number of projects and employees. This development is accompanied with new challenges. One of the challenges has to do with the planning of projects and the division of the workload over the time span of the project. When a project is initiated by a project manager a detailed planning is made in the "Project Initiation Document" (PID). This is often a flat planning with a constant number of hours per week. But the experience is that in reality the workload is not divided evenly but that peaks appear in the workload. The management of the studied company expects that most projects will show two peaks when analysing the hours spent on the project. The first is at the beginning of the project and the second is at the end of the project. The middle part of the project is experienced to be less labour intensive. It is in the interest of the company to divide the workload more evenly over the project and to have a project planning that corresponds with the actual workload because 1) this is essential for planning new projects on the basis of the resource capacity and 2) especially the second peak may bring deadlines in jeopardy. It is because of this the company would like to research what the underlying reasons are that the planning does not correspond with the utilized hours during a project and why resource peaks appear during the execution of a project. With this gained detailed insight the company would like to develop a project planning tool that can be used in the current PRINCE2 project management environment.

1.2.3 Problem statement

In many organizations the planning of the projects does not correspond with the actual workload during a project. This leads to an overrun in time and budget, which in turn has a negative impact on the success of the projects. This problem will be studied by analysing project planning procedures and the incorporation of project risks and uncertainties in this planning. The problem owner in this research is the project manager of a project-based organization that produces complex product systems.

1.3 Conceptual framework

The problem as it is stated in the previous chapter leads to a conceptual framework in which this research is embedded. This framework is shown in Figure 1.
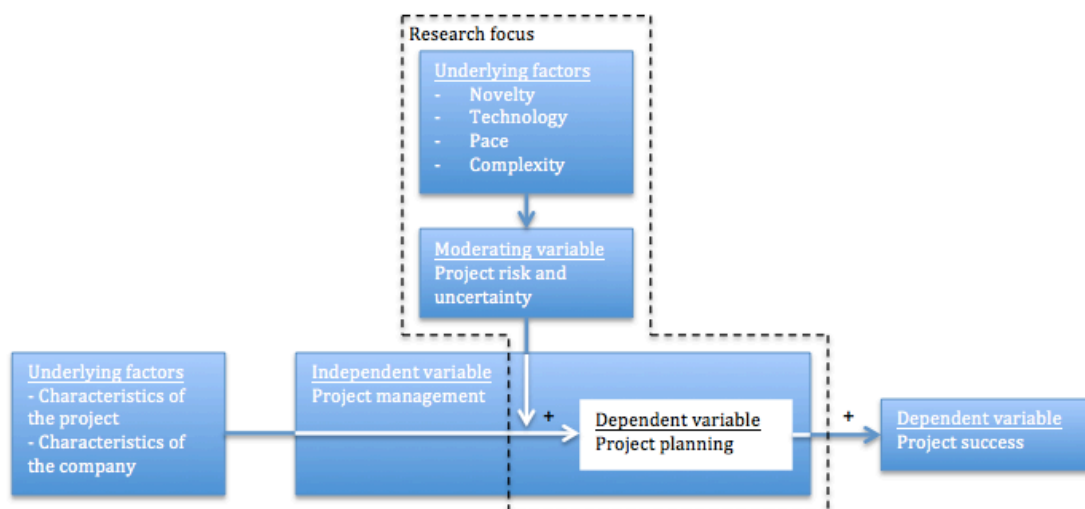
Figure 1 Conceptual framework

The conceptual framework in Figure 1 gives the foundation for the literature study presented in chapter 2. In this framework the connection between the moderating variable project risk and uncertainty, with its underlying factors, and the dependent variable project planning is indicated as the focus of the research. Project planning is a subset of the independent variable project management, which in turn needs to be studied in a certain context. This context is indicated with the underlying factors of project management. Ultimately it is the goal of the research to enhance project success by improving the project planning with risk and uncertainty. Therefore project success is indicated as the second dependent variable. However, this variable is not part of the focus of the research.

1.4 Research objective and main question

1.4.1 Research objective
The objective of this research is to investigate to what extent it is possible for a project manager to use theories on project risk and uncertainty to develop a more accurate project planning which in turn enhances the success of a project. The aim is to deliver a planning tool that incorporates these theories and will be easily usable for project managers. The unit of observation are projects in a project-based organization that develop complex product systems.

1.4.2 Research question
The objective as it is stated in chapter 2.3.1 leads to the formulation of a research question. This main research question will form the foundation of the research.

Main research question:
"How could a project manager of a project-based organisation that develops complex product systems use theories on project risk and uncertainty to develop a more accurate project planning?"

This main research question is broken down into a series of sub-questions. These sub-questions are developed to be mutually exclusive and collectively exhaustive. This makes it possible to formulate an answer to the main research question when answers are found to all of the individual sub-questions. As will be explained in the research approach in chapter 2.4.1 the research is divided into 4 distinct parts. Two sub-questions belong to phase 1 of the research, two sub-questions to phase 2 and the latter sub-question to phase 3 and 4.

Sub-question
SQ1A: What theories on project risk and uncertainty can be used to study project planning?
SQ1B: What characteristics of projects have an influence on the planning of the projects?

SQ2A: To what extent is the execution of a studied project influenced by factors that were not planned for?
SQ2B: What influence did these specific unplanned factors have on the utilization of research hours and the timespan of the project?

SQ3A: How is it possible to use this knowledge in the front-end planning phase of future projects?

1.5 Relevance of the thesis
From a scientific viewpoint a lot of research has been conducted in the past on projects, the application of project management and how the context in which these are embedded influences the project and the management of these projects. Staying within the time and

budget set for a project is considered as a very important variable for project success. A realistic planning of the human resources needed for a project can be considered a very important aspect in setting the goals for the time and budget. In its turn a realistic planning needs to incorporate risks and uncertainties. Also many aspects of project risk and uncertainty have been studied in the past. Despite all this, only limited research has been conducted on the impact of project risks and uncertainties on the project planning and if, and how, different projects should incorporate different profiles for these uncertainties in their project planning according to the characteristics of the project. This research aims to investigate this for project-based organizations that develop complex product systems. It will use case study data of one such company, but considering the characteristics of CoPS projects it is expected that the results are generalizable for the entire domain of companies.

From a managerial viewpoint achieving project success is especially for project-based organizations a vital aspect in the performance of a firm as a whole. This research will try to develop a practical solution that makes it possible to incorporate the project risks and uncertainties in the project planning. The expectation is that this tool will make the project planning more accurate which in turn can lead to more successful projects.

1.6   Research design

1.6.1   Research approach
The research will be divided into four distinct phases. The result of each phase will form the basis for the following phase. The structure is graphically displayed in Figure 2. The different phases will be introduced in this subchapter.
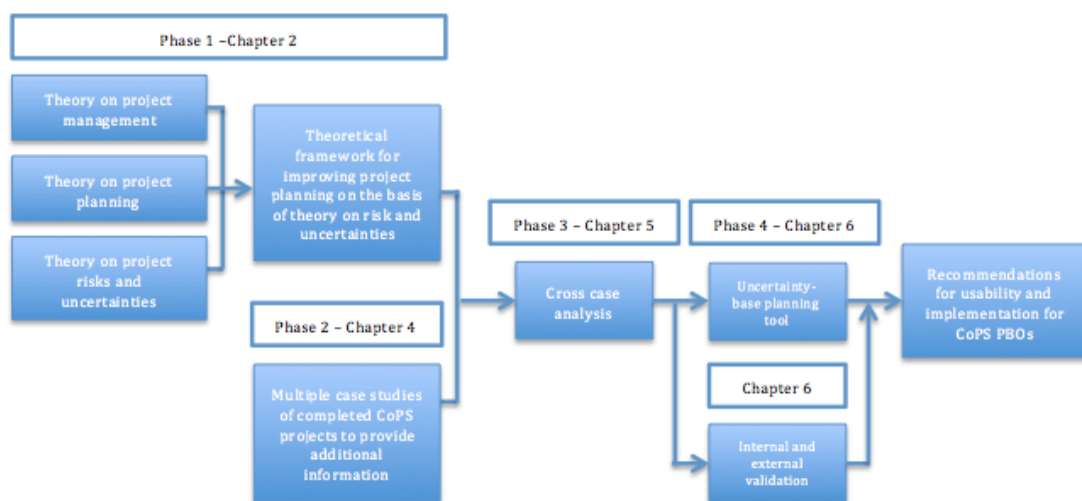
Figure 2 Graphical representation of the phases of the research

Phase 1: Literature study
The first phase of the research is an in depth academic literature study to previously performed studies on projects, project management, project planning and risks and uncertainties. It will be used to broaden the knowledge on these research fields and form a theoretical base for this study. The aim of this part of the research is to develop a clear and focussed theoretical framework that states how the front-end project planning can be adapted on the basis of the theories on project risk and uncertainty to make this planning more accurate.

The literature study will be performed using Google Scholar as an academic search engine and searching for the following specific search terms "Project risk uncertainty" and "project management planning". The first search term should give more insight into theories on project risk and uncertainty and the second on project management and project planning. The results are sorted by relevance and selected on the basis of the title, abstract and the number of references. From the first key articles found in this way (also used for the development of the conceptual framework in Figure 1) additional literature will be found by analysing cited papers and adding additional specific search terms.

Phase 2: Multiple case study
This phase of the research will provide additional, case-specific, information on projects and how these projects have been influenced by possible risks and uncertainties in a multiple case study approach. The case study is a research method that can be used to understand the dynamics present within a single setting (Eisenhardt, 1989). This multiple case study will consist of a number of different elements. The first stage is to analyse the organisation and its project management on the basis of observations. This is a data collecting method that can be used to observe "phenomena of interest in the environment studied to draw information which was not obtainable from other methods" (Noor, 2008). The goal is to learn how the company currently works with PRINCE2, what position project managers have within the company and develop an idea on the corporate culture. The results of these observations will help to put the case study in a certain perspective. These results are explained in chapter 3 (research domain).

The following step is the performance of a multiple case study of projects that have been completed. A series of 23 cases, divided among 5 different case groups, were selected for this case study. The case study will be performed in 2 different ways:

- The first part is a document analysis, which will include gathering and analysing data from the project administration (PA), and in particular hour administration in the QicsTime software. The result of this phase will be a series of graphs in which the distribution of utilized resource hours over the time span of the project will be visible. Different function groups will be separated from each other. With these graphs it will be possible to see which function groups show resource peaks at what stage of the project. This information will be used as an input in the second part of the case studies.
- The second part will include a series of interviews with employees who have been the project manager in one or more of the studied cases. This will be in the form of semi-structured interviews in which the interview questions are developed prior to the interview, but the interviewer has the possibility to ask additional questions or go more into depth on specific topics. The advantage of using semi-structured rather than structured interviews is that "it offers sufficient flexibility to approach different respondents differently while still covering the same areas of data collection" (Noor, 2008). The aim of these interviews is to gather information on the characteristic of the studied project, why a project has or has not proceeded as planned and what factors have led to overruns in resource hours or time (delays) in these projects. The questions for these interviews will be developed after the first part of the case study has been completed.

Phase 3: Cross case analysis
After all the cases are individually analysed a cross case analysis will be performed. This cross case analysis will be divided into two distinct parts. In the first part it will analyse to what extent the theoretical framework developed in phase 1 of the research needs to be altered

or supplemented on the basis of the results of the case studies. This will make the theoretical framework suited for project-based organizations that develop complex product systems. The second part is conducting the actual cross case analysis. This will be done by combining all the results of the individual case studies and try to find general finding for the entire group of cases. The cross case analysis will do this by searching for overlapping results in cases with comparable characteristics. This way it will become possible to generalize the results and use these as recommendations for future projects.

Phase 4: Uncertainty-based planning tool
The results of the cross case analysis will form the basis for this last phase of the research. In this phase a tool will be developed that gives generic advice for future projects on how resource buffers should be incorporated in the project planning on the basis of the profile of potential risk and uncertainty the project is susceptible to. This research will refer to this tool as the uncertainty-based planning tool. The tool should be able to do two things:

1. Make a front-end evaluation of potential risk and uncertainty that can arise in the to be performed project. This will have the form of a questionnaire that can be filled in by a project manager.
2. Develop qualitative advice on how and where to incorporate resource buffers in the project planning on basis of the answers provided.

This tool should be able to give a clear overview of the potential uncertainties and how this should influence the front-end project planning. Also it should be able to implement the tool easily in the project management regardless of the project management approach that is used by the organisation.

1.6.2   Scope
The scope of the research will only be the actual project: From initiation to closing. It will not incorporate acquisition of projects, possible service contracts after closing of the project and the coordination between overall management to project management. The research will take a project manager as the principal of all studied projects. The result of the research will in principal only be focussed on improving the project planning and not specifically on more aspects of project management. It will also only incorporate case study data of one company; no other case studies (within other organizations) will be conducted during this research.

2   Theoretical background

This chapter of the thesis will give the findings of an extensive literature study. It will follow the structure of the conceptual framework that is presented in chapter 2. Chapter 2.1 is named "projects" and includes all the topics that need to be studied for the dependent variable project planning. Paragraph 2 will shortly explain the different dimensions of project success and finally chapter 2.3 will investigate project risk and uncertainty and the four underlying factors that are studied in the research. At the end of each subchapter a recap is given on how the presented information is relevant to the research and how it will be used. In the final subchapter a summary will be provided in the form of a focussed conceptual framework that will include the core concepts of this research.

Information on the three elements of the conceptual framework is primarily derived from three literature fields; projects, project management (including project planning) and project risk and uncertainty. A large range of scientific papers and books in these fields were studied for the purpose of this chapter.

2.1   Projects

The main unit of observation in this research are projects, therefore this subchapter will focus on the relevant aspects of projects for this study: the characteristics of a project (2.1.1), the management of projects (2.1.2), the project planning (2.1.3) and the characteristics of the company the project is executed in (2.1.4). The final paragraph will conclude this subchapter by explaining what information in the chapter will be taken along in this research.

A project can be defined several ways. For this thesis we will use the definition as was stated by the book of Shenhar (2007). A project is "a temporary organization and process set up to achieve a specified goal under the constraints of time, budget and other resources" (A. Shenhar & Dvir, 2007).

2.1.1   Characteristics of a project

The definition as stated above is very broad and leaves room for further distinction of the term 'project'. On the basis of the aim of a project it is possible to make a distinction between operational projects and strategical projects. Where operationally managed projects focus on getting the job done and meeting the goals set for time, budget and other resources and strategically managed projects focus on achieving a certain business goal and winning in the market place ((A. Shenhar, Poli, & Lechler, 2000) as cited in (A. J. Shenhar *et al*., 2001)). Another distinction can be made on the basis of the nature of a project. Turner *et al.* (2012) used for their research six categories for the nature of a project:

- Research;
- Product development;
- Other internal projects (such as computer systems);
- Bespoke products for external customers;
- Tailored products for external customers;
- Other external products.

In this research by Turner *et al.* (2012) a distinction is made between bespoke products and tailored products on the basis that "bespoke products are a completely new design whereas tailored products are an existing design adapted to the requirements of this customer" (R. Turner, Ledwith, & Kelly, 2012).

Additionally, within a certain category it is possible to classify the projects on basis of many different variables (D Dvir, Lipovetsky, Shenhar, & Tishler, 1998). A number of these variables will be used in this thesis to study project risk and uncertainty and can be found in chapter 2.3.

Furthermore many scholars elaborate on the importance of the industrial sector (Cooke-Davies & Arzymanow, 2003; Tukel & Rom, 1998) and the market (A. Shenhar & Dvir, 2007) in which a company operates when studying projects. The market in this case relates to the consumer group: Business-to-consumer, business-to-business and business-to-government.

2.1.2   Project Management

Projects need to be managed in order to become successful. This practice has become known as "Project Management" (PM). Project management became well defined and developed in the 1950s. In this time common practices and methods were developed and codified and this led to a profession represented by the "Project Management Institute" (PMI) (Project Management Institute, 2013), later followed by several smaller national organizations operating under the Swiss-based "International Project Management Association" (IPMA) (IPMA, 2013). Besides publishing and sharing knowledge on project management, these organizations can give project managers an accreditation making them "Project Management Professionals" (PMP).

Project management has been defined by the PMI (2000) as "the application of knowledge, skills, tools, and techniques to project activities to meet project requirements". Furthermore, it is "accomplished through the use of processes such as: initiating, planning, executing, controlling, closing" (Project Managment Institute, 2000). The PMI divides the project management processes and activities into nine knowledge areas:

- Project integration management;
- Project scope management;
- Project time management;
- Project cost management;
- Project quality management;
- Project human resources management;
- Project communication management;
- Project risk management;
- Project procurement management.

Project Management can be considered as the application of a series of PM tools. Depending on the characteristics of the project and the organizational context, an organization and their project managers should choose an appropriate toolbox. On the basis of a literature study Besner & Hobbs (2004) have distinguished a set of 70 PM tools and investigated which tools are used most often in daily PM practices (Besner & Hobbs, 2004). The results of their research can be found in Table 1.

The research also investigated the differences in use among companies. Three variable of projects and organizations were found to influence this use:

- Organizational maturity levels: The maturity level of the organization relates to the experience the organization has with project management. It is found that mature organizations use a significantly different toolbox than less mature organizations.
- Project size: The size of the project measured in dollar value also makes for a significantly different toolbox.

- Product types: Three different industries (Engineering & construction, IT and business services) were found to use a significantly different toolbox.

Table 1 70 PM tools in decreasing order of average use (Besner & Hobbs, 2004)

From limited to extensive use	From very limited to limited use	Less than very limited use
Progress report	Contingency plans	Life Cycle Cost ("LCC")
Kick-off meeting	Re-baselining	Database of contractual commitment data
PM software for task scheduling	Cost/benefit analysis	Probabilistic duration estimate (PERT)
Gantt chart	Critical path method & analysis	Quality function deployment
Scope statement	Bottom-up estimating	Value analysis
Milestone planning	Team member performance appraisal	Database of risks
Change request	Team building event	Trend chart or S-Curve
Requirements analysis	Work authorization	Control charts
Work Breakdown Structure	Self directed work teams	Decision tree
Statement of work	Ranking of risks	Cause and effect diagram
Activity list	Financial measurement tools	Critical chain method & analysis
PM software for monitoring of schedule	Quality plan	Pareto diagram
Lesson learned/post-mortem	Bid documents	PM software for simulation
Baseline plan	Feasibility study	Monte-Carlo analysis
Client acceptance form	Configuration review	
Quality inspection	Stakeholders analysis	
PM software for resources scheduling	PM software for resources leveling	
Project charter	PM software for monitoring of cost	
Responsibility assignment matrix	Network diagram	
Customer satisfaction surveys	Project communication room (war room)	
Communication plan	Project Web site	
Top-down estimating	Bid/seller evaluation	
Risk management documents	Database of historical data	
	PM software multi-project scheduling/leveling	
	Earned value	
	PM software for cost estimating	
	Database for cost estimating	
	Database of lessons learned	
	Product Breakdown Structure	
	Bidders conferences	
	Learning curve	
	Parametric estimating	
	Graphic presentation of risk information	

2.1.3 Project planning

There are many stories of projects that have failed. Often an important element in the failings is that the project started with an inadequate planning (Grey, 1995). Project planning and the (human) resource capacity planning can be considered a subset of project management. Some scholars claim that too much planning "can curtail the creativity of the project team" (Dov Dvir, Raz, & Shenhar, 2003) and that it is very difficult to know all the parameters needed for a complete project planning at initiation (Andersen, 1996). It is however never debated that at least a minimum of planning is required (Dov Dvir *et al.,* 2003). It has been found that the initiation phase is the most important of all phases of the project life cycle (Meyer & Utterback, 1995) and that this phase has the most influence on the project's success (D. Dvir, Lipovetsky, Shenhar, & Tishler, 1999).

The project planning can be broken down into two parts, these parts have been named by the PMBOK guide "Project Time Management" and "Project Human Resource Management" (Project Managment Institute, 2000). This thesis has combined these two under the term: Resource capacity planning. The project Time Management can be broken down into five different processes:

- Activity definition: Identifying and documenting the activities that need to be performed to achieve the desired deliverables.
- Activity sequencing: Identifying and documenting the sequence of the activities on the basis of the interactivity between activities.
- Activity duration estimation: Involves making estimation on the duration of each of the activities on the basis of the resources and scope.

- Schedule development: Combining the first three steps in clear schedule in which the start and finish dates of the project are defined.
- Schedule control: Different factors can lead to changes in the developed schedule. Controlling of the schedule is concerned with identifying and influencing these factors that lead to change, determining if and how the schedule has to change and managing these changes when they occur.

The Human Resource Management as defined by the PMBOK can be broken down into three different processes (Project Managment Institute, 2000):

- Organizational planning: This process takes the activities of the Time Management and identifies, documents and assigns project roles, responsibilities and relationships to them.
- Staff acquisition: Getting the human resources needed assigned to the project.
- Team development: Developing individual and group competencies to enhance project performance.

This research especially focuses on the "activity duration estimation" and the "organizational planning" and the relationship between them.

2.1.4 Characteristics of the company

The characteristics of the company in which a project is executed influences the way project management and therefore project planning is and should be executed. The chosen group of companies in this research, project-based CoPS organizations, will be further studied in chapter 3 (research domain). This paragraph will shortly explain how the size of the company should influence the PM approach.

(Micro,) Small and Medium-sized Enterprise (SME) is a collective name for a company that stay under a certain threshold. These thresholds were in 2005 redetermined by the European Commission. This was necessary due to the economic development in the European Union as well as globally. The determined threshold can be found in Table 2 (European Commission, 2005).

Table 2 Thresholds for SMEs (European Commission, 2005)

Category	Employees	Annual turnover
Medium-sized	<250	≤ €50 million
Small	<50	≤ €10 million
Micro	<10	≤ €2 million

The application of project management in SMEs is a popular topic of research. In particular the difference between project management in large corporations and SMEs has been studied extensively. It has been proposed that SMEs require a "lite" version of project management that is less bureaucratic than the traditional versions (J. R. Turner, Ledwith, & Kelly, 2009). Also SMEs need simpler, more people-focussed forms of PM (R. Turner *et al.*, 2012)

Ghobadian and Gallear (1997) have made an extensive comparison between SMEs and large corporation on the basis of six central themes: Structure, procedures, behaviour, processes, people and contact. Turner *et al.* (2012) summarized these finding into four points ((Ghobadian & Gallear, 1997) as cited in (R. Turner *et al.*, 2012)):

- Processes: SMEs require simple planning and control systems, and informal planning.
- Procedures: SMEs have a low degree of standardisation with idealistic decision-making.
- Structure: SMEs have a low degree of specialization, with multi-tasking, but a high degree of innovativeness.
- People: Because of the high consequence of failure, people prefer tested techniques in SMEs.

These findings can however not be generalized for the whole group of SMEs. Turner *et al.* (2010) found that there is a clear transition from small to medium-sized enterprises; "Many companies suffer a crisis of growth at that point". When approaching the 50 employees people begin to specialize and there becomes a need for middle managers. At this point there also becomes a need for more formal processes for project management (R. Turner, Ledwith, & Kelly, 2010).

2.1.5   Conclusions

This subchapter has shown that the characteristics of the project and the characteristics of the company influence the way project management is and should be executed. Project management in its turn can be considered as the use of a series of processes and tools to manage a project. These processes are divided a series of project management knowledge areas. Two of those areas, "project time management" and "project human resources management", are of interest when studying resource capacity planning used in this thesis. In Figure 3 a graphical overview of this subchapter is given.
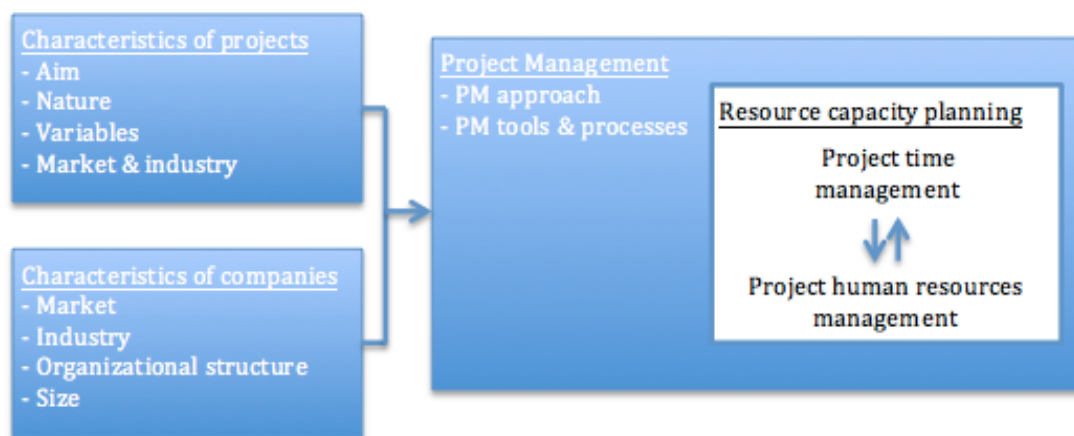
Figure 3 Graphical representation of the findings of subchapter 2.1

2.2   Project success

The variable project success is not part of the focus of the research. However, it is part of the conceptual framework of the research and therefore it is important to state what this research defines as project success. This definition will be concluded after a short analysis of a few theories on the success of projects.

Traditionally, the success of a project was measured by whether or not the project stayed within budget, time and scope (or performance goals, or requirements). This theory on project success has been named the "triple constraint" or "iron triangle". Any deviation from these three measures was seen as a negative signal that needed to be avoided. This view was accompanied by the idea that projects resemble each other and thus need to be treated the same way. (A. Shenhar & Dvir, 2007).

Recent research has defined project success as something broader than just the triple constraint. This subchapter will give theories on project success from three different influential sources on project success: Shenhar *et al* (2002), Shenhar & Dvir (2007) and Turner (2009). In paragraph 3.2.1 the implications of these theories on this research will be explained.

Shenhar *et al.* (2002) developed a list of thirteen measures that could be used to assess the success of a project (Table 3).

Table 3 thirteen measures for success divided in four dimensions (A. J. Shenhar *et al.*, 2001)

Success dimensions	Measures
1. Project efficiency	Meeting schedule goal
	Meeting budget goal
2. Impact on the costumer	Meeting functional performance
	Meeting technical specifications
	Fulfilling customer needs
	Solving a customer's problem
	The customer is using the product
	Customer satisfaction
3. Business success	Commercial success
	Creating a large market share
4. Preparing for the future	Creating a new market
	Creating a new product line
	Developing a new technology

As can be seen from Table 3 these 13 measures are divided among 4 dimensions of success. The first dimension relates directly to the project, the second dimension to the customer, the third dimension to the parent organization and the fourth dimension to the future organization.

In a later publication Shenhar and Dvir (2007) add a fifth dimension to this list: "Impact on the team". This dimension is placed between the second and the third dimension of Table 3. This dimension refers to the internal project team and it entails the following measures (A. Shenhar & Dvir, 2007):

- Team satisfaction;
- Team morale;
- Skill Development;
- Team member growth;
- Team member retention;
- No burnout.

In both publications it is argued that the relative importance of the dimensions of success relate to the time span of the project and the characteristics of the project (Figure 4 and Figure 5).
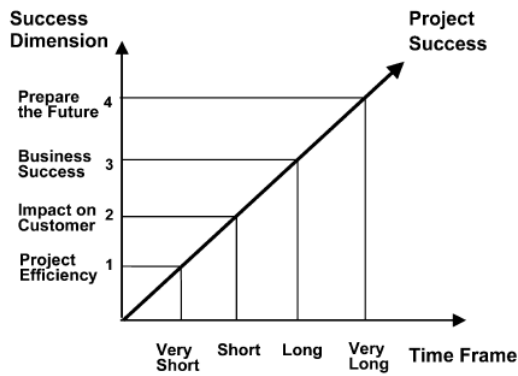
Figure 4 Success dimensions relative to the time frame of project (A. J. Shenhar *et al.*, 2001)
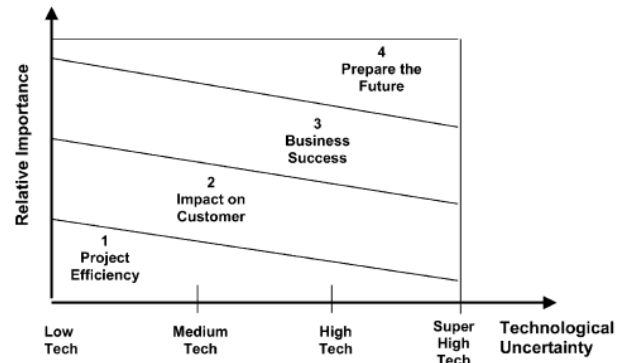

Figure 5 Importance of the success dimension relative to the project classification (A. J. Shenhar *et al.*, 2001)

A third theory on project success that will be presented comes from the well-known project management book "The handbook of project-based management" (3rd edition, 2009) by Rodney Turner. In this book Turner defines the output of a project as a new asset and new capabilities for the firm to "enable it to solve the problems or exploit the opportunities to achieve the desired benefit" (J. R. Turner, 2009). With this viewpoint he defines a set of 9 criteria for project success and also defines for which stakeholders and in which time-scale the criteria are relevant (Table 4).

Table 4 Project success criteria by Turner (J. R. Turner, 2009)

Measures of success	Stakeholder	Timescale
The project increases the shareholder value of the parent organization	Shareholders	End plus years
The project generates a profit	Board	End plus years
The project provides the desired performance improvement	Sponsor	End plus years
The new asset works as expected	Owner	End plus months
The new asset produces a product or provides a service that consumers want to buy	Consumers	End plus months
The new asset is easy to operate	Users	End plus months
The project is finished on time, to budget, and with the desired quality	All	End
The project team has a satisfactory experience working on the project and it met their needs	Project team	End
The contractors made a profit	Contractors	End

With the project success criteria in Table 4 Turner also shows that project success is something broader than the traditional triple constraint. He also indicates that different success criteria are applicable for different stakeholders and measurable on different time scales. Furthermore he states "in order for a project to be successful, you must agree on the success criteria with all the key stakeholders before you start" (J. R. Turner, 2009). This should according to this publication not only be agreed upon at the beginning of the project, but all parties must continue to confirm this agreement at multiple stages throughout the project.

2.2.1 Conclusions

This subchapter has shown that project success is measured as something broader than the traditional triple constraint (staying within time, budget and scope). It has also shown that

different success criteria are of importance for different stakeholders in a project and that different success measures become more important, and measurable, over a longer time scale.

The focus of this research is on improving the resource capacity planning on the basis of theories on project risk and uncertainty. Thus the success measure that is of direct importance is staying within the scheduled time. Indirectly the measure "Staying within the budget goal" is also of importance to the research, because "when labour is in fact the main cost in an activity, cost and schedule uncertainty are usually the same, being linked through the labour rate" (Grey, 1995). Therefore we will set the dependent variable of this research, project success, as the first dimension of project success by Shenhar *et al.* (2002), project efficiency; Meeting schedule and budget goal. Nevertheless it is important to note and to take in consideration that when projects do not meet the goals for project efficiency (due to for instance a high degree of uncertainty and risk) the project does not necessarily have to be a failure.

2.3   Project risk and uncertainty

The definitions for project risk and uncertainty were already stated in the problem analysis in chapter 1, for the purpose of this chapter these definitions will be given again. This thesis uses the definition for project risk as proposed by the PMI: "an uncertain event or condition that, if occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality'' (Project Managment Institute, 2000). Especially the positive element in the definition of risk has been debated in the literature (Hubbard, 2009), but since it is a widely used definition in the field of Project Management it will be used in this thesis. Project uncertainty on the other hand is a context for project risk and therefore project risk can be considered as a subset of project uncertainty (Perminova *et al*., 2008). This indicates that project risk and uncertainty are clearly related, but they are not the same thing. Uncertainty refers to the completely unknown elements in a project ('unknown unknowns') and risk refers to a certain event that may be thought of in advance, but if they will occur and the consequences when occurring are unknown at the initiation of the project ('known unknowns'). Both uncertainty and risk can lead to overruns in time and hours during a project.

The practice of managing project risk and uncertainty, known as risk management, can be considered a very important aspect in the field of project management as a whole. Some scholars even argue that risk management is the main purpose of project management, a view that is summed up as 'risk-driven project management'. Generally the risk management process includes a couple of reoccurring parts (Grey, 1995):

- Identification of issues that might jeopardise the success of a project.
- Assessment of the significance of this issue and the possible rejection of insignificant issues.
- Contingency and mitigation plans need to be developed for the remaining risks.

Many different methods for risk assessment have been developed. These methods can broadly be placed into three categories:

- Issue-based methods: These are techniques that make sure that you do not forget anything obvious. It commonly uses headings (commercial, technical, internal, external etc.) as a checklist of things that might go wrong. It often uses a checklist constructed of projects of the past.

- Scoring techniques: Uses questionnaires in which the respondent is asked to what extent a possible factor is applicable for the project. The total score of the questionnaire will give a measure for the overall riskiness of the project.
- Quantitative techniques: Aim to link everything that can go wrong to the existing plans of the project, especially the planning and budget. This way it will measure the quantitative impact of a risk on these plans. These techniques often make use of computer-based tools. An example of such a method is the Monte Carlo simulation.

Off course many methods are a combination of these approaches in which the knowledge of issue-based models and scoring techniques are used as input in quantitative techniques.

In the book "Reinventing Project Management" by Aaron Shenhar and Dov Dvir (2007) it is argued that in order for a project to succeed the project management needs to be adjusted to the environment, the task and the goal, rather than stick to one set of rules. This publication presents a diamond-shaped framework (Figure 6) to assess a project's risks and benefits on the basis of four dimensions: novelty, technology, complexity, and pace (NTCP). In broad terms it can be stated that the level of technological uncertainty and novelty lead to uncertainty in a project and that the pace and complexity of a project are related to the risks of a certain project. Bigger diamonds represent projects which are subjected to higher risk and uncertainty, but also have a higher potential pay-off (A. Shenhar & Dvir, 2007). This thesis will investigate how these four dimensions can be used to assess a CoPS project (Issue-based with the possibility to use scoring techniques) and how this assessment should influence the front-end project planning. The following paragraphs will elaborate on the four dimensions. It will follow the order in which according to the book a manager should assess a project: novelty, technology, complexity and pace. At the end of each paragraph the relevant 'learning points' of that dimension will be summed up. These will further be discussed in the conclusions in 2.3.5.
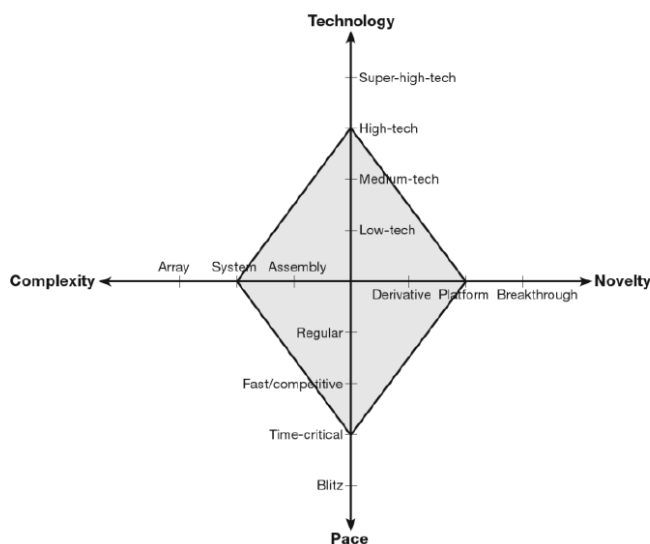
Figure 6 The diamond model (A. Shenhar & Dvir, 2007)

2.3.1   Novelty
The first measure of uncertainty relates to the product that is developed during the project. Shenhar & Dvir (2007) state that this measure explains how new the product is to the market, the customer and the potential user (A. Shenhar & Dvir, 2007). For the purpose of this research we will also include the side of the producer. So how new is this product to the project manager, the project team and the parent organization. This measure gives a good

indication of how well the product and project requirements are defined by the customer or end-user and how good the methods and processes of the project are defined and known by the project team or organization. Not knowing the requirements, processes and methods will have a large influence on the uncertainty of a project.

Wheelwright & Clark (1992) developed the levels of novelty prior to the diamond framework for the structuring of new product development projects. In this publication the scholars argue that "few companies approach the development process systematically or strategically" and therefore they propose a model to structure the projects in a project map where they define 4 categories: derivatives, platforms, breakthroughs and R&D (Wheelwright & Clark, 1992). The project map of Wheelwiright & Clark (1992) can be found in Figure 7. For the purpose of the diamond framework the R&D projects are not included.
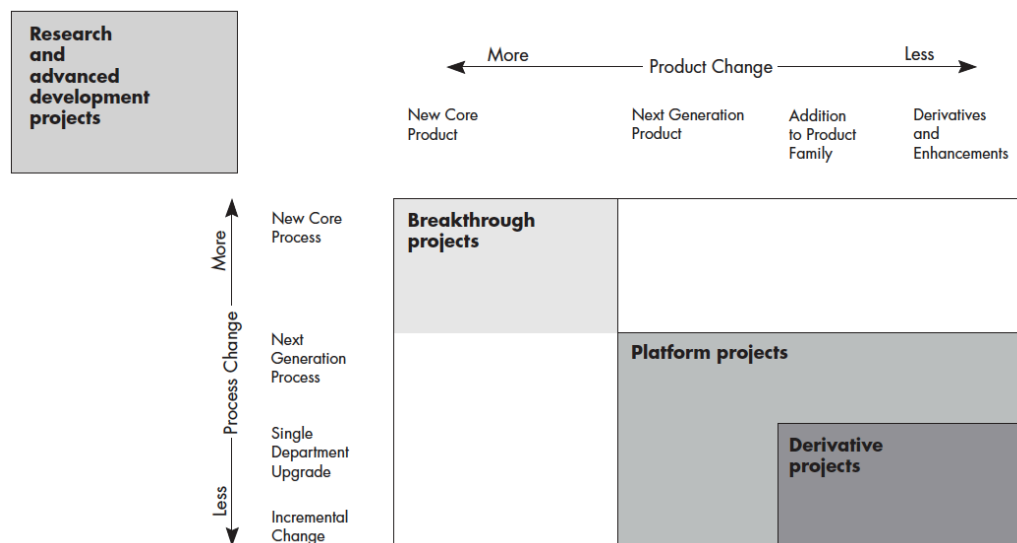

Figure 7 Project map for new product development (Wheelwright & Clark, 1992)

For the assessment of a project on the level of novelty the following definitions and explanations of the three levels will be used:

- Derivative: These are projects that include extension with (or without) improvements of an existing product or product system. For these kinds of projects a lot of information is known from the market, the end-user, and the producing company. When a project manager uses this information correctly it will greatly reduce the uncertainty in a project. Examples of such projects are the development of post-its with different shapes or colours.
- Platform projects: These are projects that are aimed at developing new generations of existing product lines. These projects replace a well-known product in an established market. Information on the users, the customers and the market is known, but the uncertainty arises internally at the development of the product. Examples are the development of a new line of aircrafts.
- Breakthrough projects: Developing and creation of new-to-the-world projects. These are projects that develop radical innovations (Abernathy & Utterback, 1978). The market information is not relevant in these projects, because it will create a totally new concept. It cannot build on previous knowledge on the project processes or methods. Obviously these projects have the highest level of uncertainty, but may also generate the highest profits.

If we want to relate the levels of novelty to the resource capacity planning it is the hypothesis that it primarily influences the initiation and the closing phase of the project. When a project is a platform of even a breakthrough project it require a lot more time in the initiation phase for acquiring the correct market data, developing methods and procedures and ultimately freezing the project requirements. In the closing phase it will take more time to finish the project due to the incorporation of market feedback in the product.

Learning points for 'novelty'
The term novelty relates to the uncertainty in a project that arises due to the how new the product is to the market and the organization developing the project. Uncertainty in this dimension arises due to the unclearness of the requirements of the product and the processes and methods that need to be used in the project. It is the hypothesis that the relation between novelty and resource capacity planning will primarily lie in the initiation and closing phase. Especially for this measure it is important to study it in relation with the context of the research, because PBOs in the CoPS domain usually do not have mass-market entries, but usually have one customer per project.

2.3.2 Technology
In assessing the risk and uncertainty of a project the level of technological uncertainty is of big importance. In the diamond framework four levels of technological uncertainty are used: Low-tech, Medium-tech, High-tech and Super High-tech. In an earlier publication by Shenhar *et al.* these levels were defined in to following way (A. Shenhar & Dvir, 2007; A. J. Shenhar *et al.*, 2001):

- Low-Tech projects: Rely on existing and well-established technologies. Every market player has equal access to these technologies and therefore these technologies will not lead to competitive advantage over your competitors. Examples of such projects are construction projects.
- Medium-Tech projects: Incorporate some new feature to an existing technology, but these are never critical technologies that will lead to project success. Examples of such projects are improvements to already existing products to develop a new series or model.
- High-Tech projects: Projects based on new technologies that have been developed prior to the project, but are used for the first time in such a project. These technologies can lead to competitive advantage in a project and can lead to success of a certain project. However such projects are also susceptible to a lot more risks and uncertainties. Many defence systems are examples of High-tech projects.
- Super High-Tech: Based on new technologies that have been developed during the execution phase of such a particular project. These technologies are often called emerging technologies. These projects can be purely internal R&D projects, but they can also have a customer (business to business or business to government). Examples of such projects are NASA's Hubble space telescope, but also start-up companies that explore non-existing technologies.

On the basis of the given definitions for the levels it should be easy to assess a project on this dimension. However, it is more difficult to link this assessment to the project planning. The hypothesis is that a higher the level of technological uncertainty leads to more iteration of design, building and testing. These cycles will put extra pressure on certain functions of a project team and this pressure will increase towards a project deadline. Nevertheless, these deadlines are important for high-tech and super high-tech projects, because improvement to the technology can always be made and therefore such projects will never be finished.

Learning points for 'technology'

The four levels of technological uncertainty need to be assessed on the basis of existing technology and the technology that needs to be developed for a certain project. It will be studied in the case study how this degree influences the resource planning. The hypothesis is that the more uncertain the technology is the more time and hours need to be invested in the design, build and test phase due to multiple iterations, this will especially put more pressure on certain function groups.

2.3.3 Complexity

The precise definition of the term "complex" or "complexity" is debated in the literature. Bosch-Rekveldt (2011) argues on the basis of a literature study that complexity in projects can be "considered to be related to structural elements, dynamic elements and interaction of these; broader than the technical or technological domain" (Bosch-rekveldt, 2011). In the book of Shenhar & Dvir (2007) no clear definition of the term complexity is provided. The dimension in the book is analysed by the framework of systems and subsystems of a project. On basis of this approach three levels are defined for complexity (A. Shenhar & Dvir, 2007):

- Assembly: These are projects with the lowest degree of complexity. It are projects that entail a certain material, a component, a subsystem or the assembly of a certain product or the development of a single service.
- System: Project that entails a platform of systems. These are more complex and often involve multiple subsystems or components and multiple stakeholders. The development of a new automobile is named as an example of this degree.
- Array: These are the most complex projects: projects that entail many sub-contractors, many components, a lot of different stakeholders, often different cultures and so on. The development of a nationwide cellular network is named as an example of an array project.

Given the definition of Bosch-Rekveldt (2011) the three levels of complexity defined by the diamond framework may not cover the entire dimension. Therefore this dimension will be analysed further. On the basis of a literature study Bosch-Rekveldt *et al.* (2011) give an overview of 40 of these factors (Table 5).

Table 5 factors contributing to project complexity (Bosch-Rekveldt *et al.*, 2011)

Elements in alphabetical order			
Clarity of goals	Interrelations between technical processes	Number of stakeholders	Size in capital expenditure
Company internal support	Level of competition	Number of tasks	Size in engineering hours
Compatibility of project management methods and tools	Newness of technology (world-wide)	Overlapping office hours	Size of project team
Contract types	Number of different disciplines	Political influence	Stability project environment
Cooperation JV partner	Number of different languages	Project drive	Trust in contractor
Dependencies between tasks	Number of different nationalities	Project duration	Trust in project team
Dependencies on other stakeholders	Number of different norms and standards	Required local content	Uncertainties in scope
Experience with parties involved	Number of financial resources	Resource and skills availability	Uncertainty in methods
Experience with technology	Number of goals	Risk management	Variety of stakeholders' perspectives
Goal alignment	Number of locations	Scope largeness	Variety of tasks

The elements presented in Table 5 were tested in a multiple case study of large engineering projects. This has led to a Technical Organizational and Environment (TOE) framework for project complexity. The goal of this framework is to better adapt the front-end development steps of a project to the complexity of that project (Bosch-Rekveldt *et al.*, 2011). This framework will not be presented here, because a framework developed on the basis of large engineering projects may not be generalizable. The subcategories presenter in Table 6 however are interesting for thesis, because they make the dimension of complexity more clear and therefore easier to assess.

When the complexity of a project increases there becomes a need for formality and more emphasis on managerial aspects of a project. When the complexity is low the setting in a project team is often informal and project management can focus on technical aspects of the project. When the complexity shifts from assembly to system or even array the task of the project manager shifts to more administrative and there becomes need for formal documentation. In the most maximal situation the project manager is primarily occupied with financial, control and legal issues (A. Shenhar & Dvir, 2007).

Table 6 Subcategories of the TOE framework for project complexity (Bosch-Rekveldt *et al.*, 2011)

Technical	Organizational	Environment
Goals	Size	Stakeholders
Scope	Resources	Location
Tasks	Project team	Market conditions
Experience	Trust	Risk
Risk	Risk	

It is the hypothesis of this research that when project complexity increases more fluctuation appears in the utilized hours leading to large resource peaks that largely deviate from the original planning

Learning points for 'complexity'
The dimension of complexity in the diamond framework is not clearly defined and the levels that are defined in the framework do not seen to cover the entire dimension. Therefore a different source will be used for this dimension, the TOE framework. This TOE framework and the list of 40 factors leading to complexity make it possible to check in a case study set up which of these factors contribute to complexity in CoPS projects and if there are more factors that can supplement this list. For the research the three subcategories of complexity (technical, organizational and environmental) will be used as sub-dimensions of the diamond framework.

2.3.4   Pace
The term pace can have a different meaning in a different context. The pace of a project is "the rate of speed in which an activity or movement proceeds" (Oxford dictionaries, 2013). More specifically "Pace involves the urgency and critically of meeting a project's time goals" (A. Shenhar & Dvir, 2007). The pace of a project can have internal reasons (limited time access to resources or managerial strategy), external (deadline set by the customer or the circumstances) or market (create a strategic position on the market before the competitors get the chance). Some of these reasons for the pace of a project put more pressure on the project than other reasons. Therefore Shenhar & Dvir developed 4 levels on which the pace can be assessed (A. Shenhar & Dvir, 2007):

- Regular: These are projects that are carried out to achieve long-term goals, but without clear time pressure. Although completion dates will be set at the beginning of such a project, there are no real consequences when these deadlines are passed. Examples of such projects can be internal organizational improvements or construction work on for instance public buildings.
- Fast/competitive: These are projects that are carried out to create a strategic positioning within the market place. Priority will be given to timely completion, because it is one of the factors of influence for the project success of such projects. Missing the deadline will not be fatal for a project, but it does influence the competitive advantage or hurt the profits.
- Time-critical: These projects have one specific deadline that cannot be changed. Missing this deadline will lead to direct failure of the project. Examples of such projects are the construction of an Olympic village or organization of an event with a definite date.
- Blitz: These are the most urgent projects and are often initiated by a crisis or an unexpected event. There is no real time to set up the project, because immediate action is required. An example of a blitz project evacuation of a village after a natural disaster.

When the pace of a project increases there becomes an increased need for a dedicated project team or even a project team that operates completely autonomous from the organization. The need for formalization decreases, because 1) it is claimed that there is simply no time for bureaucracy and 2) communication is flat and fast. When projects are regular paced individuals in a project team only spend part of their time on the project and the project is not their main priority. Therefore the need for planning and formalization is higher. Also in time-critical and blitz projects top management should be available on demand to make critical decisions when needed. For the resource planning this means that especially projects that have a lower pace need to plan their resources very clearly. When a time-critical or blitz project starts it is important to assess the consequences for the resource planning of the other projects in the portfolio.

Learning points for 'pace'
The front-end assessment of the pace will need to be done of the basis of the deadline and the amount of work in relation to how far this deadline lies in the future. Also it is important to determine what the consequences are if a project team fails to finish the project before the deadline. If the pace of the project indicates the need for a dedicated project team, it is important to assess the consequences of this for other projects in the portfolio.

2.3.5   Conclusions
Every project is subjected to risk and uncertainty, which can be harmful for the success of a project. The practice of risk management has focussed on the identifications of risks, the assessment of the significance and making contingency plans. This research will do this on the basis of the diamond framework presented by Shenhar & Dvir (2007) and supplemented by the three subcategories of complexity (technical, organizational and environmental). In a case study set up it will be studied how this framework can be used to study and improve resource capacity planning. It will do this for the domain of PBOs that produce CoPS. In the next chapter the four dimensions of the framework will be placed in the context of the case study company. An overview of the proposed framework for project risk and uncertainty can be found in Figure 8. In this framework the definitions and the levels for novelty, technology and pace used by Shenhar & Dvir (2007) are shown. For complexity the definition presented by Bosch-Rekveldt (2011) and the three sub-dimensions are used. For the three sub-dimensions no levels are defined, but these will be analysed with the presented factors.

All given definitions and levels were defined to be of use in any project regardless of the context. Since this research studies the use of this framework for a specific research domain the definition and the levels will be redefined on the basis of the outcome of the case studies. The new definitions and levels will be presented in the cross case analysis in chapter 5.
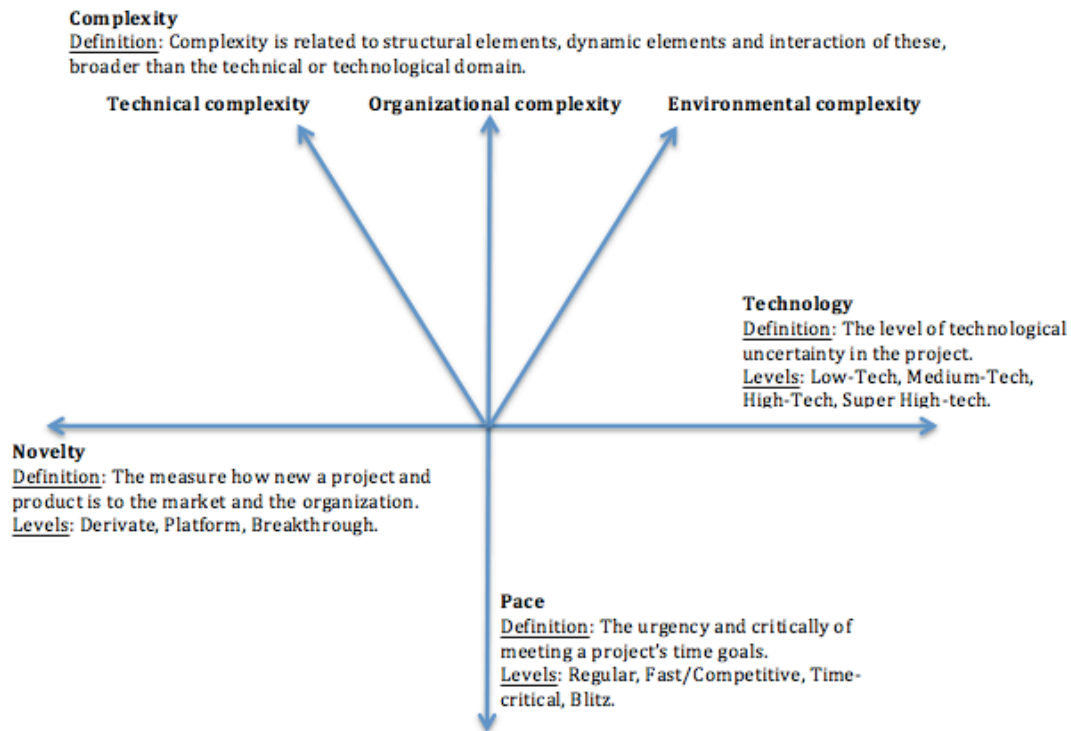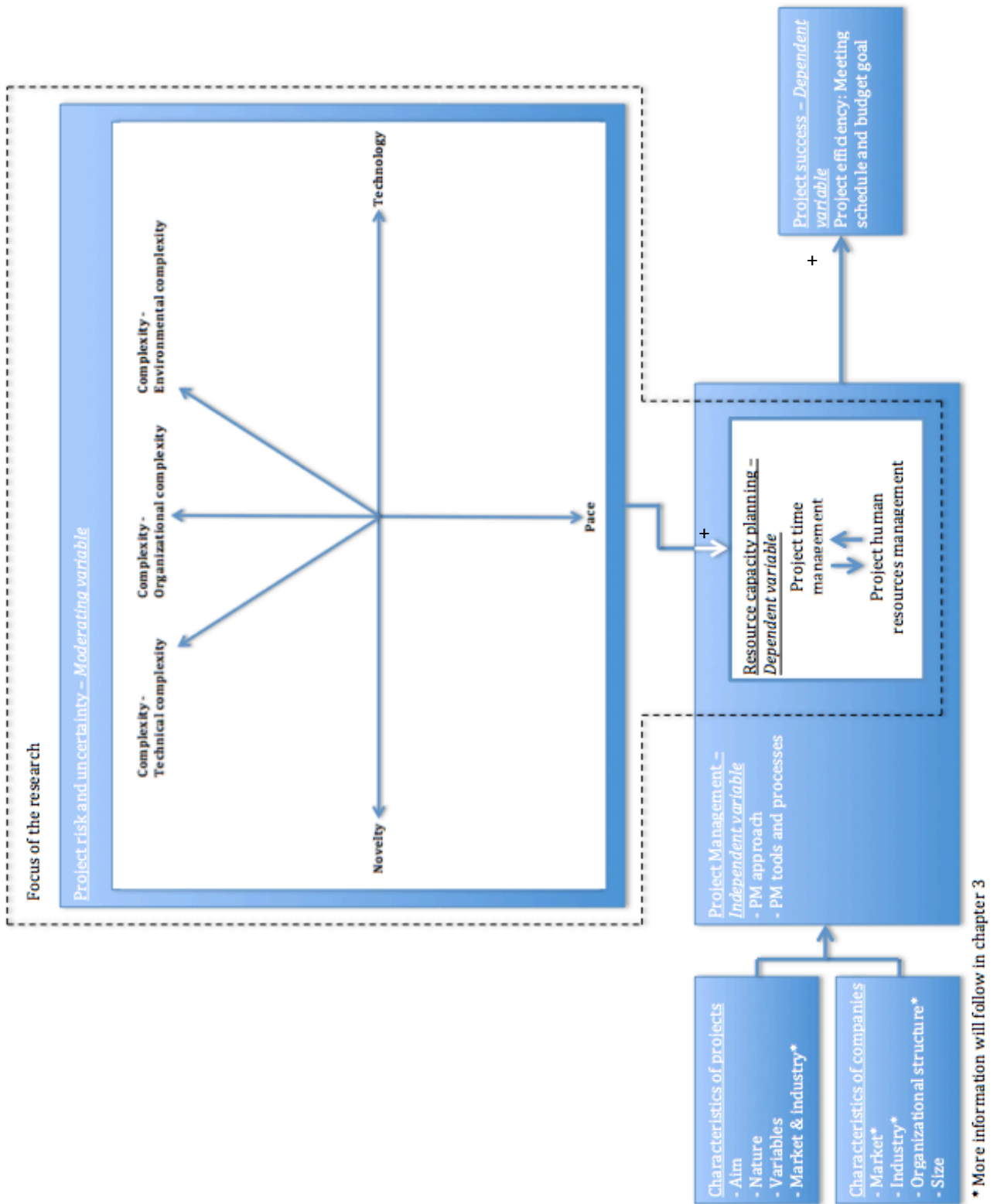
Complexity
Definition: Complexity is related to structural elements, dynamic elements and interaction of these, broader than the technical or technological domain.

Technical complexity **Organizational complexity** **Environmental complexity**

Technology
Definition: The level of technological uncertainty in the project.
Levels: Low-Tech, Medium-Tech, High-Tech, Super High-tech.

Novelty
Definition: The measure how new a project and product is to the market and the organization.
Levels: Derivate, Platform, Breakthrough.

Pace
Definition: The urgency and critically of meeting a project's time goals.
Levels: Regular, Fast/Competitive, Time-critical, Blitz.

Figure 8 Framework for project risk and uncertainty used in this research

2.4   Conclusions and theoretical framework

Chapter 2.1 of this chapter has shown that project planning can be considered a subset of the project management practices. For the purpose of this research project planning is broken down into 'project time management' (timespan) and 'project human resource management' (resource hours). The main focus of the research is to investigate how project risk and uncertainty, presented in chapter 2.3, can improve this project planning. To be able to do this a framework for assessing a project on its risk and uncertainty was constructed. This framework was presented in Figure 8.

To place the focus of this research in a certain context a few other conclusions will shortly be mentioned. Chapter 2.1 has furthermore shown that project management is executed through the use of certain tools and processes and is often organized in a certain project management approach. In itself project management is influenced by the characteristics of the company and the project. Finally chapter 2.2 has concluded that project success will be defined for the purpose of this research as project efficiency; Meeting schedule and budget goal.

All these conclusions are graphically summarised in the theoretical framework in Figure 9. This framework will be the foundation for the research. The focus of the research is indicated as the area within the dotted line.

Focus of the research

Project risk and uncertainty – *Moderating variable*

Complexity - Technical complexity

Complexity - Organizational complexity

Complexity - Environmental complexity

Novelty

Technology

Pace

Project Management – *Independent variable*
- PM approach
- PM tools and processes

Resource capacity planning – *Dependent variable*

Project time management

Project human resources management

+

Project success – *Dependent variable*
Project efficiency: Meeting schedule and budget goal

+

Characteristics of projects
- Aim
- Nature
- Variables
- Market & industry*

Characteristics of companies
- Market*
- Industry*
- Organizational structure*
- Size

* More information will follow in chapter 3

Figure 9 Theoretical framework

3 The research in an organizational context

To make this research generalizable it will need to be focussed on and studied for a specific group of companies. This group of companies will be named the 'research domain'. This chapter will shortly introduce this domain in chapter 3.1. Chapter 3.2 will introduce the company in which the case studies will be performed and this company will be analysed on the basis of the theoretical background presented in the previous chapter.

3.1 Research domain: PBO and CoPS

As already introduced in chapter 1 this research aims to be generalizable for a specific group of company: project-based organizations (PBO) that develop complex product systems (CoPS). To understand the organizational dynamics, and the characteristics of the projects these organizations execute, the two concepts will be shortly introduced.

3.1.1 Project-based organizations

Organizations are structured in a certain way. The most traditional structure is a functional organization structure in which the organization is structured according to the main business functions (production, finance, R&D, marketing etc.). There are also more dynamic structures known as matrix structures, in which some functions overlap all the different functional departments. A third organizational structure is the project-based (also known as project-oriented) structure. In a project-based organizations (PBO) the projects are the main business mechanism and these projects embody most of the business functions normally carried out by departments of functional or matrix organizations. The PBO "creates and recreates new organizational structures around the needs of each product and each customer" (Hobday, 2000). By doing this, the PBO ensures, among other things, organizational flexibility and concentration on complex problems (Gareis, 1991). Furthermore, PBOs have the potential to "foster innovation and promote effective project leadership across the business functions" (Hobday, 2000). On the other hand, PBOs are inherently weak where the more functional structures are strong, in coordinating processes, resources and capabilities across the organization as a whole. Success in projects does not necessarily enable the organization to continue executing projects successfully. It has been shown that the PBO has a problem of learning-closure around major projects, "as there were no structures or incentives in the PBO for cross-project learning" (Hobday, 2000).

3.1.2 Complex product systems

In the 1990's a new field of innovation research developed around the theme 'Complex Product Systems' (CoPS). CoPS are defined as "high cost, engineering-intensive products, systems, networks and constructs" (Hobday, 1998). They are usually made out of many interconnected, often customized, parts and are usually produced within projects that deliver small bathes or single units. Also CoPS projects are always executed within a large web of stakeholders that are directly involved in the processes of the project (Hobday & Rush, 1999). The CoPS projects are usually considered unique. Davies & Brady (2000) on the other hand introduce the concept of 'project capabilities'. This concept refers to the ability to create organizational learning from the first bid in a new domain of business onwards. By putting in place organizational changes, routines and learning procedures a firm can achieve 'economies of repetition' making similar projects more effective and less costly (Davies & Brady, 2000). The CoPS are usually produced for one specific customer. These customers are either businesses (business-to-business) or governmental organizations (business-to-government) and seldom consumers.

A number of examples of CoPS are aircraft engines, clean rooms for semiconductors, offshore oil production platforms, robotics equipment and road traffic management systems (Hobday, 1998).

3.2 Relating the case study company to the theory

As mentioned in chapter 1, the case studies (chapter 4) will be performed in a medium-sized project-based organization that develops intelligent transport systems. This company will be introduced in this subchapter and the theoretical background of chapter 2 will be related to this company. This chapter has been developed on the basis of observations.

3.2.1 Project management and project planning

The company adopted a standardized PM approach. The used approach is the well-known PRINCE2 approach. All of their project managers are trained on this approach and are accredited as a PRINCE2 project manager.

PRINCE2 has been developed in the UK by a governmental agency in 1996 as a process-driven PM method (ILX Group, 2013). The official PRINCE2 manual by the Office of Government Commerce (2009) argues that there are six variables in any project that lead to project performance (costs, timescale, quality, scope, risk and benefits). These six aspects of project performance need to be managed. PRINCE2 does this in seven different processes (Figure 10). Each of these processes has a number of predetermined key activities that need to be fulfilled in that stage (Office of Government Commerce, 2009).
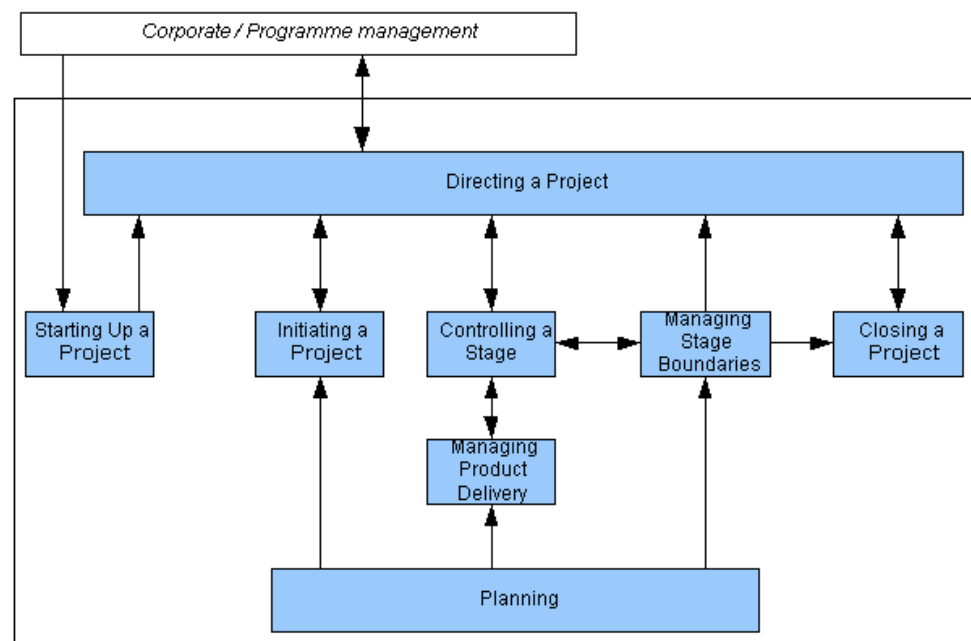
Figure 10 Overview of the PRINCE2 approach (Wikipedia.com, 2013)

Front-end of a project there are a series of steps taken by the organization. These steps are part of the PRINCE2 procedure. Because the front-end stage is important for the purpose of this research, they will be shortly introduced:

- When an invitation for the bidding on a tender arrives, a bid team is appointed. This team consists of sales representatives as well as specialists in the field of project management and technology. This team develops estimations on the required parts and resources. This leads to a cost/benefit calculation on which the offer will be based. The offer is made in full and presented to the potential customer.
- When a tender is won or the offer is accepted, the sales department makes a "Project Brief" (PB). This PB is a two-page document in which the most important information is explained: Customer, Objectives, end date, key deliverables,

cost/benefit, roles and responsibilities within the organization etc.). This document is hand over to the responsible project manager.

- The assigned project manager's first task is to write a "Project Initiation Document" (PID). This document resembles the set-up of the project brief, but is much more detailed. It involves a planning in which on a monthly basis is planned what activities need to be executed and how many hours of which function groups are needed for these activities. Also the cost benefit analysis is much more detailed and it is calculated how the CBA of the project brief differs from the version in the PID. This is a way of encouraging organizational learning through feedback. Furthermore information on the project board, project approach, controls, risk contingency and communication are given in the PID.

When the project is initiated and the project team starts working each individual employee needs to do their hour administration in which they specify how many hours were used for what activity and for which project. On the basis of the progress of the project and the upcoming deliverables the project manager gives a weekly prognoses of the human resources he is going to need for the upcoming four weeks. Top management eventually decides how the human resources will be divided over the projects in the company's portfolio. Overall resource utilization is evaluated, but the distribution over time compared with the initial planning is not.

3.2.2 Risk and uncertainty
The four dimensions of risk and uncertainty that have been explained in chapter 2 will be related to the case study company.

Novelty
Within the company the dimension of novelty mainly refers to how new the product system is to 1) the company, the project manager and the project team and 2) the customer. When the product is unknown to the customer the requirements are usually not clear at the beginning of the project. The customer has an idea what they want, but does not really know this precise. This can lead to time overrun at the initiation phase, but also at closing since last minute adjustments need to be done on the system to fit the changes in requirements. Novelty with respect to the organization and project team will lead to uncertainty in the processes, methods and activities that need to be used or executed. This can put extra pressure on the project team during the execution of the project.

Within the case study company projects can be on any level within the dimension of novelty. Some projects are very well known and are therefore derivative, but other projects are both completely new for the organization as well as the client.

Technology
All projects within the case study company have a lot of IT embedded in them. There is also a lot of integration work between software and hardware systems. A lot of the software programming within the projects is outsourced to a daughter company. When the level of technology becomes higher there will be more interaction with this outsourcing company. Individual parts of the project will have constant iterations of design, build and test of which the 'build' is often outsourced (at least for the software side). The constant interaction and communication will cost a lot of time and will pressure the team especially when the deadline approaches.

The projects within the case study company are never low-tech or super high-tech. It will almost always be either medium-tech or high-tech.

Complexity

As been said in chapter 2 it is the expectation that when the complexity of a project increases the amount and severity of the resource peaks and fluctuations in the human resources can be observed. All these fluctuations and peaks have different causes in different projects. Assessing the level of complexity and the consequences of this complexity on the resource capacity planning is therefore the most difficult task in this research. On the basis of the 40 factors mentioned in by Bosch Rekveldt *et al.* (2011) and the TOE framework that led from this a list has been constructed for factors that can lead to complexity in CoPS projects (Table 7). This list will be tested and supplemented during the case study and the effect of these individual factors on the resource capacity planning will be studied.

Table 7 Potential factors that lead to complexity in CoPS projects

Technical	Organizational	Environmental
Size of the project	Size of the project team	Number of stakeholders involved
Clarity of the goals and requirements of the project	Experience of the individual member of the project team	Involvement of the customer during the project execution
Dependency between individual tasks	Experience of the project team in working together	Experience with the customer
Number of deliverables and deadlines	Experience of the project manager	Experience with the suppliers
Total duration of the project	Internal support in the company	Number of different suppliers
Availability of skills	Number of different functions in the project team	Dependencies on other stakeholders
Clarity of the scope of the project	Pressure on the project team due to other involved projects	Dominance of rules and regulations
Number of different tasks that have to be executed	Trust in project team	Trust in the involved stakeholders

The projects within the company are foremost B2G projects and always rely on dependencies of stakeholders. Generally the projects will have a level of complexity that resembles the "Platform" level of Shenhar & Dvir (2007). But few of the projects can either have a much higher degree of complexity or lower. Therefore the projects range over entire scale of complexity.

Pace

Usually the projects in the case study research come with a clear deadline. Often penalty clauses are part of the project contract. This means that when a project is past its deadline often very high fines need to be paid. However, this does not apply when time overrun is caused by the changes in the scope/requirements of the project.

Projects within the company can be on every level of pace. Nevertheless the projects will usually be fast/competitive or time-critical and seldom regular or blitz.

3.3   Conclusions

This thesis research focuses on project-based organizations that produce and deliver complex product systems. This is an interesting research domain, because due to the characteristics of these companies the projects are susceptible to a large degree of risk and uncertainty. The case study company is also expected to range on all different dimensions of the framework for project risk and uncertainty.

4   Case studies

This chapter will explain the case studies that have been performed for the purpose of this research. The chapter will proceed as follows: First the approach of the case study will be explained, including the case study selection, design and protocol. Subsequently each of the individual case groups will be explained in a different subchapter. For each of these case groups a small description is given, the results of the projects document analysis and the results of the interviews are given per case and finally a general conclusion for the group of cases is presented.

4.1   Case study approach

4.1.1   Methods

The gathering of empirical data for this research will be done with a case study methodology. This methodology is chosen because it enables to study a contemporary phenomenon in a real-life situation in which the researcher has little control (Yin, 2002). It will study the same phenomenon within the boundaries of several cases (multiple case study) and it will also investigate how this phenomenon differs from or corresponds with the different cases (cross-case analysis, presented in chapter 6) (Dooley, 2002).

4.1.2   Case selection

To maximize the amount of information that could be obtained from the case studies, a case selection was performed to selected specific cases out of the entire portfolio of completed projects of the studied company. The cases were chosen to be very different from one another, so that information could be gathered from a large range of different circumstances. The different cases were selected on a set of criteria in which the total group of projects should range:

- Functional scope of the project;
- Time-span of the project;
- Total number of utilized hours;
- Estimated complexity;
- Estimated level of technology;
- Estimated level of novelty;
- Estimated pace;
- Internal perception of the success of the project.

The cases that were selected on basis of the criteria were then filtered on usefulness. This was done on three criteria:

- The project should have been officially finished and closed by the project manager, because otherwise it would be unclear if all aspects of that project could be taken into account.
- The project should have been executed recently. The criterion for this was projects executed between 2008 and present. The reason for this was that the interviewee should be able to recollect their memories from the project correctly. When this project manager managed the project too long ago this could become very difficult.
- There should be enough information available to the researcher in the form of written information. Also the project manager should still be employed at the company.

On the basis of both groups of criteria 23 projects were selected. These cases were divided over five different function groups on the basis of functional scope. The results of the cases

of each case group will be presented in subchapter 4.2 t/m 4.6. In these subchapters the case groups will be shortly introduced, the results of the individual case studies will be provided and an overall conclusion for the case group will be presented. The cases are divided over the following 5 case groups:

- Case group 1: Measuring campaigns; 4 cases; subchapter 4.2
- Case group 2: Dynamic information displays, 7 cases; subchapter 4.3
- Case group 3: Real-time detection, 4 cases; subchapter 4.4
- Case group 4: Product development or improvement; 4 cases; subchapter 4.5
- Case group 5: Congestion avoidance; 4 cases; subchapter 4.6.

4.1.3   Case study design
The case studies will take an individual project as the unit of analysis. These can be either internal projects or external projects of different magnitudes and with different characteristics. It will focus on all activities from initiation of the project by the project manager to the closing of the project. It will not incorporate any activities executed for the acquisition of the project done by the sales division. Each case consists of 1) document analysis of this project, in which data on resourcing and utilized hours is acquired, made visible and studied, and 2) a semi-structured interview with the project manager of that project. Some of the project managers have managed several of the studied projects; therefore the number of projects will not equal the number of conducted interviews. However, all of the projects will be covered with the conducted interviews. Descriptions of the studied cases can be found in Appendix A.

4.1.4   Case study protocol
For each of the cases the first step was to acquire data on the utilized hours of the resources in the project. This data was acquired using the project administration software "Qicstime". The data was processed in such a way that it became transparent to the researcher and graphs of each project were made (Appendix C to G). Observations on the basis of these graphs were noted (Appendix H to L). Besides the information on the utilized hours the Product Initiation Documents of the projects were studied when possible. All this information was used as preparation for the interviews and as input in the interviews. It was also used to focus the interviews on the relevant aspects of the projects.

It needs to be noted that the project administration information may be susceptible to a small bias. On basis of observations within the studied company it can be concluded that it differs from employee to employee how precise the hour administration is done. Some employees treat this with less precision than other employees. However, it is assumed that the overall fluctuations in the resource hours can still be used as input for this research.

For the interviews a list of project managers was constructed on the basis of the analysed projects. These project managers were approached to schedule an interview and all of them were willing to participate in the research. Before starting the interviews a list of 55 interview questions was made as the basis for every interview. These questions can be found in Appendix M. The questions were divided over 10 groups of questions that were related on the basis of the content. To minimize bias in the questions on risks and uncertainties the first question for the question group "novelty", "technology", "complexity" and "pace" was to what extent these dimensions influenced the project. After the participants answered this question the interview would go into specific factors of each dimension. The intention with this set up was to reduce the suggestiveness of the questions.

During every interview notes were made and minutes were produced just after the interview. The interviewed project manager checked the produced minutes. In some cases interview questions did not apply to the research or could not be answered by the interviewee. Also it needs to be noted that setting in some interviews was more rushed than in other interviews and some interviewees were more sceptical about the research. However, all the interviewees have answered all the questions that could be answered and therefore it was not necessary to discard interviews on the basis of potential harm to the validity of the research.

4.2 Case group 1: Measuring campaign

4.2.1 Description of the case group

Measuring campaigns are typically very short projects that serve to measure traffic or transport related issues. These could be for instance the traffic flow on a specific road segment over the course of a week. The deliverable of such a project is a report in which the measuring results are presented and explained to the client. The client could use this information for decision making surrounding infrastructural projects. For the case study company such a project would entail designing a measuring approach, the installation and testing of measuring devices, acquiring the needed data by means of the measurements, analysing the data and finally developing and delivering a report.

This case group consists of four projects. The first three are clear examples of a measuring campaign. The fourth was more a data analysis project. It has been decided to place this project in this group due to the apparent straightforward character of the project. All graphs with the distribution of the utilized resource hours can be found in Appendix C. A short analysis of this distribution can be found in Appendix H and in Appendix N some comments on the resource distribution can be found. An explanation of the function groups can be found in Appendix B.

4.2.2 Results of the case study of group 1

Case 1.1

When looking at the hours utilized in this project there are a couple of observations that can be done. There is a project management peak at initiation followed by a smaller data analyst peak. The hours drop in the weeks thereafter and eventually reach a 'large' data analyst peak. After this it takes an additional 3 months before the project is closed.

The project is based on technology that was developed by the company prior to this project. Although there was not a lot of experience with deploying this technology it can be considered a rollout project and the 'measuring campaign' solution had also no degree of novelty. Although a deadline was set, the pace was relatively low. What led to (internal) complexity is that a project manager started with this project and after a very short period (2 weeks) the project was transferred to a project assistant who was assigned as project manager. The fact that work had to be redone and the relative inexperience of the new manager led to an overrun in project management hours. A lack of pressure for the results at the client's side has led the large 'tail' at the end. The front-end planning for this project can be considered realistic, but there were too little project manager's hours planned. The experience of the project manager was not taken into account in the planning

Case 1.2

A couple of observations can be done when analysing the graphs. The project starts with a project management peak, followed by a peak of both project management and data analyst. After a small dip a large data analyst peak is visible. After the peak the project continues with small effort for another 2 months.

The project is a very common measuring campaign based on one of the most well known technologies of the company; a rollout project. The scope of the project is also not new for the company. There was however some degree of pace since the measurements needed to be done at set dates not long after initiation. This meant that everything had to be installed and tested before these dates. What led to complexity was internally the same as with case 1.1 (they ran along side each other). At the final phase of the project additional effort had to be invested to get the report up to the required standards. This results in a 'tail' in the resource hours. Comparable with case 1.1, the project planning was realistic except for the project management hours, which were underestimated.

Case 1.3

Two observations can be done from the graphs of this case. An initiation peak is visible that last for four weeks, as well as a large data analyst peak. In between these peaks activity is low. It takes approximately two months before the project is closed after the large peak.

The technology is the same as in case 1.2 and thus very well known. In terms of novelty this specific solution did not appear to be novel, but for this specific scope a new system had to be thought out. In terms of complexity this project was quite complex. The initial scope set by the client raised ethical concerns and also this could not be achieved with the technical system. This led to long discussions on the scope, which eventually led to a scope change. Also the location was unknown and because of the pace of the project, no location research was done, this led to complications with the installation. Additional effort and time needed to be invested to get to the final version of the report in this project. This can be observed in the final stage of the project. In terms of pace the project was relatively high-paced. The complexity eventually led to an hour overrun during the initiation and installation phase. For this project no front-end resource planning over time was made, so it is therefore difficult to say if this planning would have been realistic.

Case 1.4

The graphs indicate primarily a very dynamic pattern of resource hours. Also a tail of two months is visible.

As explained in chapter 5.2.1 this project differs from the other three as being not really a measuring campaign. It was a project that appeared to be very simple, but was never done before. This degree of novelty was accompanied by several factors that led to complexity. The project lacked a normal initiation phase and went directly to a data analyst. After some initial effort it turned out that the initial set scope was not possible with the data that was provided. This led to a discussion on a new scope for the project. Also the resources assigned to this project were only limited available. Additionally the pace was very low (no real deadline), which made this project drag along for a long time. Eventually the pace was increased (internal deadline was set) in order to finish up the project. The tail at the end had to do with client acceptation that took longer than anticipated. Comparable with case 1.3, no front-end resource planning over time was made in this project.

4.2.3 Conclusions case group 1

Projects like these measurement campaigns are an interesting addition to the portfolio, with a well-known solution and a technical system that has been implemented before. It might also be interesting as learning project for new resources. However, these projects are too small to take a lot risks. Therefore it should be known precisely what the scope of such projects is.

In terms of planning they rely on limited resources (2 or 3) and they all go through the same phases (initiation, installation, measuring, data analysis and reporting). These should be easily predictable and therefore be easy to plan. From the cases it shows that when the

uncertainty increases a shift in the phases (phases may take longer) is visible and an overrun in resource hours is experienced.

Front-end assessment of the four dimensions of uncertainty for 'measuring campaign' projects can have two uses. First, it can help determining if taking on the project is a smart decision. It can easily determine if the (small) project is not susceptible to too much uncertainty. Second, it can help with planning of the resources. It will give an indication in what phases a potential buffer in hours or time is needed.

4.3 Case group 2: Dynamic information displays

4.3.1 Description of the case group

This group of cases consists of projects in which travel information displays are produced, installed and operated. These are displays that provide public transportation travellers with dynamic information on how long it will take before their train or bus will arrive. These projects roughly entail 1) the development of an IT environment that creates useful information on the expected arrival time of a bus or train on basis of certain input and sends this information to displays, 2) the development of these displays (often in collaboration with a partner), 3) testing of the solution and 4) finalizing and delivering the project. After this a long term contract for maintenance and IT support starts (this is not part of the analysed project). A total of 7 projects have been analysed in this group of cases.

All graphs with the distribution of the utilized resource hours of this case group can be found in Appendix D, a short analysis of these graphs can be found in Appendix I, and some comments on the graphs can be found in Appendix N.

4.3.2 Results of the case study group 2

Case 2.1

The graphs of this case show a lot of system development hours. These hours primarily cluster around a long lasting peak in the first half of the project and a peak towards the end of the project.

The scope of this project resembled several other information display projects executed prior to this one. However, it entailed new displays that the company had never worked with. In terms of technology the project was primarily software development (and a very small part hardware). The development itself was not very challenging, but there was a lot of testing involved because of the unknown displays. Due to this, the outsourcing of the software development also became complicated and the coordination took more effort.

In this project the system developer also had taken on most of the project management tasks. It could be argued that the lack of experience has cost an overrun of hours. Technically the project was quite complex. A company that was bankrupt once made the displays and detailed documentation was not available. This meant that the software had to be tailor made for a system that nobody knew. Also the company was not familiar with the local infrastructure (energy, cables etc.) on the site, for which documentation was also not available at the customer. A lot of time had to be spent on testing the system and working on site. This has cost a lot of development time. The pace of the project was relatively low. Due to factors outside the fault of the company the first deadline was not met. After failing to meet this deadline the pressure on the project decreased.

The project planning made for this project is not considered to be realistic. There were too few hours planned given the uncertainties. Therefore the execution of the project went over the planning.

Case 2.2

The graphs of case 2.2 show two large development peaks at the beginning of the project. After the peaks the project runs for almost another two years in which the systems were

delivered in clusters. In this period only project management hours would be expected, but there were also system developer hours utilized.

The system that needed to be developed strongly resembled another information display project executed prior to this one. The development work was nevertheless extensive, but not very challenging. However, when the software was developed it was not up to the required standards. This resulted in extra work that had to be performed in-house. The outsourced development team responsible for the software development did not have the required experience, which led to a suboptimal system. A partner developed the displays in this project and therefore the involved (technical) complexity was primarily situated at the side of this partner. For the case study company the project was not very complex. The pace of the project was, especially at the beginning, very high. Large penalties would be given if a deadline would not be met. The planning made for this project is not considered to be realistic for the resource hours. The project utilized more hours than planned in the initial resource planning.

Case 2.3

The graphs show a lot of fluctuations in both the development and project management hours. The hours lead up to several peaks in the resourcing.

This project entailed a large amount of small displays. These displays were a bit different from the ones worked with before in terms of energy consumption. Because of this a complete new software system had to be designed and developed. But the problems in this project were primarily caused by different factors that led to complexity. The project started of with a different project manager who left the organization. This caused some organizational complexity. The client hired a project management consultant that required a lot of managerial attention. This made the project environmentally complex and this cost a lot of project management hours. Technically this project had a lot of potential risk because it was very uncertain if the promises made about the energy consumption could be met. Additionally, a partner delivered the entire hardware, including control unit. Since the case study company developed the hardware for the controllers, there was a lot of communication on the system. The pace of the project was very high and the deadlines were very strict, but most of this pressure was put on the partner developing the displays. When considering the project planning, the first phase corresponded with the planned resource hours and time, but after this phase a deviation from the initial project planning was experienced.

Case 2.4

The graphs of this case show a couple of peaks of system developer hours. The utilized hours fluctuate strongly over the time span of the project. The project management hours remain relatively stable, but increase towards the end.

This project very much resembled the project of case 2.2, it had only a few minor changes in the scope (almost a rollout project). However, internally the decision was made to update the back-end of the system. Updating this back-end system caused for some challenges. This was primarily due to the development work that was done at the outsourcing company. This team had only minor experience with such projects. When the system came back from the outsourcing partner it required additional in-house development work. This has cost more time and hours than anticipated.

The project was not very complex. The internal project team was small and experienced; communication with client and stakeholders went well and technical complexity did not arise for the company. Due to the high pace of the project, some time goals were not met. This did however not lead to any penalties.

In hindsight, the project manager of this project does not consider the project planning made at project initiation realistic.

Case 2.5

The graphs show a small initiation peak and a very large peak after the development, which lasts for a few months. This peak is very long and intensive acceptance phase.

This should have been a very small (pilot) project, but it turned out to be very complicated. The project itself was not very novel, but it included new elements. For instance the type of displays that were used were new for the organization. The development work in the project was not very complicated and it can be considered medium-tech at most. The outsourcing partner subcontracted a part of the development work to a third company, due to a lack of resources. This led to very difficult web of communication and responsibility.

There were several things that led to complexity in this project. Although internally this project was considered a pilot project, the client demanded a lot of attention. This required the utilization of (relatively) a lot of project management hours. The client also did not want to sign a service contract, which made it necessary to use the client's server. This was an impossible task since their IT personnel needed to be trained for maintaining this system. All these elements made that there was internally very little support for the project.

The initial deadlines were fast-paced and also not met due to the explained complications. This did not lead to any consequences.

Case 2.6

The graphs show primarily project management hours. The largest part of these hours was utilized around a peak at the start of the project. In the rest of the project the hours remain low and relatively stable.

This project was a part of larger project (not incorporated in the case studies). It involved the rollout of a series of information display systems. Nothing had to be developed and the project team knew everything. Both for novelty and technology it can be considered a rollout project. There were, however, a couple of things that led to complexity in this project. Because in this project the display partner was a supplier instead of a co-developer, the installation work was the responsibility of the case study company. Some parts of the installation were outsourced to a new installation company. Due to additional effort for coordination, this cost some extra coordination effort. Also the project has had three project managers over the time span, which also led to extra project management effort. The pace was relatively high and it had a bonus structure as incentive to meet certain deadlines. The project did not receive any bonuses or penalties. The front-end project planning is considered to be realistic in this project. Although there were some (unplanned) time delays during installation, the overall planning did correspond for a large degree with the project execution.

Case 2.7

The graphs show a large development peak in the beginning of the project and a smaller development peak just over half the project. The project management hours fluctuate over the time span, but remain under the 50 hours/month.

This project was a precursor of case 2.3. In this project the entire system (hardware, software and installation) was done by the case study company without a partner. This was not entirely new, but it did involve some new challenges that had to be faced. The individual components were made (in a slightly different form) for other projects, but combining everything in this way was new. So there was definitely a degree of novelty. This also goes for technology. Both the hardware and software had to be designed and developed and a prototype needed to be made. It wasn't high-tech, but certainly medium-tech. The project was technically quite complex. An energy solution with a battery stored in the ground led to challenges during installation and operation. Also, there were many stakeholders involved in this project. Especially during installation this often led to delays. The planning in this project is considered to be realistic.

4.3.3 Conclusions case group 2

Despite the fact the information panel solutions have been developed many times within the company and that the project teams are often small and experienced, the projects often lack the desired result. The different case studies indicate different reasons for this. There are several reoccurring issues in these projects:

- Due to several reasons the internal knowledge transfer at the outsourced software development company is limited. This means that the wheel has to be reinvented in new projects. The result is that often more time needs to be invested in developing the software at the outsourcing company. When the software is eventually delivered, often additional hours and time need to be invested to meet the set requirements.
- The displays often have to be installed at remote locations. This generates challenges in the designing of the system and the installation of the panels. This technical complexity is often on the site of the display partner, but it has still consequences for the planning of the case study company due to dependencies. This factor is often underestimated.
- Because the scope of the information panel projects often includes the delivery and installation of a large amount of systems (in clusters), the time span of the projects is often very long. This means that resources have to be committed for a very long time, which is challenging.

These elements along with the fact that there are often quite some stakeholder involved in these projects gives the information panel projects uncertainty. Keeping a clear overview of these projects, expectation management towards the client and overall stakeholder management (including the technical development) are very important elements in such projects.

4.4 Case group 3: Real-time detection

4.4.1 Description of the case group

This group consist of projects that generate real-time information on traffic and transport by means of detection devices. This information can be on, for instance, the amount of transport units, the speed of the individual units, the amount of units (trucks) that carry a dangerous load, and the weight of individual units. This information is often used for enforcement when road users go beyond a certain threshold or drive somewhere they are not allowed, but it is also used by clients to react on, for instance, congestion. These projects entail the design of a system that receives signals from hardware (loops or cameras), processes this information and delivers this to a back-end in which the client gets the information. These systems are tested and these projects are documented and finalized. Also these projects involve long-time contracts for maintenance and IT support, but these are not part of analysed projects.

This group of cases consist of four projects that are different from one another in terms of scope, but are all based on the explained principal. All graphs with the distribution of the utilized resource hours of this case group can be found in Appendix E, a short analysis of these graphs can be found in Appendix J, and some comments on the graphs can be found in Appendix N.

4.4.2 Results of the case study group 3

Case 3.1

The graphs show that this project starts with a large resource peak consisting of project management and development hours. This peak remains for approximately 5 to 6 months. After this the resource hours drop, but activity remains for a year.

This project was a totally new product group/solution for the case study company. It has been developed from both totally newly developed parts as well as (altered) "off-the-shelf" parts. Therefore both on novelty and technology this project ranges high, but not the highest level possible. During the development stage there was quite a degree of pressure on the resources to reach the time-goal, which was in turn a very strict goal. Therefore the pace of the project was quite fast. In terms of complexity there was especially a lot of technical complexity. A couple of factors mentioned were:

- The location of the project asked for physical presence when work on the system had to be done.
- Some of the work had to be outsourced to another company. It took a time tong before the project team acknowledged this.
- The specific solution required high quality detection cameras. The supplied cameras could not meet these requirements.

Also on an organizational level complexity did arise due to the change in project management half way and finally on an environmental level complexity arose in the closing of the project.

The interviewed project manager was not part of the planning phase of this project and has never seen this planning. However, due the direct result of the project, an initial planning could not have been realistic.

Case 3.2

When analysing the graphs one large resource peak just after the start of the project can be observed. After this peak the project continues for another 4/5 months. Especially system architect hours were utilized in this project.

From the interview it became clear that the project was a previously developed technical system that was sold as a product to a foreign customer. The project was considered as a pilot project. In terms of novelty it was however not an off-the-shelf project. The technical system needed some design work to customize the solution and also some new features were incorporated. Technically it was therefore considered low-tech to medium-tech. In terms of environmental complexity the fact that the client was situated abroad made communication more difficult and which made expectation management more difficult. Also the technical development was outsourced to two companies. The companies could not communicate with each other and this led to responsibility and interpretation issues. Another factor that made the project technically complex is the fact that no English manual for the hardware installation was available. This needed to be made during the project, which consumed quite some time. Finally, the pace was relatively low. Although there was a deadline it was not very difficult to meet this deadline.

Case 3.3

The graphs show (almost) only one single line of system development hours. This line fluctuates in the amount of hours over the entire time span of the project.

This project was a relatively small project that only consisted of software development. This was entirely done by the outsourcing partner and this development team was managed from the case study company by a system developer. The specific solution that was developed was new, but systems that resembled this were developed in the past. Therefore

it was not very novel. Also the technology was based on something that has been developed several times in the past, but this time with small alterations. It was not a very complex project. The stakeholders were limited and the development team had a good project manager. These factors facilitated the project management tasks and therefore a system developer without a lot of project management experience could lead the project. There was some degree of time pressure on the first part of the project, but over the whole project the pace was quite low. There was never a project planning made for this project by the project manager, partly because there was only one person working on this project. However, during the bid phase a planning was made. The execution of the project stayed within this planning.

Case 3.4
The graphs show an unusual pattern of resource hours. It starts of with a small peak of developer and project management hours. In the six months that follow this peak there is almost no work. Eventually, 9 months after initiation, a large resource peak is visible consisting of both PM and system developer hours (for approximately 5 months). It takes an additional 5 months before the project was closed.

In terms of technology the project was about medium-tech. The individual elements (software, servers, hardware and integration) were not very complicated, but together it brought some degree of uncertainty. Also the pace can be considered medium. Although there was a clear deadline, the pressure on the resource to meet this deadline was limited. Both the novelty and the complexity are of a high level in this project. In terms of novelty the scope of the project was totally new. This degree of novelty has led to a large period of testing, acceptance and bug fixing. In terms of complexity there were many factors that have led to complexity. The handover from sales to operations was unclear and this has led to a misunderstanding of the scope. No project manager was assigned, which caused for a missing initiation phase. Furthermore the project has had three different clients over the total time span. All these factors made that the project did not have the internal support needed. Also another company co-developed the system and there were many different suppliers. All factors accumulated led to a lot of complexity on all three levels (technical, organizational and environmental).

4.4.3   Conclusions case group 3
The cases in this group range from very small to very large. This case group gives a clear overview of projects with different levels of novelty and technology. A few general conclusions can be made on basis of this group of four cases:

- The dimension of novelty clearly has an impact on the resourcing in the post-development phase. The more novel a certain solution is the longer (and more intensive) the period of testing, acceptation and the related bug fixing is.
- Physical presence on-sight for testing or development can have a delaying impact on the time-span of the project, but will also require more resource hours. This factor should be taken into account when setting up the planning as it might have a considerable impact.

4.5   Case group 4: Product development or improvement

4.5.1   Description of the case group
Many projects are based on the alteration of well-known soft- and hardware systems. It also occurs that new products for one specific project or a future range of projects are developed or that established products are improved. These projects are grouped in this case group. It is difficult to explain the typical process of such projects, because this is dependent on the

scope and aim of the individual projects. These projects either entail fundamental work in software development, hardware development or a combination of both.

Within this group, four cases were selected and analysed. All graphs with the distribution of the utilized resource hours of this case group can be found in Appendix F, a short analysis of these graphs can be found in Appendix K, and some comments on the graphs can be found in Appendix N.

4.5.2   Results of case study group 4

Case 4.1 and 4.2

These two projects are analysed together, because they are related to one another. Also many of the resource hours were administrated randomly between the two projects. From the graphs of both projects it can be observed that the project is divided into two parts: a relatively intensive period of five months consisting of project management, system architect, system developer and project support hours and a period of approximately eight months consisting of relatively few project management hours. It became clear from the interviews that the first part was the development part of the product and during the months that followed the product was produced and delivered to the client. The most important tasks in this second phase were communication and bug fixing.

Technology wise this was a medium tech project. The development work was not very complicated and most of the work was outsourced. Internally new firmware needed to be developed and there was a lot of integration work. The project also had a small degree of novelty. The concept of the product was already known, but new elements were introduced. Initially the project was medium-paced, but due to delays caused by the client pressure was gradually reduced. Finally in terms of complexity the project was primarily complex due to the number stakeholders that were involved (environmental). Internally (organizational) it did not have a lot of complexity.

In these projects no overall resource planning over time was made, therefore it is difficult to say if the execution went as expected.

Case 4.3

The graphs show two resource peaks. A small peak just after initiation and a larger resource peak in the second half of the project. The project consists of system architect and project management hours.

The project was a modification of a system previously developed by the company. Since the entire system was known by the project team, this modification was not particularly novel. For the same reasons this project was technologically not very challenging. But since the system needed to be certified there were very high demands on quality. The consequence of this was that still quite some testing and analysis by the developers had to be done in-house, after the system came back from the software development company, to assume that the deliverables met the requirements. In terms of complexity the project was organizationally not that complex. Environmentally there were several stakeholders involved that needed to be managed which off course required managerial effort. What made it technically complex is that this modification needed to be implemented in an operational system. Therefore simulations had to be made for testing the system. Also the required certification made it slightly more complex. Lastly, although there was a deadline, the time pressure was relatively low. Also, the project did not involve any possible penalties. The project manager considers the project planning made during initiation realistic.

Case 4.4

When analysing the graphs of this project there is an immediate peak visible consisting of system architect, system developer and project management hours. After approximately 3

months the hours of the resources reduce almost to zero. It takes a very long time before the project eventually is closed.

In terms of technology it was a high-tech project. Some of the requirements to deliver the goal were never done before and involved development of new systems. The combination of hardware and software was also quite complicated. Because such a project was also never executed before, it also ranges high on the novelty dimension. Furthermore, the project team only had 2/3 months to deliver the project and therefore it was also very high-paced. The project team worked almost dedicated on this project throughout the development phase. In terms of complexity the project was quite orderly. The requirements were clear and the project team was very experienced. There were suppliers and the project was co-developed by another contractor. This could have potentially led to complexity, but this was not experienced.

4.5.3 Conclusions case group 4

It is difficult to develop general conclusions for this case group since the different projects range high to low in almost all dimensions on the basis of the different characteristics of each project. Alterations of an existing product can be very easy for the organization or may be very complex. When a completely new project has to be developed the project is obviously very novel, even if the product resembles existing products developed by the organization. The requirements of the new product will create unforeseen difficulties during development. Also, there is almost always a large degree of software development involved in these projects. Because of the novel element in the projects the development work has to be done either in-house or a lot of effort has to be given to coordinating the outsourcing partner. Furthermore attention has to be given to the required level of quality and the amount of stakeholders involved in the project.

4.6 Case group 5: Congestion avoidance

4.6.1 Description of the case group

The final group of cases are congestion avoidance projects. These are projects aimed at reducing the amount of traffic during rush hours. Basically these projects reward people who decide to leave the house earlier or later, stay at home or drive along with someone else in order to avoid the rush hour traffic. The short-term goal of such projects is to reduce the amount of traffic and the long-term goal is to change the habit of the road users.

The projects basically entail the development of a system that can register whether or not a car has been in traffic during the rush hours, the recruitment of participants, the communication with participants and the payment of the reward, and making the results insightful for the client. Generally congestion avoidance projects are relatively large projects in the portfolio of the case study company.

A total of four congestion avoidance projects have been studied in this group. All graphs with the distribution of the utilized resource hours of this case group can be found in Appendix G, a short analysis of these graphs can be found in Appendix L, and some comments on the graphs can be found in Appendix N.

4.6.2 Results of the case study group 5

Case 5.1

The graphs show a very large and extensive project consisting of a lot of resource hours and different function groups. Multiple resource peaks can be observed as well as high fluctuation both in the total amount of hours and the hours of the individual function groups. In terms of time span, this project is also among the longest of the projects analysed in this multiple case study.

The interviews (two different project managers interviewed) show also that this project had a lot of uncertainty on all dimensions:

- Novelty: the concept of congestion avoidance was not entirely new for the company, but the scope of this project was incredibly extensive and included elements that were completely new. It also involved 'soft' deliverables, which were difficult to measure and therefore experienced as difficult to manage.
- Technology: The scope of this project included technical elements known to the company, but also elements that were completely new. Above all it included the development of a high-tech product. There was also a large degree of system integration. Overall this project can be considered high-tech.
- Complexity:
  - Organizational complexity: There were a couple of elements that made this project organizationally very complex. The project team was very large, while at the same time the project manager also had to communicate with the customer extensively and frequently. This gave less room for internal coordination. Within the project team, team leaders were assigned to specific parts, some of them were very experienced and some lacked the required experience. Lastly, there were a couple of changes in project management at the start of the project; this made the start of the project challenging.
  - Environmental complexity: This complexity arose due to the large amount of stakeholders involved, which included among others new suppliers. What was very positive was that the project management consultants hired by the client, as well as the client, did have a positive attitude towards the project.
  - Technical complexity: The scope changed over time and included 'soft' goals that were difficult to grasp. Additionally, technical parts had to be installed in the cars of participants; this made the execution of the project dependent on the availability of all the participants. Also complexity did arise with the availability of parts form the suppliers at the desired moment.
- Pace: The pace was high due to several reasons. There was a lot of work even for the relatively long time span. During the project there were several scope changes, partly because of this the work became very dynamic. An extensive penalty structure would become active when deadlines would be missed.

The interviewed project managers in this project have not been involved in the initiation of the project and therefore also did not make an overall planning for this project. The managers also were never confronted with one. However, the project did utilize more resource hours than anticipated.

Case 5.2
When analysing the graphs and the interviews (two project managers were interviewed for this case) it becomes clear that this case has a lot of resemblance with case 5.1 in terms of uncertainty. There are however a few differences in the dimensions.
In terms of novelty the project could still be considered very novel. It did entail a different scope, but also a scope with soft goals that were difficult to manage for the company. The client side in this project was also very new with the concept. Technology wise, the project was a bit less uncertain than case 5.1. Some technical parts in the scope of 5.1 were used in this project and therefore were not part of the scope of this project. The project was especially environmentally more complex than case 5.1. In this case the client hired a group of project managers to lead this project. They demanded a lot of managerial effort from and

were very suspicious towards the project execution. This negative attitude made the project management task very difficult. In terms of pace this project was comparable with case 5.1. As explained in case 5.1 the interviewed project managers have not been involved in the project planning of this project.

Case 5.3

The graphs of this case look different from the graphs of the other projects in case group 5. The project is executed over a shorter time span and the utilized hours were more stable. The hours do add up to a large resource peak half way the project, but this happens gradually over time.

Within the case study company this project is considered to be a successful congestion avoidance project. Some managerial changes in the setup of these projects may have contributed to this. This will be explained by analysing the dimensions of uncertainty:

- Novelty: It was a classical congestion avoidance project and therefore not very novel. But in these large projects there are always specific requirements that make every individual project a bit different. Therefore it had a small degree of novelty.
- Technology: The demanded technology of this project was not very uncertain, but still a lot of things needed to be developed. For the first time in these congestion avoidance projects the development work was outsourced. To react on the possible problems this may cause, one of the internal resources went over to the development company to coordinate the development task.
- Complexity:
  - o Organizational complexity: There were many things that could have led to organizational complexity. Primarily the project had a large project team and many different function groups were working on this project. To overcome this uncertainty a clear organizational chart was made with a clear communication hierarchy. Also one project manager was put solely on the internal part of this project. What did led to complexity however was that the project was managed by 2 different project managers at the start who had to stop after a certain time. This made the start chaotic.
  - o Environmental complexity: There were also factors that could have led to environmental complexity, but this was dealt with in a very good way. There were quite a large amount of stakeholders involved in this project for instance. One project manager was set on all the external relations, which went very good. Also the client was very goal oriented in this project, which was very helpful.
  - o Technical complexity: Technically the project was not very complex. The goal and requirements were very clear and the specific technical solutions did not lead to very complex situations.
- Pace: The pace was very high. Some of the resources worked even dedicated on this project. There was a large sense of responsibility in the project and priority was put on the project from the organization. Even though the pace was high, the project team worked very organized. The project manager in this project sees a strong connection between the (almost) dedicated team and the strong sense of responsibility and commitment. Because of this the project team stayed relatively small.

The front-end planning in this project was very ambitious and the whole team knew this. In hindsight, however, it can be considered realistic, since everything was delivered in time and goals on resource hours were met.

Case 5.4

When analysing the graphs it can be observed that after initiation a large resource peak is visible consisting of development, communication, data analyst and project management (visible as product specialist) hours. This peak lasts for approximately 6 months. After the peak the hours of all the function groups decline gradually towards the end.

From the interviews it became clear that concept of this congestion avoidance project was not new, but the way it was managed from the client's side gave this project a novel approach. The same goes for the technology dimension. Some new elements needed to be developed within the scope of the project. In terms of complexity the project had particularly environmental complexity. The required managerial attention by the client was high in this project. Internally there was a large project team that has to be managed. Another factor was that the project manager in this project was an experienced consultant in this domain, but he hadn't had the end responsibility for such a project yet. Finally, the pace was at the beginning of the project very high.

The project planning made for this project is considered to be unrealistic by the project manager.

4.6.3   Conclusions case group 5

The congestion avoidance projects are clearly the most uncertain projects of all the case groups. These are always very large projects spread over a relatively long time span with many specific requirements and deliverables. Even though the company has been executing these kinds of projects for many years, each individual project is always different and there is always new development work required as customer requirements change between projects. Internally there are many different function groups working on different aspects of these projects. Because the projects have high budgets, the clients and the most important stakeholders require a lot of managerial effort. The projects often have elements such as technology, marketing and communication, legal etc., which have all dependencies on each other. This combined with strict deadlines often results in the utilization of more hours than anticipated front-end. Technology wise the project often consist of many interrelating technical elements. This makes the development of the technical system often complex. Because of this there is a lot of communication and coordination required when the development gets outsourced.

It has been shown that increasing the amount of managerial effort, for instance by appointing a different project manager for internal and external project management, and appointing smaller and more dedicated project teams has a positive influence on the success in these projects.

5   Cross case analysis

This chapter will take the results of the individual case studies presented in chapter 4 and will present a cross case analysis. To do this the chapter will firstly present new definitions for the dimensions of the framework that are more applicable to the domain of the research explained in chapter 3. These will be presented in chapter 5.1. In the second subchapter all the factors that have contributed to uncertainty in the cases will be presented and related to project management as a whole and more specifically to the project planning.

5.1   Redefining the dimensions for the research domain

The definitions of novelty, technology, complexity and pace drafted by Shenhar & Dvir (2007) and Bosch-Rekveldt *et al.* (2011) and presented in the theoretical background in chapter 2 were drafted to be of use for any project regardless of the context. With the knowledge gained by the case studies it is possible to redefine the different dimensions of the framework and the different levels within the dimensions in a way that better suits the research domain. The new definitions that will be presented in this subchapter are therefore drafted by the author of this thesis on the basis of the knowledge gained by the case studies. With these new definition project managers can better relate to the dimensions, and therefore the assessment of the level of uncertainty with the framework will become more accurate. The levels of each dimension are labelled with a number (1 to 4). These numbers give an indication of the level of uncertainty that arises due to this dimension in ascending order, where level 1 causes the least uncertainty and level 3 or 4 the most uncertainty. The dimension complexity is broken down in the three pillars technical, environmental and organizational complexity. This will be further explained in chapter 5.1.3.

5.1.1   Novelty

Definition: The extent to which the scope and requirements of a project are new to the contractor and the client(s).
Levels:

- 1. Roll-out: These are rollout projects. The specific solution/product has been implemented very often in the past and no alterations need to be done. It can directly go to implementation.
- 2. Familiar, but new requirements: These are projects that rely on a well-known principal, but in which specific parts need to be altered on the basis of the wishes of the client.
- 3. Completely new elements: These projects are very novel either in one of two ways. 1) The contractor is familiar with the concept of the project, but the system needs to be (almost) completely altered on the basis of the requirements set by the client or 2) the concept of the solution is completely new, but the scope of the project includes some parts that are known to the contractor.
- 4. Never done before: These are projects that are completely new to the world. The concept of the solution needs to be developed from scratch as goes for the individual parts of the system. In these projects it is very difficult to determine the precise scope and requirements in an early stage.

5.1.2   Technology

Definition: The technological uncertainty of a project that arises due to the (technological) development of parts as part of the scope.

- 1. Roll-out: These are technological rollout projects. These projects rely on 'off-the-shelf' technologies and systems; no development has to done.
- 2. Low-Tech to Med-Tech: These are projects that require minor technical development. The required technological knowledge is limited and the resources are experienced in the technical procedures.
- 3. Med-Tech to High-Tech: These are projects that involve many interrelating technical parts of which many have to be (partially) developed. The projects often involve hardware and software development as well as system integration work.
- 4. High-Tech to Super High-Tech: These are projects that involve the technical development of completely "new-to-the-world" technical products or parts. These projects can't rely on previously developed technology.

5.1.3 Pace

Definition: The extent to which the resources and the organization are pressured to meet time-goals.

Levels:

- 1. Low-paced: These are gap-filling projects for the resources. These projects have no real deadline and there is no pressure on the organization and the resources to finalize the project.
- 2. Medium-paced: These are projects in which either internal or external deadlines are set, but the pressure on the resources to meet the deadline is limited. Also the consequences when missing the deadline are limited.
- 3. High-paced: These are fast-paced projects in which clear deadline(s) are set. The organization and resources are forced to make this project a priority in order to meet the deadline. Failing to meet the deadline will have consequences for the success of the project.
- 4. Blitz: These are the fastest-paced projects. In these projects the project team has to work dedicated in order to meet the deadline. Failing to meet this deadline will lead to the direct failure of the project.

5.1.4 Complexity

Definition: The degree of organizational chaos and managerial difficulty that arise due to organizational, environmental and technical aspects.

The three pillars of complexity, and its levels, will be individually defined:

- Technical complexity: Uncertainty that arises due to the clarity of (technical) goals and requirements and dependencies on parts, location and (outsourcing) partners. The levels of technical complexity are:
    - o 1. Low: In these projects the technical requirements and goals of the project are completely clear. There are no additional factors leading to technical complexity.
    - o 2. Medium: In these projects the technical requirements give room for misinterpretation and/or progress relies on one or more uncertain factors.
    - o 3. High: In these projects technical goals and requirements set by the client are vague and/or ambiguous. Additionally there are several factors that make it difficult to ensure progress at certain stages of the project.
- Organizational complexity: Uncertainty that arises due to the amount of, availability of, dependency on and experience of internal resources. The levels of organizational complexity are:

- o 1. Low: In these projects the project team consists of a small group of experienced resources that get the internal support the project requires.
  - o 2. Medium: In these projects one or a few of the factors that lead to organizational complexity are present. Extra effort needs to be done to manage internal processes.
  - o 3. High: In the highest level of complexity many different, both internal and externally oriented, function groups work on a certain project. The project team consists of a large group with different types of people, with different background and experience who work simultaneously on the project. Communication is difficult and requires hierarchy.
- Environmental complexity: Uncertainty that arises due to the amount of and dependency on stakeholders and the managerial pressure arising from these stakeholders. The levels of environmental complexity are:
  - o 1. Low: These projects have clear one-on-one relation between client and contractor (project team). This is a previously established relation and both parties know each other. There are only limited additional stakeholders on which the organization does not depend for progress.
  - o 2. Medium: These projects have a slightly more complicated web of stakeholders, which have interdependencies. More managerial effort must be in invested to manage the stakeholders.
  - o 3. High: These are projects that are highly dependent on a large web of stakeholders (client(s), supplier, co-developers, governmental organizations etc.) for the progress. A lot of project managerial effort must be invested in these stakeholders.

5.2   Relating uncertainty to project management

5.2.1   Cross case analysis

In this subchapter the newly defined dimensions will be related to the complete group of cases. To achieve this all the minutes of the interviews (not incorporated in this report) were analysed for factors that have influenced the outcome of the project, either positive or negative. This led to a large table of factors with their influence (negative or positive) and the degree of influence (mentioned or explicitly mentioned) on the cases. This table can be found in Appendix O. For the purpose of the cross case analyses, some of the factors mentioned in the interviews have been grouped and made insightful.

In this cross case analysis the dimensions of novelty, technology and pace will be treated differently than the dimension of complexity. For the first three dimensions the cases are categorized in one of the four levels by relating the interviews to the defined levels of the dimensions. For complexity it is more difficult to directly relate the cases to the levels. Therefore all mentioned factors that have led to complexity have been gathered. This has led to 16 factors for technological complexity, 11 factors for organizational complexity and 10 factors for environmental complexity. Most factors applied to several different cases and had a different influence on these projects.

Furthermore this research wants to investigate how the 4 different dimensions of risk and uncertainty have influenced the project execution in these cases and thus how they should influence the project planning in future projects. Unfortunately for many of the analysed cases no detailed resource planning data over time was available. Therefore this will be analysed qualitatively on the basis of the experiences of the project managers indicated in the interviews. If and how the execution of the project has corresponded with the planning (or if no planning was made: the initial expectation) will be categorized in 5 different levels:

- " + + ": The project has utilized less time/hours than planned or expected. Even though the planning cannot be considered accurate, this deviation has had a positive impact on the direct project result (schedule and budget goals).
- " + ": The project planning (or expectations) have corresponded with the actual execution of the project. The goals on schedule and (resource) budget were met and the project can be considered successful.
- " 0 ": The project execution has deviated to some extent from the planning of the project. This did not lead to significant problems and did not have a clear impact on the direct results of the project.
- " - ": The execution of the project has deviated on several occasions from the project planning on timespan and/or resource hours. This deviation has had a negative impact on the direct success of the project measured in resource budget and schedule goals.
- " - - ": The project has utilized a lot more time and/or resource hours than planned or expected. These hour and time overruns have had a severe impact on the direct project result. Measured in schedule and (resource) budget goals the project can be considered a failure. (Note: this does not necessarily have to mean that the overall project is a failure.)

Table 8 on the next page shows a complete overview of all the cases. The table includes 1) the categorization on the level of novelty, technology and pace for each case, 2) which factors of technical, organizational and environmental complexity have applied to the cases and 3) to what extent the project execution has corresponded with the planning (or expectation) in the cases. The explanation for all the levels and factors can be found in Table 9.

Table 8 Cross case analysis

Table 8 Cross case analysis — a large rotated cross-case analysis matrix with dimensions: Novelty (N-01 to N-04), Technology (T-01 to T-04), Pace (P-01 to P-04), Complexity (Technical complexity C-T-01 to C-T-16, Organizational complexity C-O-01 to C-O-11, Environmental complexity C-E-01 to C-E-10), and Deviation from planning (++, +, 0, -, --). Rows are cross case analysis items 1.1 through 5.4 plus Total and Further.

Footnotes:
* Will be further analysed in chapter 5.2
** Will be fruther analysied in chapter 5.2 in the context of the dimensions
*** Explanation on the levels and factors will be provided in the table on the next page

Legend	
X Project applies to this level	o Mentioned, but had no inluence
+ + Explicitely mentioned as positive	- mentioned as negative
+ Metioned as positive	- - Explicitely mentioned as negative

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Table 9 Explanation of dimensions and factors

			Novelty

#	Category	Factor	Explanation
N-01	Levels of novelty	Roll-out	See chapter 5.1.1
N-02		familiar, but new requirements	See chapter 5.1.1
N-03		Completely new elements	See chapter 5.1.1
N-04		Never done before	See chapter 5.1.1

			Technology

#	Category	Factor	Explanation
T-01	Levels of technology	Roll-out	See chapter 5.1.2
T-02		Low-Tech to Med-tech	See chapter 5.1.2
T-03		Med-Tech to High-Tech	See chapter 5.1.2
T-04		High-tech to Super High-Tech	See chapter 5.1.2

			Pace

#	Category	Factor	Explanation
P-01	Levels of pace	Low-paced	See chapter 5.1.3
P-02		Medium-Paced	See chapter 5.1.3
P-03		High-Paced	See chapter 5.1.3
P-04		Blitz	See chapter 5.1.3

			Complexity - Technical complexity

#	Category	Factor	Explanation
C-T-01	Project	Size	Size of the project in terms of budget relative to the entire portfolio.
C-T-02	Scope	Clearity	When the scope is not clear there is room for ambiguity or different interpretations.
C-T-03		Focus	A less focussed scope has incorporates multiple related or unrelated aspects.
C-T-04		Changes	Changes of the scope can have a large influence on the execution.
C-T-05		'soft' deliverables	Soft deliverables are difficult to measure to what extent they are delivered.
C-T-06		Demands on quality	Depending on the project the demands on quality of the deliverables can be higher.
C-T-07	Location	Unknown location	If work has to be executed at unknown locations it might involve additional analysis work.
C-T-08		Need for permits and licenses	When permits and licenses are incorporated in the scope of the contractor it can lead to delays.
C-T-09		Need for physical presence	On-site presence for modifications or testing of a system has impact on the hours of the resources.
C-T-10	Technical system	Combination software/hardware	A combination of hardware and software can lead to more complex situations than solely software.
C-T-11		Interrelating parts	Development work will get more complicated when it consists of multiple (interrelating) parts.
C-T-12		Familiar with hardware	Unknown (supplied) hardware system will extra time and possible extra technical modifications.
C-T-13		Knowledge available	It is important to consider front-end if all the required knowledge is available in-house.
C-T-14	Development	Outsourced: clearness of task	Unclear development tasks (regardless of the difficulty) will require more coordination.
C-T-15		Outsourced: Experience of team	Unexperienced development teams can have a severe impact on the quality and development time of a system.
C-T-16		Outsourced: Number of organizations	The coordination task will become more difficult when development is outsourced to multiple organizations.

Complexity - Organizational complexity			
#	Category	Factor	Explanation
C-O-01	Project management	Experience	Less experienced project managers will utilize more hours due to less familiar processes.
C-O-02		Changes	Changes in project management will lead to extra project management hours.
C-O-03		Familiar with project team	If a project manager is unfamiliar with the resources communication might require more effort.
C-O-04	Project team	Clearly defined	When the resources are not clearly defined it will require more managerial coordination.
C-O-05		Dedictated	(Almost) dedicated project teams can work more efficiently because their attention focussed.
C-O-06		Size	Larger project teams require more communication and coordination and are therefore less efficient.
C-O-07		Amount of functions	The amount of functions tells something about the amount of tasks that have to be conducted simultaneously.
C-O-08		Experience	Less experienc resources will utilize more hours and require more coordination.
C-O-09		Availability	If the resources are preoccupied by other projects possible time overruns can occur.
C-O-10	Internal support	Project team	If the project is disliked among the resources it will reduce the efficiency of the work.
C-O-11		Management	When a project has less priority and can be put aside in favor of other projects. This will generate delays.

Complexity - Environmental complexity			
#	Category	Factor	Explanation
C-E-01	Client	New	New clients will require more managerial effort at the start of the project, also more uncertainty arises during the execution of the project.
C-E-02		Project management outsourced	It is in the interest of hired project management professionals to increase the amount of communication.
C-E-03		Attitude	The goal-oriented client can enhance the execution of the project strongly, while suspicious clients can harm the progress of a project.
C-E-04		Managerial attention	Some clients demand more attention than other clients, this will have impact on the utilized hours.
C-E-05		Foreign	Foreign clients can lead to difficulties in communication and coordination.
C-E-06	Stakeholders	Amount of stakeholders	Projects become less focussed and require more coordination with more involved stakeholders.
C-E-07		Amount of suppliers	The more suppliers the stronger the project depends on an external planning.
C-E-08		New to the organization	New stakeholders are very dfficult to gauge and can lead to unforseen situations.
C-E-09		Dependecies on stakeholders	The more dependencies on external parties, to more possibility for time overruns.
C-E-10	Development	Development partner	Depending on the partner, and whether or not the partner is known, it can enhance the result of the project or have a negative imput on the result.

The following step in the cross case analysis is to relate the factors of the sub-dimensions of complexity to the levels ("High", "Medium", "Low") presented in chapter 5.1. This is done by counting the number of pluses and minuses and determining ranges for the levels. The ranges were determined by analysing the definition of the levels in combination with the cases and the amount of mentioned factors. For each of the three different types of complexity the same ranges were determined. The following ranges were used:

- > -3 = Level 1 ("Low")
- -3 to -5 = Level 2 ("Medium")
- < -5 = Level 3 ("High")

Using these ranges and the indicated level of novelty, technology and pace a summary of the cross case analysis could be made. This summary can be found in Table 10. In Table 10 the highest levels in each of the dimensions, as well as the cases that have deviated severely from the planning, have been indicated in grey (light and dark).

Table 10 Summary of cross case analysis

Cases	Overview						
	Novelty level 1 – 4	Technology level 1 – 4	Pace level 1 – 4	Tech. compl. level 1 – 3	Org. compl. level 1 – 3	Env. compl. level 1 – 3	Deviation from planning
1.1	1	1	2	1	1	1	0
1.2	1	1	2	1	1	1	0
1.3	2	1	3	2	1	1	-
1.4	3	2	1	1	1	1	-
2.1	2	2	2	2	1	1	-
2.2	2	2	2	1	1	1	0
2.3	2	3	3	1	1	2	-
2.4	2	2	3	1	1	1	-
2.5	2	2	2	1	1	2	-
2.6	1	1	2	1	1	2	0
2.7	2	2	-	1	1	1	0
3.1	3	3	2	3	1	1	- -
3.2	2	2	2	2	1	1	-
3.3	2	2	2	1	1	1	+ +
3.4	3	2	2	1	1	1	-
4.1	2	2	2	1	1	1	+
4.2	2	2	2	1	1	1	+
4.3	2	2	1	2	1	1	+
4.4	3	3	4	1	1	1	+
5.1	3	3	3	3	3	2	- -
5.2	3	2	3	3	3	3	- -
5.3	2	2	4	2	1	1	+
5.4	2	2	3	1	2	2	-

Further in this subchapter it will be explained for each of the four dimensions how an increased level has influenced the execution of the project in the analysed cases. Furthermore it will give a generic advice on how project planning and project management procedures should be altered on basis of the predicted levels in future projects. This will be done for the dimensions novelty, technology and pace. For the three sub-dimensions of complexity the most significant factors, indicated with an asterisk (" * ") in the bottom of Table 8, will be analysed. Also some general remarks on the sub-dimensions of complexity will be provided. The other factors are shortly explained in Table 9 and they will also be incorporated in the assessment model of project uncertainty presented in chapter 6.

5.2.2 Novelty

There were four levels of novelty defined in chapter 6.1.1, but the highest possible level was not applicable to any of the studied cases. Each of the first three levels however has been applicable for more than one of the studied cases. This gives the opportunity to study what the consequences have been of an increased level of novelty.

Almost all the studied projects with level 3 novelty have utilized more hours than expected. Except for case 4.4, the direct success of these projects, in terms of goals set for resource hours and time can be considered very limited. It needs to be noted that this does not necessarily have to mean that these projects are not successful on the long run (e.g. business development function), but this is beyond the scope of this research.

These projects have lacked a detailed resource planning over time. But regardless of the planning the project managers have indicated that the projects have utilized a lot more hours than anticipated and often did not meet the deadlines because of time overruns. These overruns in both time and hours were experienced throughout the project. Furthermore it has been experienced that especially the client acceptation phase in these projects have been long and extensive. Often these phases involved last minute alterations and bug fixes. In terms of planning it is very difficult for very novel projects to make a realistic project planning. Buffers in resource hours and time should be incorporated throughout the project.

When analysing the level 2 novelty cases there are both successful and unsuccessful projects, but project managers indicate that this does not particularly have anything to do with the degree of novelty. Almost always in level 2 novelty cases the tasks and elements were clear, they could however be very difficult to develop, but this will be analysed with the dimension 'technology' in chapter 5.2.2.

5.2.3 Technology

Similar to the dimension novelty, the studied cases range in the lower three out of the four defined dimensions. There have not been 'high-tech to super high-tech' cases within this study. It needs to be noted that there is some overlap in the levels of novelty and technology. However, in a technological organization this is not very strange. Projects that are novel often include the development of a technological system that is never developed before and also the other way around. This cannot be seen as a general rule, because exceptions in both directions (high-tech, but not very novel and vice versa) can be thought of and also examples can be found among the studied cases. The recommendations in chapter 9 will further reflect on the managerial implications of this overlap.

The level three technology cases in this study show to have a couple of things in common. All of the projects show very large development peaks especially in the beginning of the project when the system had to be designed. The interviews also have showed that the projects did not meet certain time goals for technological deliverables. This means that after the large resource peak, development work continues. This has also shown to be the case in the testing and acceptation phases of these projects. The development work often exceeds the expectations of the project managers. Some of these projects have been developed completely in-house, the projects that did outsource the work (partially) to an outsourced development team experienced this to be very complicated. Because the technological systems always consist of many interrelating technical parts the coordination of an outsourced development team was challenging. Also it has been experienced that when a system would come back from the outsourcing company it did not set requirements for the

projects. This led to additional in-house development work and put pressure on the deadline.

The development work in high-tech projects has shown to be much more work than anticipated front-end of the project. In the project planning a large buffer for development hours should be incorporated especially at the start of the project (designing) and towards the deadlines for the technological deliverables. Not only a buffer in the amount of hours should be incorporated, but also in the time span. This also goes for the testing phase in the final stage of the project. Additionally it needs to be noted that due to the uncertainty in high-tech projects outsourcing the work might not have the desired result. In one of the cases one of the technical resource was sent went over to the outsourced development team for the time that the development took place in order to do the coordination fast and efficient. This has been experienced as very positive and might be interesting for future large scale high-tech projects.

In the level 2 technology projects much less time has to be invested in the designing of the system. The development work in these projects was almost always outsourced with different results (further explained in chapter 5.2.4). Depending on the quality of the development team, a buffer in the development hours has to be incorporated for potential bug fixing and extra effort for testing.

5.2.4   Pace

Among the studied cases there are two projects identified as level 4, blitz, the highest possible level. Another 6 projects are considered as high-paced (level 3). First an analysis will be done of the blitz projects.

Both level 4 projects have a couple of things in common. Obviously in both projects the project teams were working very hard and utilized a lot of hours throughout the project. These were the only projects in this study that made use of (almost) dedicated project teams. This had a very positive impact on the project. Both projects met their deadlines and are considered to be successful. It has been argued that due to the dedicated project teams, the resources became very committed to the project.

Almost all of the level three projects missed some of the deadlines during the execution and were therefore less successful. In the projects the resources worked on several projects and sometimes the project teams were not clearly defined. It has been said in two of the projects that the responsibilities within the team became unclear.

Most of the level 2 projects did not have any problems concerning the pace of the project. It was however mentioned that the level 1 projects, lacking a deadline altogether, experienced the projects to last for a very long time, which made the work less efficient. In these cases internal deadlines should be set for the project.

It can be concluded that dedicated project teams can have a positive impact on the outcome of the project. When this is not possible or not desirable in high-paced projects, a project team should be clearly defined and the project should be prioritized.

5.2.5   Complexity

As can be seen in Table 8 and 9 the dimension of complexity has been researched by collecting all the factors that were mentioned in the interviews during the case studies. These factors have led complexity and could be grouped in one of the three sub-dimensions. For each of the factors it has been determined what influence these has had on the projects,

either positive or negative, and if the factor had a large influence or just an influence. In this section (chapter 5.2.4) the most mentioned and/or influential factors will be analysed. These are the factors that are mentioned in Table 8 with an asterisk (" * "). For the other factors a short description is given in Table 9.

Technical complexity

In the interviews with the project managers in the case studies many factors were mentioned that led to technical complexity. These were ultimately grouped in 16 factors. Six of these factors were mentioned several times. These will be shortly explained below.

- C-T-01 / Size of the project
  This factor was mentioned in 6 cases. All of these were large projects in terms of time, budget and resource hours. The interviews for these cases have shown that larger projects are more difficult to oversee front-end. Therefore larger projects rely much more on estimations than calculations. This factor increased with the size. The two largest projects have indicated that this factor was severe. A planning buffer for all function groups over the entire time span is required in these projects. Also in very large projects it could be beneficial to divide the project in separate parts, for which an individual planning will be made.
- C-T-04 / Scope changes
  This factor has been mentioned in 6 cases and has had different influences on these cases. Depending on the contract and the arrangements made with the client these scope changes could lead to more billable work. However in one case scope changes have had a very negative impact on the project. In this case a lot of time was spent on developing a technical system, which the client later did not want. It is almost impossible to foresee scope changes, but managing the expectation of the client, and making clear arrangements with the client at initiation, can possibly help prevent them from occurring.
- C-T-09 / Need for physical presence
  In many of the analysed cases in which a hardware system was part of the scope, physical presence was required to make alterations on the system or test the system. In two of the analysed cases this need for physical presence has had a large influence on the project. It was found that on the one hand the transportation to and from the location can take up a lot of time and on the other hand it makes the development very iterative. When planning such a project this factor should be incorporated both in an hour buffer and a time buffer.
- C-T-11 / Many interrelating parts
  It has been shown in four of the cases that when the technical system consists of many interrelating parts requires more coordination by the project manager and/or the developer who is coordinating the outsourced development work. Also the dependencies between the technical parts can lead to delays during development (one has to wait for the other). This has once led to large overrun in the schedule.
- C-T-14 / Outsourced: clearness of task
  This factor is in line with the previous analysed factor, C-T-11. Some tasks are, regardless of the level of technology, easier to communicate with a development team than other tasks. Projects with many interrelating parts, for instance, are usually more difficult to coordinate. Such projects will require more coordinating effort by the project team. But on the other hand the cases have shown that clear tasks can be easily outsourced and that this can be positive for the project.
- C-T-15 / Outsourced: experience of team
  Within the group of factors that have led to technical complexity this factor has been mentioned most and as the factor that has had the most influence in the analysed

cases. Whether or not the outsourced development team was experienced, or experienced with the task at hand has had a major influence, both positive and negative, on the project result. Experienced teams require less coordination and deliver good technical systems and inexperienced teams often the other way around. Often a lot of in-house development work has to be done after an inexperienced team developed a system. Information on the experience of the development team can therefore be very relevant input for the project planning.

As can be seen from the 6 factors analysed above different factors influence the project in a different way. Overall it can be concluded that technical complexity refers primarily to the amount of work and time that is needed to develop, install and test the technical system. It also gives an indication of the amount of technical coordination that is required to manage either an internal technical team or an outsourced development team.

Organizational complexity
The factors were mentioned in the interviews during the case studies can be grouped in 11 factors leading to organizational complexity. 4 of these factors were mentioned very often or had a severe impact on the cases. These will be explained below.

- C-O-01 / Experience of the project manager
  Even though the experience of the project manager was mentioned in eight cases, it has generally not been considered to have a very large impact on the project execution. However, some additional project management hours need to be planned to compensate for the experience. Depending on the size of the project, the influence of this factor can become larger.
- C-O-02 / Changes in project management
  Among the analysed projects 10 projects have had changes in project management due to several reasons. These changes are generally very difficult to foresee at front-end of the project, because they are due to unexpected issues. This factor did not lead to very large problems in the cases, but it does take additional project management effort to take up an already on-going project.
- C-O-06 / Size of the project team
  When the project team gets larger the more coordination is required. In two of the analysed cases this has had a large influence on the execution of the project. Very large project teams might require a communication hierarchy in which the project manager communicates with team leaders and so on. The extra communication effort that is required in such projects needs to be incorporated in the project planning. When no clear communication structures are developed, large project teams will become chaotic. This will not be beneficial for the project result. Also it has been experienced in the cases that the work in larger project teams is less efficient than in smaller teams.
- C-O-09 / Availability of the project team
  In the analysed cases the resources almost always work on several projects simultaneously. Sometimes this has meant that there simply are not enough resources to cover the resource demand of all the project managers at a particular moment in time due to deadlines that fall approximately around the same date. During the execution of some of the analysed projects this has led to time delays.

Also in the case of organizational complexity the found factors have had different impacts on the execution of the projects. In general term it can be said that when a project has a high degree of organizational complexity a need for formalization and hierarchy in the project management arises. Also, it will reduce the efficiency of the project team and therefore more hours are needed from the individual resources. Furthermore, an increase in this

complexity will require more internal coordination from the project manager throughout the project, which will require more project management hours.

Environmental complexity
The mentioned factors in the interviews that have led to environmental complexity are grouped in 10 factors. Three were mentioned several times or have had a severe impact in the case. These will be analysed below.

- C-E-02 / Client's project management outsourced
  Governmental organizations often hire project management consultants/professionals to manage the projects of which they are the clients. This has been mentioned as a factor in eight of the cases. In several cases it has been experienced that it is in the interest of such parties to enhance the demand for communication and documentation by the contractor, because they are able to bill their hours for this. In two cases the result of this has been that the project manager was primarily occupied with stakeholder management. The consequences were that that the internal processes lack the required attention. Among the studied cases there was one example of a project that used two project managers, one internal and one external, to manage the project, which is experienced as positive.
- C-E-04 / Managerial attention demanded by client
  In line with the previously analysed factor, C-E-02, some clients demand more attention than other clients. This can have a major influence in the hours a project manager needs to utilize for stakeholder/client management. In no less than five cases this factors has had a severe impact on the work of the project manager. Therefore assessing this factor front-end can generate important input for the project planning.
- C-E-06 / Number of stakeholders
  In eight of the cases the amount stakeholders in a project has had an impact on the utilized hours for stakeholder management by the project manager. In three cases this has even had a severe impact. It has also been shown that this factor creates dependencies that might generate delays during execution. Assessing the amount of stakeholders should be possible front-end and will be important input in determining the hour and time buffers that will need to be incorporated in the project planning.

Overall it can be stated that the degree of environmental complexity mainly refers to the project management effort. When the environmental complexity of a project is high, more project management hours will be utilized throughout the project. In such cases it might be beneficial to invest more project management effort in the initiation phase of the project. Also a buffer in both hours and time need to be incorporated in the acceptation phase of these projects.

5.3 Summary of the cross case analysis

On the basis of the knowledge gained with the case studies presented in chapter 4 the dimensions of the framework were redefined. Also new definitions for the levels of each of the dimensions were defined. With these new definitions it became possible to classify each of the analysed cases in one of the levels of each dimension. This was done by gathering all factors mentioned in the interviews of the case studies that have had an influence on the execution of the project.

For novelty, technology and pace the cases could be directly related to the different levels of the dimensions. For the dimension of complexity the empirical data from the case study was used to determine factors leading to complexity. 16 factors were found for technical

complexity, 11 factors for organizational complexity and 10 factors for environmental complexity. For all the cases the information on the dimension for risk and uncertainty was compared with whether or not the execution of the projects has deviated from the planning (or the expectation) in these projects. Over all these data a cross case analysis could now be performed that would indicate how the dimensions have influenced the execution of projects and thus how the dimensions should influence the planning in future projects. A short summary will be presented:

- Novelty: The degree of novelty has been found to have a large influence on the total amount of hours and time utilized in a project. Novel projects utilize throughout the project often a lot more hours than planned or expected. Especially time and hour overruns were experienced in the latter phase of the project: the client acceptation phase.
- Technology: The degree of technology has a large influence on the technical development during the project. High-tech projects require a lot more hours and time for the development than planned or expected. Also a lot of delays are experienced at the final testing and client acceptation phase. Furthermore, when it is decided that the technical development of high-tech projects is outsourced the coordination of this outsourcing team requires a more effort than usually foreseen.
- Pace: It has been shown that very high paced projects (level 4) have had a project execution that corresponded with the planning. These projects make use of smaller, dedicated project teams in which the individuals have been committed towards the end-goal. This has been shown to have a positive effect on the direct project result. On the other hand in high-paced projects (level 3) often work on several project simultaneously. These projects often did not meet the goals set for resource hours and schedule.
- Complexity: As explained, different factors have been found for each of the sub-dimensions of complexity. These influence the execution of the project in a different way. However some general findings will be presented below.
    - Technical complexity: This complexity primarily refers to the amount of work and time that is needed to develop, install and test the technical system. It also gives an indication of the amount of technical coordination that is required to manage a development team (either internal or external).
    - Organizational complexity: When there is a high degree of organizational complexity in a project, 1) there becomes a need for formalization and hierarchy in the project management processes, 2) the efficiency of the project team will decrease and therefore more hours are needed from the individual resources, and 3) more internal coordination from the project manager throughout the project will be required.
    - Environmental complexity: This complexity mainly refers to the project management effort. When the environmental complexity of a project is high, more project management hours will be utilized throughout the project. In such cases it might be beneficial to invest more project management effort in the initiation phase of the project.

6   Uncertainty-based planning

This chapter will use the information from the cross case analysis in the previous chapter to develop a method to relate the expected level of uncertainty in a project to the front-end project planning. This way the results of this research can be directly used to make the project planning of future projects more accurate. The tool developed for this will be discussed in chapter 7.1. In subchapter 2 it will be discussed to what extent the project managers of the case study company consider the results of this study useful and if they could relate a randomly chosen new project to the framework, the definitions of the dimensions and the levels and factors within these dimension. Finally it was tested to what extent the results of this study are generalizable for other companies that fit the research domain presented in chapter 3. The results of this can be found in chapter 6.3.

6.1   Developed project planning tool

The developed uncertainty based planning tool is a combination of the in chapter 3 mentioned 'issue-based' and 'scoring technique' method for making a front-end assessment of a project's susceptibility to risks and uncertainties. It makes use of a MS Excel questionnaire in which a series of questions about the characteristics of the project at hand need to be filled in by a project manager. These questions were constructed on the basis of the empirical data gathered by the case studies and the results of the cross case analysis.

For novelty, technology and pace the project managers are asked to categorize the project on one of the four levels by means of the definitions for the dimensions and the levels. For the three sub-dimensions of complexity questions are constructed for each of the factors found in the research. For each of these questions it can be answered if the factor applies to the project at hand and to what extent this factor applies (multiple choices are given). The questions are furthermore grouped in categories of questions:

- Technical complexity:
  - Project size;
  - Scope (clarity, focus, possible changes, 'soft' deliverables, quality demands);
  - Location (unknown, permits and licenses, physical presence);
  - Technical system (software/hardware, interrelating parts, familiarity, available knowledge);
  - Outsourced development (clearness of task, experience of team, number of organizations).
- Organizational complexity:
  - Project management (experience, possible changes, familiarity with team);
  - Project team (clearly defined, dedicated, size, amount of functions, experience, availability);
  - Internal support (project team, management).
- Environmental complexity;
  - Client (new, outsourced management, attitude, demanded attention, foreign);
  - Stakeholders (amount, number of suppliers, new, dependencies);
  - Development partner.

Each possible answer generates a value on the basis of the uncertainty that arises due to that factor. Per category the total of these values is calculated which determines what advice will appear per category.

This advice is specific qualitative advice on how to alter/improve the project planning and project management practices per dimensions (novelty, technology, pace) and the categories of factors. This advice is based on the empirical data gathered by the case studies and analysed by the cross case analysis. The advice helps to improve the project planning by telling specifically where time or hours buffers should be incorporate. These can be for instance: "A large buffer in project management hours should be incorporated in the project initiation phase" or "It is likely that the client acceptation phase will require more time, incorporating a time buffer in this phase is advised". Also some of the additional advice on project management practices found in this research will be provided, this is for instance: "The pace of the project is very high. The project team should be kept small and needs to work dedicated throughout the project".

After the project manager has filled in all questions, the final sheet of the tool will provide an overview of where the risk and uncertainty of the project is situated. This will both be done textual and graphical. This graphical representation will draw a chart on basis of the answers provided in the tool in which the surface area represents to what extent the project is susceptible to risk and uncertainty and where this risk and uncertainty is situated. Furthermore this overview sheet will also give a summary of the advice presented.

As explained, all the advice is qualitative as opposed to quantitative. It has been chosen to do this because of a couple of reasons:

- The data incorporated in this research is not precise enough to give a quantitative advice on the use of resource buffers. Also, 23 cases might not be enough to give reliable advice, since some factors have only been mentioned a few times.
- Every project is different from one another and in every project the advice therefore needs to be interpreted differently. Planning a project will therefore always rely on the experience and knowledge of the project manager.
- Organizations are susceptible to changes over time. Growth of the organization and changes among the resources will lead to changes in the execution of projects. A buffer at this moment in time could not be the same buffer a couple of years in the future.

In Appendix P an overview of all the sheets incorporated in the tool is given. In the example presented in this appendix all questions have been answered randomly. The advice that has appeared on the basis of these answers is also shown.

6.1.1   Additional opportunities of the tool

As explained, a project manager can use the presented tool for the front-end planning of a project. Besides the planning there is number of additional processes for which the tool can be helpful when such a tool is implemented in an organization. A number of these processes will be explained.

The tool forces project managers to think about all different aspects of a project at the start of this particular project. By doing so, more emphasis is put on the initiation period of the project. This does not only involve the project planning, but a large range of different processes. This may improve the execution of the project altogether.

The overview of all the risk and uncertainty profiles of the projects currently being executed can also be of help for the portfolio management of the entire organization. It can help develop strategic decisions on acquiring new projects on the basis of the uncertainty profile of the already on-going projects. It can for instance be a strategic decision to only acquire

low profile projects (in terms of uncertainty), if there are already two large and highly uncertain projects running. Also it can give an overview if the uncertainty decreases in a specific new group of solutions/products if more projects are executed.

It might be difficult to oversee if an organization will have enough resource capacity on the long run when decisions need to be made regarding the acquisition of new projects. With the aid of this tool it could be made insightful where the largest resource buffers are needed, and thus where the resource capacity will be under pressure. Depending on how large the business opportunity is of acquiring a new project, it could be chosen to not take on a project because of resourcing problems in the future.

This tool is constructed out of the experiences of a large range of different project managers. Therefore using this tool may result in cross-project learning, which on the long run can lead to organizational learning. It is also possible to add factors that may currently not be incorporated in the tool (because they were not applicable in the case studies). This will further stimulate the process of organizational learning, which is something that can be very important in a dynamic organization.

6.2 Usefulness

To test the usefulness of the results of the study and the presented tool it was tested in the front-end stage of a new project of the case study company. In a group consisting of a Sr. project manager, a junior project manager and the researcher the new project was discussed, the framework of the study was discussed and the excel tool was filled in by both project managers the best way, they believed, fit the project at hand. The researcher made notes during this session, to see to what extent the tool was clear, useful and delivered satisfying outcome. The comments and feedback will be shortly summarized.

The framework for assessing the level of project risk and uncertainty with the four dimensions and 3 sub-dimensions was clear for all the project managers present. There was however some discussion on the overlap between the dimension of 'novelty' and 'technology'. This overlap will be further addressed in chapter 9.1. The definitions of the first 3 dimensions and all the individual levels were clearly understood and could be related to project at hand. For the dimension of technology a discussion between the project managers arose in which they discussed in the project was level 2 or 3. This discussion led for both project managers to more insight into what the technical development encompassed. The project managers also understood the sub-dimensions of complexity as well as the individual factors. In this specific project many of the factors of organizational complexity were not applicable to the project. In the case of technical and environmental complexity all factors could be related to the project and all questions could be answered. The outcome of the assessment indicated that the project was primarily very uncertain due to the environmental factors (client and other stakeholder). This was for the project managers an interesting outcome since this was not considered before. The outcome (with the advice on the project planning) gave therefore valuable input for the project planning.

This test indicated that the assessment tool was very easily usable for the project managers. By filling in all questions of the tool the project managers were forced to think every aspect of the project through, which was considered very valuable for the initiation of the project. The advice on project planning that resulted from the tool was considered interesting input for the development of the project planning. Even though this test did not incorporate the actual development of a new project planning, the project manager did say that several buffers (at certain stages and for certain function groups) would be incorporated in the planning as a result of the advice given.

6.3   Generalizability

In chapter 3 of this thesis report an explanation of a research domain was given. The goal of the research was to make the results generalizable for this research domain. However, the study has only incorporated data from one company and therefore this generalizability is an issue. Two companies that fit the research domain were approached: Damen Shipyards Gorinchem and InteSpring. The results of this research were presented to project managers within these organizations and they explained to what extent the framework, the individual dimensions of the framework and the results of the study would be applicable for their organization. To make the results from both organizations comparable a semi-structured interview approach was chosen. The questions and short explanation of the approach for these semi-structured interviews can be found in Appendix Q. These companies were chosen as cases to test the results of this study because they are very different from one another, and from the case study company, in terms of product, company size and market. First the results of both interviews will be shortly summarized bellow and finally a short conclusion on the generalizability of the research will be given.

6.3.1   Intespring

InteSpring is small engineering company specialized in the development of prototype products for companies based on gravity balancing by means of suspension systems. They were founded in 2006 and have currently 9 people on permanent staff. The products are almost always tailor made to specific requirement, high-cost and labour intensive. The interview was conducted with the founder and general director of InteSpring who in his role also has been a project manager for four years.

The interview (Appendix R) showed that InteSpring is familiar with the problem that the project execution deviates from the project planning and this is often caused by unforeseen factors. The definitions of the first three dimensions of the framework (novelty, technology, pace) were all applicable to the projects. However, in terms of novelty, they don't have rollout projects and in terms of technology their projects are either rollout or low-tech to med-tech, but never high-tech. Nevertheless assessing these three dimensions was considered valuable to the interviewee. The three sub-dimension of complexity were more difficult to relate to their projects. The definitions of all three pillars of complexity were understood and could be applied to InteSpring, but several of the factors were not applicable to the organization. This especially was the case for the factors of technical complexity. The factors of organizational and environmental complexity were for the most part applicable to InteSpring, but may not have the same impact on a project (and thus a project planning) at InteSpring than they have at the case study company. It is therefore questionable if the factors for complexity found in the research are directly generalizable for this company. This will be further explained in chapter 6.3.3 and discussed in the discussion in chapter 7.

6.3.2   Damen Shipyards Gorinchem

Damen Shipyards Group is a shipbuilding company with fully owned, as well as partly owned, shipyards all over the world. Their core business is the construction of a large range of different ships, but Damen also has yards for the repair & maintenance of ships and the construction of parts. The company works according to a standardised design formula where they have many parts in stock and start building from this stock. This way they can guarantee high quality, a good price but most of all fast delivery. Off course there is room for requirements by the client. The interview has been conducted with Jos Govaarts, a project manager for Damen high-speed crafts in Gorinchem. Jos has worked at Damen for 2,5 years, of which 1,5 years as a project manager. Within this time he has worked on approximately 10 projects.

The interview (Appendix S) showed that Jos recognizes the problem that the project execution does not correspond with the planning. This is one of the problems currently addressed within the company by means of implementing an ERP system. When analysing the framework with the dimensions, Jos is able to apply all definitions for the dimensions to the projects at Damen. However some dimensions have more impact on the project execution than others. Jos can recognize the first three levels of novelty. The highest level 'never done before' does not apply to the shipbuilding industry. The effects on the project planning found for novelty also applies to Damen. This also goes for pace, where they have projects in all 4 levels. The interviewee acknowledges the differences in execution between dedicated teams and teams with low priority for a project. The dimension technology is different from this study. Damen became more a matrix organization in which some business processes are disconnected from the projects. This for instance is the case with R&D. Therefore the projects will always remain in level 1 (rollout) or level 2 (low-tech to med-tech). The R&D department executes more advance technical projects, but also never higher than level 3. In contrast to InteSpring all three sub-dimensions of complexity could be applied to Damen, as well as almost all categories of factors. There were however some differences in the individual factors and the interpretation of categories. Jos feels that the factors mentioned could be extended for Damen to make it fit even more to the organization. A lot of complexity, for instance, originates from the 'flag' a ship is going to operate under and the classifying agency that is going to be used. These organizations have all kinds of different requirements.

6.3.3 Conclusions regarding generalizability

The two interviews conducted to test the external validity of the research corresponded in many ways with the results found in this research. Both companies indicated that the framework, including the definitions of the dimensions, would be applicable to their organization. The projects of both InteSpring and Damen range in several levels of the dimensions novelty, technology and pace. Not all levels of these dimensions are applicable to the projects, but this is also not the case for studied company in this research, and also not necessary in using the framework. Both interviewees could also relate the results on how the dimensions influence the resourcing and planning to their projects. The dimension of complexity with the three sub-dimensions was a bit more difficult. In the case of Damen the categories of factors in each of the sub-dimensions were almost all applicable to the organization, but additional factors could be added. Also the effect some of these factors had may have differed between the results found in this study and possibly could be found in Damen projects. For InteSpring the three sub-dimensions could be applied to the organization and the projects, but many of the factors were not applicable. At InteSpring the degree of complexity in an average project seems also to be less than found in the case study company of this research and Damen.

A possible explanation for the differences in the dimension of the complexity could be found in the differences in the size of the organization and the projects. According to the classification on small and medium-sized enterprises (Table 2 in chapter 3), InteSpring is a micro organization, the case study company is a medium-sized organization and Damen is a large organization. The size of the projects, in this case, differs also more or less proportional to the size of the organization. It could be argued that larger, more expensive projects have more factors that lead to complexity than smaller projects.

In terms of generalizability it could be concluded that the framework for assessing a project's risk and uncertainty proposed in this research could be a very interesting foundation for future research. It seems that the results found for novelty, technology and

pace can be applied to a larger range of organizations. The factors found for complexity may not be directly generalizable. Additional research, in a larger group of companies, may provide more generic factors that will be more widely applicable.

7 Discussion

This chapter will provide a discussion on the results of this research. The first subchapter will deal with the validity of the research. The second subchapter will go in to the scientific contribution and finally the limitations of this research are discussed.

7.1 Validity of the research

This subchapter will address the validity of the research by discussing the concepts of construct validity, internal validity, reliability and external validity (Yin, 2002).

The concept of reliability of the research addresses the issue if the study could be repeated with the same results. It has been tried to make this research as reliable as possible by developing case study protocols, making appointments with the interviewees at least a week in advance, developing the interview questions prior to the interviews, using the same questions for every interview and making minutes of the interviews directly after the interview was finished which were checked. Even though all this is done to ensure the reliability, it is not possible to guarantee complete repeatability. There are a couple of things may have had influence on the reliability:

- Some interviewees had more time for the interview than others. This resulted in that the project managers that had more time gave more detailed answers and the interviewees that had less time gave short, summarized, answers. This might have led to a bias.
- Because some of the interviewees did not feel comfortable with this, the interviews were not recorded. Instead of a recording, extensive notes were made during the interview, which were made into minutes directly after the interview. However, it is a possibility that bias may occur in the two steps from interview to the minutes.
- Some interviewees were experienced to be more sceptical towards the research than others. The interviewees did answer all the questions best they could, but it might have generated a bias in the answer that were given.

The first part of the case study, the analysis of the resource hours, is completely repeatable. In the case of the interviews it might always be questionable if it can be repeated, since the interviewees might be biased after the first interview. In this case a case study protocol would not have the desired result.

The concept of internal validity addresses the issue if the causal relationships found in the research are warranted. This is a concern in this research since the study has an explorative character. Often experienced peaks in the resourcing in projects were not the result of just one factor. The precise amount a factor has contributed is therefore difficult to pinpoint. To address this issue, a large amount of cases have been selected. This makes it possible to investigate factors in several different projects and therefore several different circumstances. Also, the results given only have a qualitative character, because a definite quantitative relation would be impossible to prove in this explorative study. Finally only extensive results are shown for the dimensions and factors of complexity that have been mentioned several times (novelty, technology and pace applied to all cases and for complexity an influence of at least 5 times "−" or "+" was used).

The third concept of validity is construct validity. This construct validity refers to if the used observations or measurement tools actually represent or measure the construct that was investigated. This was addressed by combining quantitative data (information on the utilization of resource hours in projects) with qualitative data (interviews). For the interviews

the graphs of the resource hours were used as input. This made it possible to relate the mentioned factors to a certain period in the project. Therefore there could not have been confusion to how the mentioned factors have influenced the resourcing. This could have been the case if only interview data was used. By mixing these two methods it was not only possible to develop a list of factors leading to risk and uncertainty, but also relate this list to the resourcing of projects.

The final concept the validity the research is the external validity. External validity refers to the extent to which the results of this study can be generalized to other situations. This concept is a concern in this research since the study was only performed in one company. As explained in chapter 3 it is intended to be generalizable for a domain of companies. Therefore the results of this study have been evaluated and tested in two other companies that fit in the domain explained in chapter 3: InteSpring and Damen Shipyard Gorinchem. The interviews that were conducted in these companies have shown that the results found in this research correspond to a large extent with the experiences of these two organizations. Both interviews have shown that the framework could be applied to these organizations, since the projects ranged (in two or more levels) on the dimensions of the framework. The definitions for these dimensions as proposed by this study could also be applied to both organizations. The results of this study on how the dimensions influence the resources and project planning were for the dimensions novelty, technology and pace all applicable to the two organizations. For complexity this was not very clear. Even though the three sub-dimensions could be applied to both organizations, the found factors were not always applicable to the organizations. Also these organizations have other specific factors that lead to complexity. To develop a list of factors that is generalizable for the complete research domain, additional research will be required. A conclusion on the external validity is therefore that the framework is generalizable for the research domain, but specific results and factors (particularly for complexity) are at this moment not generalizable.

7.2   Scientific contribution

This research has built a theoretical framework out of two key publications: the diamond framework by Shenhar & Dvir (2007) and the TOE framework by Bosch-Rekveldt (2011) (Bosch-rekveldt, 2011; A. Shenhar & Dvir, 2007). Both publications are recent and never studied in this combination before. The diamond framework makes it possible to assess a project on four completely different dimensions. Even though it can be argued that there may be some overlap in definitions among the different dimension, they are collectively exhaustive for the factors that lead to uncertainty in a project. However, the diamond framework treats the dimension of 'complexity' as a 'black box' and therefore it is still very difficult to assess this dimension. The TOE framework has opened this black box by defining three different categories of complexity and investigating which factors contribute to the degree of complexity in each of these three categories. By combining these two theories in one framework and studying this in relation to resourcing and project planning this study has done something relatively novel in the scientific literature.

The specific domain in which this research has been studied is particularly suitable for this research. CoPS projects are often tailor made projects, which range due to the characteristics in all dimensions of the theoretical framework. Particularly for project-based organizations the project planning is of high importance since the entire business result is dependent on the successful progress of its projects. The combination of product and organization therefore proposes an interesting domain. Even though research has been conducted on this particular domain, not many studies have focussed on improving project planning.

Although, this study touches on an interesting and relevant research topic, it is still an explorative study. The results therefore need to be interpreted as a first step in grasping this uncertainty and relating it to project planning in the specific domain. In chapter 9 more attention is given to recommendations to further research.

7.3   Limitations of the research

One of the largest limitations of this research has been that it has only been conducted in one company. Even though a relatively large set of cases has been studied as part of the research, one company may not be representative for the entire domain. The results of the interviews conducted at InteSping and Damen Shipyards Gorinchem (presented in chapter 7.1) do shine some more light on the processes at other companies within the domain, but it is not the same as conducting the full case study protocol at other companies.

Another limitation is that the theoretical framework used in the project is very broad. By focussing on 4 different dimensions of uncertainty (including the 3 sub-dimensions for complexity) it is difficult to focus the results. Because the interviews conducted in this research were quite large in terms of the amount of questions it was difficult to really go in depth on a certain topic. Therefore the results of this study touch a lot of interesting relations, but it cannot make definite statements on these relations.

Furthermore another limitation has been that not enough planning data of the studied cases was available to incorporate this information in the research. The initial plan was to investigate how the utilized resource hours in a project had deviated from the front-end project planning made in these cases. However, many of the projects lacked the required detailed resource planning over time to do this. To enhance the validity of the research it has therefore been decided that the planning information would not be quantitatively compared with the research data for any of the cases. With the interviews it did become possible to integrate this information qualitatively by asking questions on if time and hour overruns have occurred and if the project planning (or expectations) in hindsight could be considered realistic. The qualitative data that this has provided is incorporated in the cross case analysis in chapter 5 to be able to see how the dimension influence the execution of the project in terms of the utilization of resource hours and time. However, this data is not as precise as it would have been if the research had incorporated quantitative planning data. Concluding this point it can be said that even though qualitative data on deviation from the project planning or expectation did give interesting results, quantitative data maybe could have provided more substantial connections between planning overruns and project risk and uncertainty.

8   Conclusions

The conclusions in this chapter will be given by first answering the research questions that have been stated in chapter 2 of this thesis. Thereafter some overall conclusions will be presented.

8.1   Answers to research questions

In this research the main question was:

RQ   *How could a project manager of a project-based organisation that develops complex project systems use theories on project risk and uncertainty to develop a more accurate project planning?*

To answer this main question, first answers will be provided to the sub-questions. The sub-questions are drafted in a way that the answer to a sub-question forms the basis for the answer to the next sub-question. After all the sub-questions have been answered, an answer will be provided to the main question.

SQ1A   *What theories on project risk and uncertainty can be used to study project planning?*
The research is in principal based on a theory by Shenhar & Dvir (2007) that states that the approach to the project management should be altered on the basis of the characteristics of the project. To do this they propose a 'diamond framework' to assess the uncertainty and risks (and the potential opportunities and benefits) of a project (A. Shenhar & Dvir, 2007). In this research, this 'diamond framework' is further expanded with a theory by Bosch-Rekveldt (2011). This publication has aimed to make the concept of 'project complexity' more insightful. Several factors have been found that influence the complexity of a project in large engineering projects. These factors were divided between three categories: Technical, Organizational and Environmental complexity. This has been named the TOE-framework (Bosch-rekveldt, 2011). Because the factors found in the research on engineering projects may not be applicable to projects within the domain of this research, only the three categories have been used to construct the theoretical framework of the research. The result is a framework consisting of the four dimensions novelty, technology, complexity and pace in which the dimension complexity is further divided in the three sub-dimensions technical, organizational and environmental complexity.

SQ1B   *What characteristics of projects have an influence on the planning of the projects?*
The two theories explained in the previous sub-question use several characteristics of projects to assess a project's risk and uncertainty. The characteristics derived from these theories are: the level of novelty of a project, the level of technology used in the project, the pace of a project and the extent to which a project is susceptible to complexity. The latter is than divided into technical, organizational and environmental complexity. These are all characteristics of the project within a certain context. This context is for instance the organization leading the project. The mentioned characteristics all have an influence on the degree of uncertainty and risk such a project is susceptible to and therefore these characteristics should influence the project planning in certain way. How exactly these characteristics should influence the planning is studied in this research and the conclusions will be presented in the answers of sub-questions 2A and 2B.

SQ2A   *To what extent is the execution of a studied project influenced by factors that were not planned for?*
As can be read in the case study results in chapter 4, many of the interviewed project managers, in hindsight, considered the project planning of studied project unrealistic. A clear

overview of how much the projects have deviated from the project planning (or is no planning was made; the expectations) can be found in Table 10 in the cross case analysis in chapter 5.2. The reason for this deviation can be found in factors that might have influenced the execution of the project. In almost all studied cases these unforeseen factors have influenced the project in terms of time delays and the utilization of resource hours. All these factors can be placed in one of the dimensions mentioned in the previous sub-question. The amount of influence these factors have had, differed between the different projects. To make this more insightful the dimensions and levels in each dimension were redefined to fit the research domain (chapter 5.1) and for each case it was analysed on what level of each domain they could be categorized (Table 10, chapter 5.2). This made it possible to conduct a cross case analysis in which the influence of a higher level of each dimension on the project execution could be analysed. The results of this analysis can be found in the answer of sub-question 2B.

SQ2B *What influence did these specific unplanned factors have on the utilization of research hours and the time span of the project?*
To answer this question the influence of the different dimensions will be concluded individually:

- Novelty: It has been shown in the research that when the degree of novelty increases the required internal processes and tasks become less clear. Therefore the planning of projects will rely more on estimations than calculations. It has also been shown that because of this, very novel project often utilize a lot more resource hours than initially planned. Also overruns in schedule goals were experienced. Novelty reflects on all different functions in a project and depending on how novel the project is a buffer should be incorporated both in hours and time throughout the project.
- Technology: The case study results have shown that when the level of technology increases (more high-tech) that often the technical development team utilizes a more hours than anticipated. It has been suggested that this increase in hours can be led back to an increase in the amount of development iteration cycles (design, build, test). Also it has been found that a lot more effort must be invested towards the end of the project (testing and client acceptance), this often leads to time overruns. This dimension primarily reflects on the resource hours of the technical development team. Depending on the level of technology buffers in the resource hours should be incorporated for these functions in the design and development phase. Also a buffer should be incorporated in the final stage of the project, both in hours and time.
- Pace: This dimension mainly reflects on how the project team should execute the project. When the pace of a project is high or even very high the project team should prioritize this project over other possible projects. In some cases the team should work dedicated or even autonomous on this project. To increase the efficiency, project teams should be kept small and the formalization of (project management) processes should be reduced to a minimum. The commitment for these projects is experienced to be high. Because of this a high pace in a project does not have to be a negative factor for the direct project success and it has even been shown to be a positive factor in the execution of these projects. On the other end of the spectrum, for very low-paced projects that lack a deadline all together, it is often necessary to incorporate an internal deadline. Without such deadline these projects often drag on longer than is considered optimal.
- Complexity: As mentioned the dimension of complexity has been divided into three categories, which will be explained below. Because complexity is more difficult to

relate to than the other dimensions, the different types of complexity relate to several factors that, if applicable, increase the complexity of the research. These factors were found during the case studies.

- o Technical complexity: A list of 16 factors has been found that influence to technical complexity of a project. These factors can be found in the cross case analysis in chapter 6. Each of the factors influence the project execution is a different way. However, some general findings on technical complexity can be presented. It has been found that technical complexity refers primarily to the amount of work and time that is needed to develop, install and test the technical system. It also gives an indication of the amount of technical coordination that is required. On the basis of the amount of factors (out of the 16) that apply to a project at hand and the extent to which they apply buffers should be incorporated in the project planning in the development, installation and test phase both in time and hours.
- o Organizational complexity: 11 factors have been found that influence the organizational complexity of a project. Once again each factor influence the execution in a different way. Some general results will be explained. It has been found that when the organizational complexity increases, a need for formalization and hierarchy in the project management arises. Also, it will reduce the efficiency of the project team and therefore more hours are needed from the individual resources. Furthermore, an increase in organizational complexity will require more internal coordination from the project manager throughout the project, which will require more project management hours. Therefore depending on the amount of factors that apply to a project and the extent to which they apply, hours buffers should be incorporated to compensate for a reduction in efficiency and also a buffer for the amount of project management hours should be planned for the extra coordination effort that is required.
- o Environmental complexity: For the final category, environmental complexity, 10 factors have been found which all have a different influence on the project execution. The factors relate to the client, the stakeholders and potential development partners. The general conclusions are that an increase in the environmental complexity mainly refers to the project management effort. When the environmental complexity of a project is high, more project management hours will be utilized throughout the project, but primarily in the initiation phase. Also, environmental complexity refers to the dependencies on stakeholders and therefore may cause time delays. On the basis of which factors apply to a project and to what extent they apply buffers should be incorporated in the project management hours throughout the project and especially in the initiation phase. The dependencies will primarily cause time overruns in the latter part of the project (acceptation phase). This should be incorporated in the planning on the basis of a time buffer.

SQ3A *How is it possible to use this knowledge in the front-end planning phase of future projects?*
To use the information that is concluded in the previous sub question new definition of the dimensions and the different levels within a dimension were developed. These definitions can be found in the cross case analysis in chapter 5. With these new definitions it will be able for project managers to relate the project to the dimensions and with this assess the level of

uncertainty the project is susceptible to. Also a practical tool has been developed (chapter 6) that helps project managers to assess the uncertainty of a project by answering questions on the characteristics of the project. The tool will provide qualitative advice on how to adjust the project planning on the basis of the answers given on the potential uncertainty for that project. This advice specifically indicates where time and resource hours need to be incorporated in the project planning. The advice is based on the results found in this study.

With the given answers to the sub-questions it is possible to provide an answer to the main question of the research.

RQ *How could a project manager of a project-based organisation that develops complex product systems use theories on project risk and uncertainty to develop a more accurate project planning?*

On the basis of a literature study, a multiple case study and a cross case analysis a framework was developed and tested that can be used to assess the potential risk and uncertainty of a project on the basis of four dimensions: novelty, technology, pace and complexity. The latter has three sub-dimensions: technical, organizational and environmental complexity. On the basis of the results of the case studies these dimensions (and sub-dimensions), along with the levels of the dimensions, have been given a definition that fits the research domain. Each studied case was categorized on one of the levels of each dimension and this was compared with the extent to which the case has deviated from the project planning or initial expectations (Table 10, chapter 5.2). This made it possible to investigate, across all cases, how an increase in each of the dimensions influences the deviation of time and resource hours from the initial project planning. These results of this cross cases analysis, combined with the more specific results of the individual case studies, have led to the overall results on how the dimensions of risk and uncertainty influence the amount of resource hours and the timespan over the course of a project, which were presented in sub-question 2B. This has been done, where possible, for specific function groups at specific stages of the project. A project manager of a project-based organisation that develops complex product systems can use this information to assess a project on its potential risk and uncertainty and relate this to the front-end resource planning of that particular project. To make this process more clear a tool has been developed in which a project manager can assess this on the basis of a questionnaire with questions regarding the characteristics of the project. When completely filled in, this tool will provide the project manager with qualitative advice on how to adapt the project planning on basis of the risk and uncertainty this project is susceptible to.

8.2 Overall conclusions

This research and also the central question of the research has specifically focussed on the project planning and how this planning can be improved on the basis of theories on risk and uncertainty. However, the interviews in the case studies have led to more interesting additional results that are not directly related to the project planning. A number of these were already mentioned in SQ2B in the previous subchapter. This subchapter will further elaborate on the most interesting result found in the research.

- Of all dimension analysed in this study, novelty has the most severe impact on the direct success of a project (meeting goals on schedule and budget). A completely new project will almost always fail to meet the goals set for resource hours and schedule. This may not be a problem if the specific concept will be used more often in future projects. However in such projects a thorough analysis should be made of the business potential of the concept of this novel project.

- Very high-paced projects have been shown to have a positive project result. The dedicated teams need to be smaller to work more efficient and to reduce formalized, bureaucratic, procedures. The individuals of these smaller, dedicated, teams have a larger feeling of responsibility towards the end-goal. In turn, this feeling of responsibility leads to more commitment for the project among the resources and with this to more project success.
- Many of the interviews have elaborated on the importance of the initiation phase in a project. Nevertheless many of the studied projects did not have a full initiation phase. The most common reason for this is that the pace in these projects doesn't allow time for a proper initiation phase. However, by not taking the time to initiate the project only more pressure will be put on the project later on in the process due to unforeseen factors. In a couple of circumstances the importance of the initiation phase will even be greater. These will be explained below.
    o In these studied cases where the scope of a project is not completely clear (or not focused) it will almost always lead to problems towards the end of the project. The interviewed project managers that managed such a project with an unclear or unfocussed scope have indicated that this eventually led to problems with the client towards the end of the project. These problems were often that the client wanted something slightly different, which caused for more time and hours at the end of the project and furthermore often has had an influence on how satisfied the client was with the execution. In these cases it is therefore very important to discuss the scope, and the complication surrounding this scope, with the client at the project initiation phase. This will not only help to make the scope more clear, but it also helps in the expectation management towards the client. This also goes for when a client is new to the organization or is likely to be suspicious. Gaining their confidence at initiation will reduce the amount of managerial attention during the actual execution of the project.
    o In the interviews of the studied cases in which the technical system was complicated, due to for instance the amount interrelating technical parts or a very high demand on quality, it has been shown that responsibilities become less clear and the work therefore less focussed. In such cases it will be beneficial to have an extensive technical brainstorm front-end of the project. Such a brainstorm can give a clear picture of the responsibilities and therefore will make the development work more efficient. Also, brainstorming with group of technicians, with different specialities, will give a better overview of the problem areas of the technical system.
    o The case studies have shown that the project teams were often not clearly defined front-end of the project. The interviews in these cases have indicated that a lot more effort had to be invested in internal coordination and also that the work became less efficient since the individual resources were less committed to a project that is not 'theirs'. It is therefore very important to take the time to clearly define these teams.
- Finally it was found by comparing the numbers of resources in the project teams with the process of internal coordination that the internal coordination task for a project manager becomes bigger in larger project teams. At a certain point there becomes a need for communication hierarchy by means of team leaders. It has been found over the cases of the research that this is the case when project teams exceed 8 people.

9   Recommendations

The final chapter of this thesis will deal with the recommendations for both project management practices and future scientific research.

9.1   Recommendations for project management practices

The interviews that have been conducted with the project managers during the case studies indicate that almost all project managers consider the project planning is a very important aspect in any project. The value of a planning within a project and an organization can therefore be considered high. The interviews also indicate that uncertainty is currently only incorporated in a project planning on the basis of the experience a project manager has gained in previous projects. By using the results of this study and the presented tool during the initiation of the project, the combined experience of a series of project managers in a large range of projects can be used. By combining and recording this experience the information is available and applicable for future projects regardless of the experience of the project manager. With this it will stimulate the process of organizational learning. However, the results of this study will not directly create a perfectly accurate project planning for any project. It needs to be considered as an aid for the project manager. The results can be regarded as a checklist of factors in a project that can lead to uncertainty in the execution of the project on basis of its characteristics. By following the checklist a project manager is forced to consider all characteristics and factors for the project at hand. By doing this a more accurate project planning can be developed, and also a list of attention points for a project will be developed. The latter may be even more important for the project. Knowing the attention points of a project will help to properly prepare for these, on a larger scale than just incorporating buffers in the project planning.

The developed "uncertainty-based planning" tool was tested in the front-end stage of a new project (chapter 6.2). This test has shown that the results do create the much-needed discussion of possible uncertainty in a project among the project management. The test has also shown that the tool helped considering more aspects of the project than previously thought of, which helped to prepare for the project. Therefore implementing this tool at the case study company can directly aid the project management practices within this company. The tool that has been created can therefore be considered an important recommendation for the project management practices. This recommendation does not only apply to the case study company, but may also apply to other companies.

However, as shown in chapter 7.3 and further explained in chapter 8.1, the results may not be directly implementable for all organizations that fit the research domain (chapter 4). The external validation has shown that the framework (novelty, technology, pace and technical, organizational and environmental complexity) is applicable to three very diverse companies within the domain, but not all elements and factors incorporated in the results are the same for all these organizations. Primarily the factors leading to technical complexity differ greatly among the studied companies. Also the extent to which all the factors that lead to complexity have an influence of the resourcing in projects will differ among different companies. Therefore implementing this research in the front-end stage of other companies in this research domain will require additional research.

Furthermore it needs to be noted that that the research has found that there is some overlap between the factors of novelty and technology. Also the project managers had some problems with seeing these two dimensions completely separate. As can be seen from the cross case analysis (Table 10), there is clearly some overlap between the two dimensions,

but also in many projects the two dimensions do not overlap. In the case study company all projects have (IT) technology imbedded in them and starting a new kind of solution almost always means developing a new system. In other organizations this does not have to be the case. In for instance the example of the ship building industry a project for a new ship can be completely novel, but still low-tech, due to the fact that no additional research and development has to be conducted within the project. Since the framework has been constructed to be of use in a larger organizational context, this study will not do any recommendations on how to deal with the overlap issue.

9.2   Recommendations for future research

This research has developed a framework for grasping project risk and uncertainty by combining the 'diamond framework' developed by Shenhar & Dvir (2007) and the TOE-framework developed by Bosch-Rekveldt (2011) (Bosch-rekveldt, 2011; A. Shenhar & Dvir, 2007). The research has applied this framework to project planning as a specific project management tool and within a specific research domain. As already explained in the previous subchapter, the framework may be of use and generalizable for the entire research domain, but specific results on project planning may not be of use in all organizations that fit the research domain. To further exploit the potential of the presented framework there are three different research challenges that can be further studied. First, more research will be required to give generalizable results on the impact this framework has on the project planning for the entire research domain. Second, additional research can extend the use of this framework to other project management practices besides project planning. Furthermore it can be studied whether or not the framework would be applicable to a different research domain. These three mentioned research topics will be shortly explained below.

As explained in the previous subchapter three (very different) companies within the research domain have indicated that the framework for assessing project risk and uncertainty is applicable to their projects. However, the results on project planning may not directly be generalizable for all different companies. Therefore additional research will be required. The framework can form the basis for this research. This research should incorporate a large a range of different companies that fit in the research domain. The research should roughly follow the same procedure as this research, but in this case over a larger range of different projects. The result of such research will give insight on how risk and uncertainty influences resourcing in the entire research domain. This domain includes companies that are due to the dynamic and complex characteristics of "project-based organizations" and "complex product systems" very susceptible to this risk and uncertainty.

As explained in the conclusions in chapter 8 this research has found more interesting results on project management practices than just the project planning. This research has specifically focussed on the planning to make the scope feasible in the given time. However, broadening this scope to for instance front-end project management activities, or font-end development (Bosch-rekveldt, 2011), or the use of project management tools (Besner & Hobbs, 2004) can further exploit the potential of the theoretical framework.

Furthermore it might be interesting to investigate the potential of the framework to other research domains. Although the framework is only applicable to projects as they were defined in the beginning of this thesis, the framework can potentially be of interest to projects outside of the CoPS domain. A possible interesting research domain could be the field of innovation projects (innovation management) in (high-) technology companies. Internal innovation projects in these companies are often classified as incremental or radical innovations projects on basis of for instance the required amount of new knowledge that is

needed (Dewar & Dutton, 1986). However, classifying the projects in this way does not directly indicate where the managerial difficulties will arise and therefore it is difficult to prepare for these difficulties. The internal innovation projects in technological companies also range on all dimensions of the framework of this research (pace often in terms of market pressure in stead of formal deadlines). Researching if and how this framework could be applied to innovation projects could develop more insight into project management in innovation projects and how to improve the project management practices.

In terms of research methodology the use of quantitative data as input in the qualitative techniques (interviews), as used in this research, can be highly recommended for future research. This gave the opportunity to specify certain questions to a specific phase or time points in a project. This makes the result of the qualitative research technique more valuable.

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Appendix A   List of analysed projects and descriptions

Case 1.1
One of the Dutch provinces wanted to investigate the traffic flows on a provincial road in order to decide on possible alternative traffic light scenarios. A report with average travel times over 11 trajectories at specific time points during the day needed be developed and delivered. This was a relatively small project.

Case 1.2
A municipality wanted to optimize the usage of a parking lot underneath a football stadium. To do this they wanted to install a system that indicates the amount of free parking spots at the entrance. This project needed to investigate the efficiency gain when such a system was installed. This was done by measuring the amount of cars before a football match and during a football match. This was a very small project.

Case 1.3
In order to build a new provincial road a farmer needed to be bought out. They could not agree on the price of the farm and therefore the province wanted to know how many clients came by the farm every week. Measurements were done on the amount of cars stopping at the farm. This was a relatively small project.

Case 1.4
A large Dutch city wanted to perform an analysis on the accessibility of the city for car users. To do this they had a lot of data from the NDW, but this data was not in a form that they could use it. The company was requested to deliver the data in a different format that could be used. This was also a relatively small project.

Case 2.1
A bus station already had a dynamic travel information display system installed. They wanted to change this back into a static system and also change the panels for this. The panels were still ok, so the client just wanted a software change in the existing system. This software had to be delivered. In terms of size this project was about average.

Case 2.2
This project entailed the development and deployment of a relatively large amount information displays for regional buses in a province. This project was executed with a partner who delivered the displays and did the installation. The case study company was responsible for the development of the server software and the communication with the displays in the field. This was a relatively large project.

Case 2.3
This project entailed the development and delivery of a large amount of small displays at bus stops. This project was executed with a partner. The responsibility of the case study company was a server and the software. This was a large project.

Case 2.4
This project entailed the development of the same displays as in case 2.2. The project was almost a rollout project, but the case study company needed to update the backend system. The size of the project was about average.

Case 2.5
In this project TFT displays had to be developed and delivered that should provide travellers transferring from train to metro, information about the departure time of the subway trains. To achieve this the client wanted a small amount TFT displays. The size of the project was average.

Case 2.6
This client already had a project that entailed a large range of travel information displays. A part of this large project was this project for the displays along a high-speed bus track. A relatively small amount of displays needed to be delivered. In terms of size the project was about average.

Case 2.7
This project was the precursor of case 2.3. A series of small bus displays needed to be delivered. The case study company developed both the hardware and software of this system and outsourced the production of the displays. This was also an average sized project.

Case 3.1
For this project a camera detection system to detect vehicles that carry dangerous goods had to be placed in tunnels of one of the Dutch highways. This system would record it when these trucks go it the tunnel and out of the tunnel. This way the highway authorities and the rescue team will know if one of such trucks is in the tunnel when the traffic gets stuck. This was a very large project.

Case 3.2
This was a camera detection system similar to case 3.1, but on a much smaller scale for a foreign client. They received a camera, a processing unit and a manual to install the system for 1 lane. It was more a pilot project than an actual project. The project did entail that the data would be processed on a website and would be visible for the client. This was a very small project.

Case 3.3
Previously the case study company had developed a system for the route planning of special vehicles that were restricted due to the dimensions or weight. According to EU regulations this information had to become public. Therefore a site needed to be built on which this information would be accessible. This was also a very small project

Case 3.4
The scope of this project was a camera system that registered license plate information of trucks and compare this with information on the weight on these trucks. This system is basically an enforcement system. When trucks that are above a certain threshold (in terms of weight) enter a zone where this is prohibited they are fined. This size of this project was about average.

Case 4.1
The case study company had previously implemented a tracking & tracing system for all transport units of one of public transportation companies in the Netherlands. This needed to be updated to keep up with the latest technology standards. A completely new hardware system was developed. This project entailed the hardware of the project. This project was about average sized.

Case 4.2
This project is the software side of the system of case 4.1. The project also involved the integration of the hardware and software. This was also an average sized project.

Case 4.3
Previously, the case study company had developed an enforcement system that enables the authority to measure the average speed of a vehicle over a certain road segment. These systems were designed for a fixed maximum speed, for instance 100-km/h. Currently many road segments make use of dynamic maximum speeds. The goal in this project was to enhance the systems so it could react on dynamic maximum speeds. This project was average sized.

Case 4.4
This project was the predecessor of case 4.1 and 4.2. It entailed the development of two completely new systems as proof of concept. When these were delivered to the client, the project for the development of a whole new range of Track & Trace devices was signed. This led to the project of case 4.1 and 4.2. This project was average sized.

Case 5.1
This project involved a system in which travellers would avoid travelling to two city centres during rush hours. In all the cars of the participants GPS devices were installed and everyone got a navigation system. The development of this navigation system was also part of the scope of this project. Furthermore the scope entailed participants, the technical system for the detection of the cars and the reporting of the project. This was a very large project in the portfolio of the case study company.

Case 5.2
This was also a very large congestion avoidance project. It involved the avoidance of two city centres during rush hour. Registration was done using cameras. This was also a very large project for the case study company.

Case 5.3
In this project the client had a fixed budget and wanted as much traffic avoiders as possible. In the tender they asked the companies to bid for the amount of traffic avoiders they could deliver for this budget. This budget should cover everything: camera systems, recruitment of and communication with participants, payment of the rewards etc. The project had an ambitious lime line. This was a relatively large project.

Case 5.4
This congestion avoidance project did not entail the camera system, but did entail data processing and the acquisition of participants. This was also a very large project for the case study company.

Appendix B   Description of function groups

<u>11 – Senior Management</u>
The Senior Management of the company consists of 5 people: A general director, an operational director, a technical director, a sales director and a financial director.

<u>10 – Project Management</u>
The project managers have the responsibility to lead the projects. This can be divided into an internal and external responsibility. The internal responsibility relates to leading the project team, controlling the quality, scope, budget and schedule of the project, making the required documentation for the project and communicating with the senior management. The external responsibility relates foremost to the communication with the client. Typically there is one project manager assigned per project, but pilots have been done with two project managers. In this set up one of the project managers has the internal and one the external responsibility.

<u>9 – Service Manager</u>
A service manager is actually a project manager, but for all the projects that are in the service and maintenance phase. They control often long service contracts with clients.

<u>8 – Product Specialist</u>
This function groups are the consultants. They are conceptual specialists and can fill the gap between the project managers and the system developers/architects.

<u>7 – Communication Consultant</u>
Communication consultants are responsible for communication on large scale (mass communication) and for corporate image (marketing).

<u>6 – System Architect</u>
These are the highest-level technical resources. They are the architects for the technological systems of the company.

<u>5 – System Developer / Designer</u>
System developers and designers are the technical developers of the technical systems in the projects. From their position they also control and coordinate possible outsourced development.

<u>4 – Data Analyst</u>
Data analysts are very specific technicians who are responsible for the analysis of data; find connections, and relationships etc.

<u>3 – System Administration</u>
The system administration is support staff for the installation and maintenance of computer systems and other ICT infrastructure. This function group does internal work for the company, but also support project teams in projects.

<u>2 – Project Support</u>
This function group supports the project manager with a variety of tasks, such as purchasing, administration and practical support.

<u>1 – Service Desk</u>
This is the first line service desk for customers of specific solutions.

Appendix C   Division of labour hours case group 1
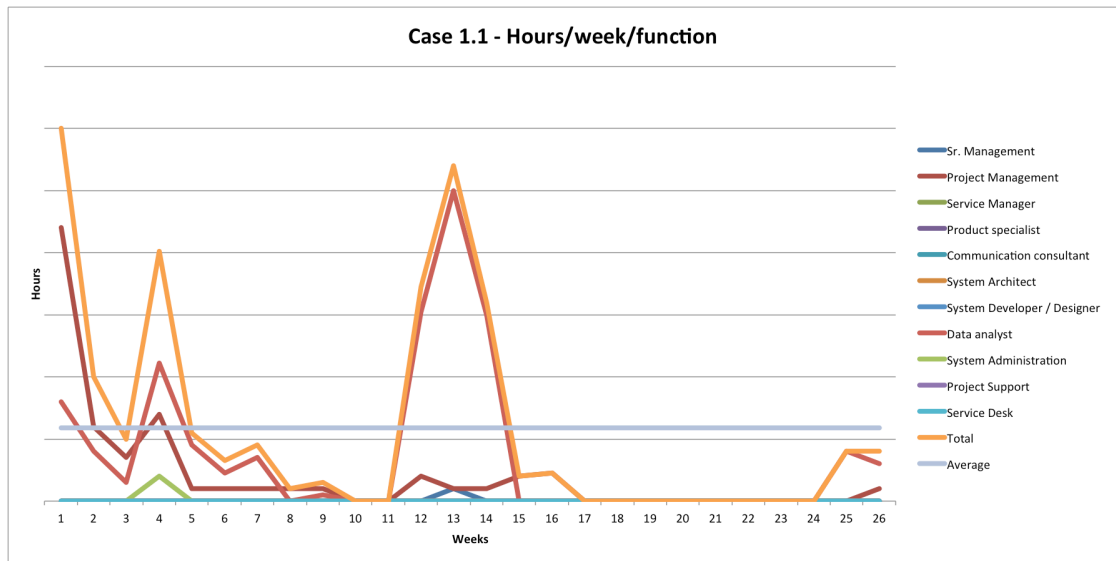
Figure 11 Hours/week/function – Case 1.1
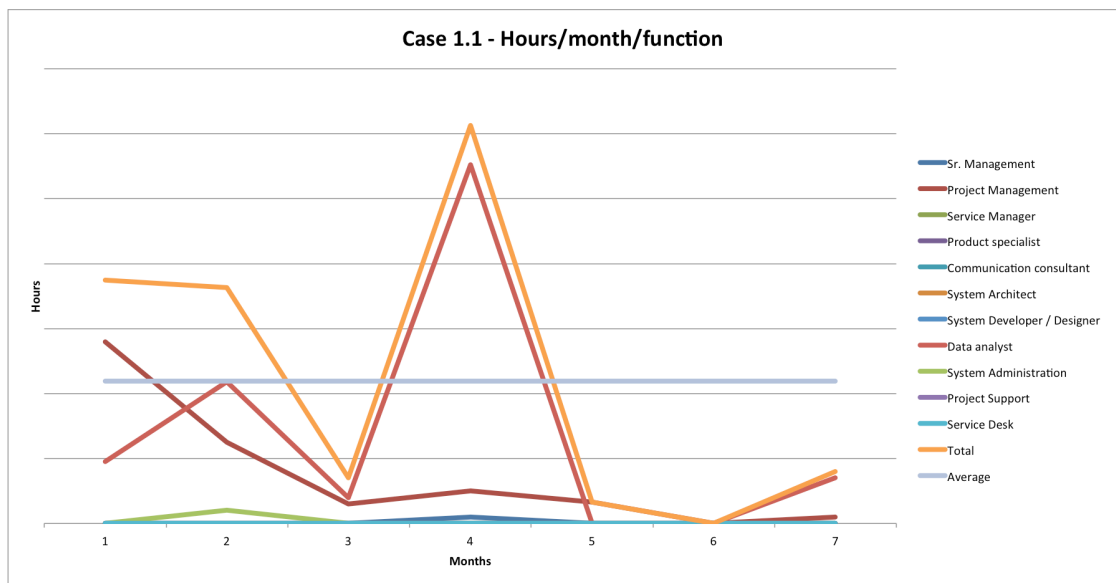
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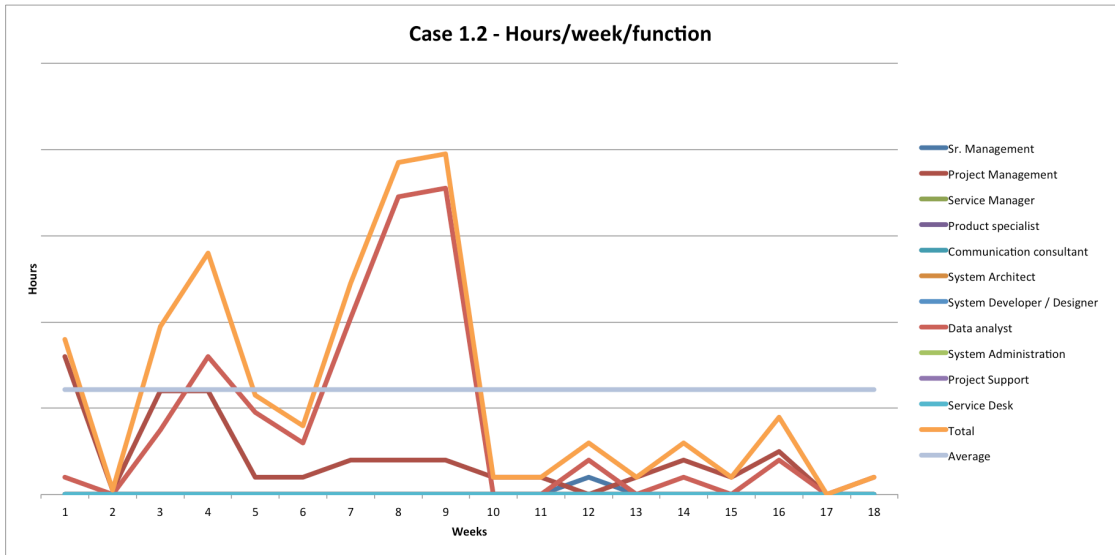
Figure 13 Hours/week/function – Case 1.2
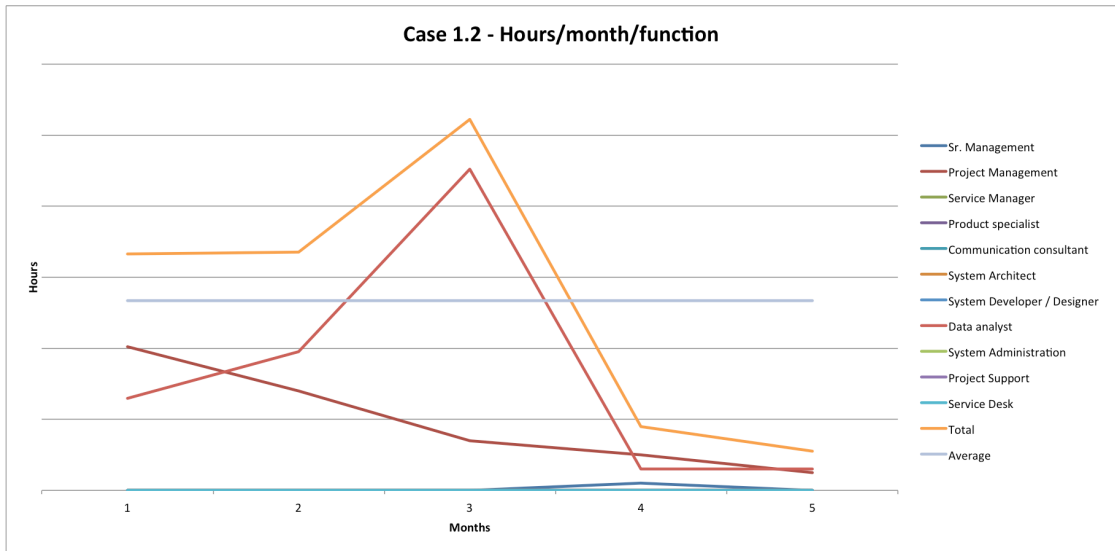
Figure 14 Hours/month/function – Case 1.2
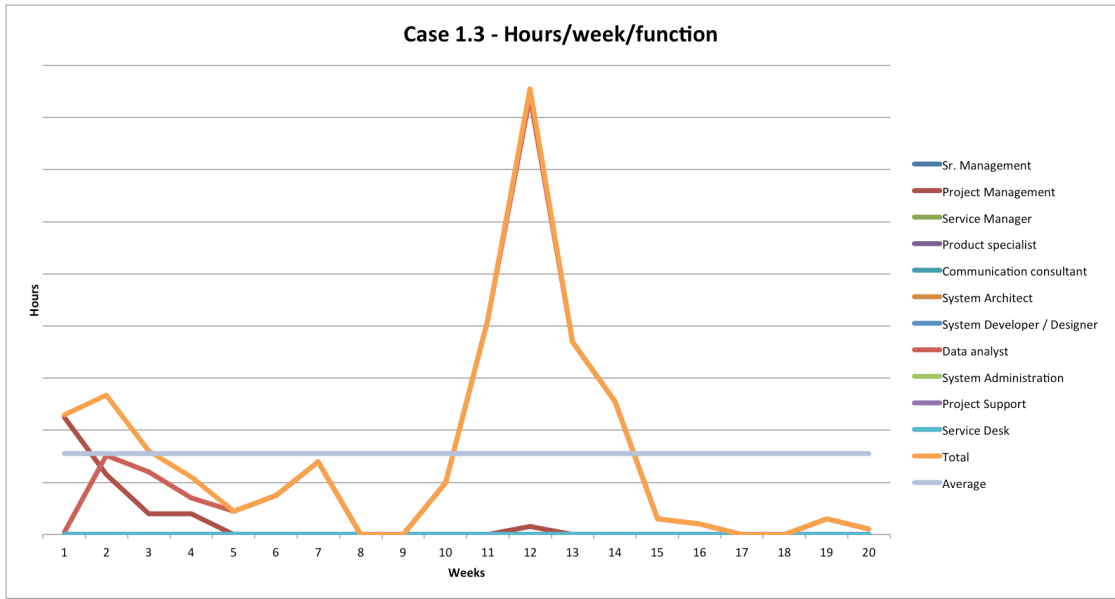
Figure 15 Hours/week/function – Case 1.3
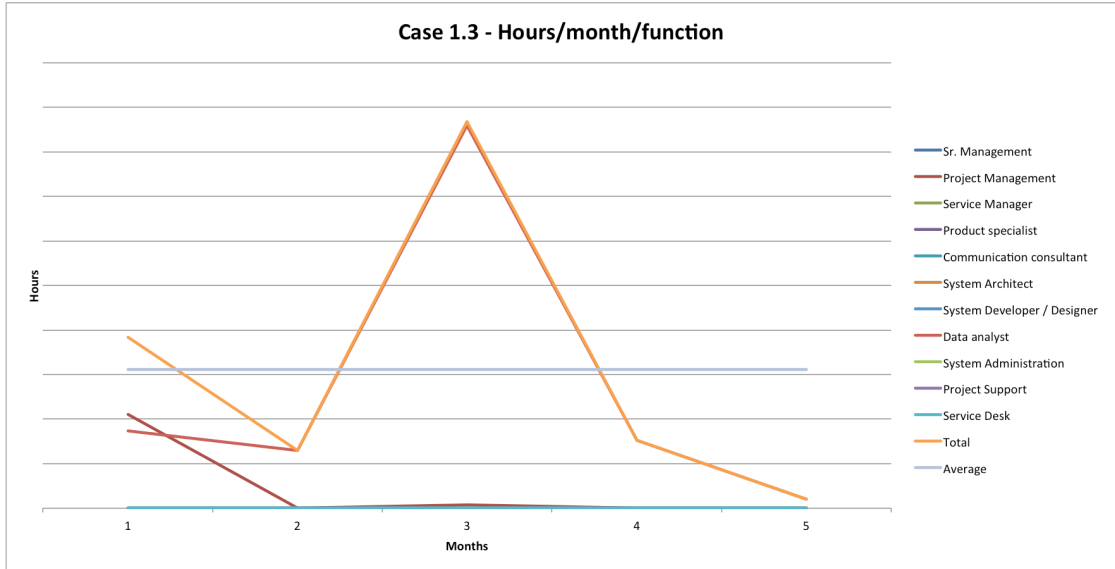
Figure 16 Hours/month/function – Case 1.3
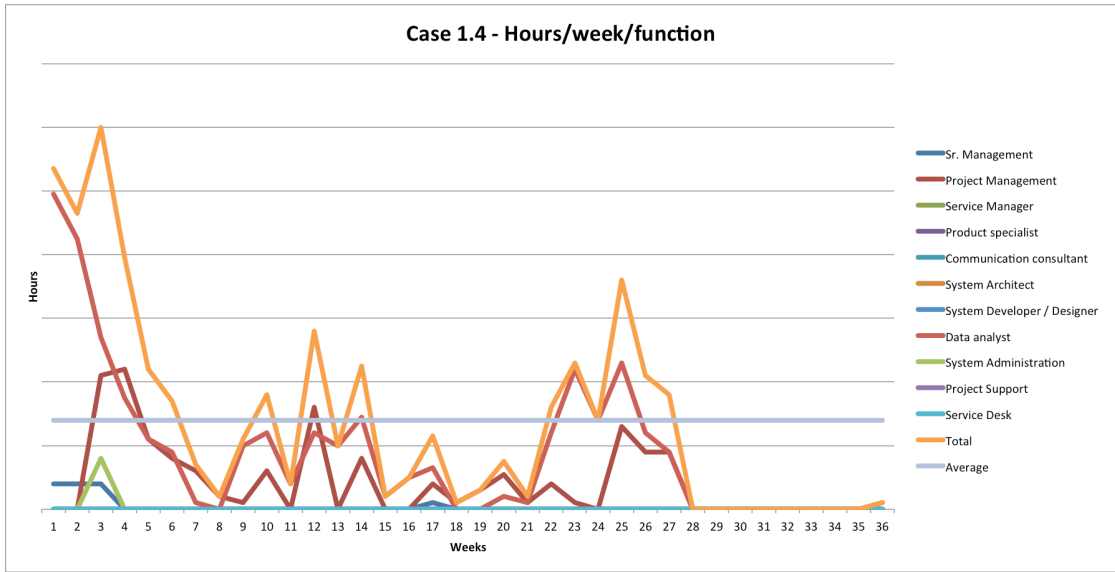
Figure 17 Hours/week/function – Case 1.4
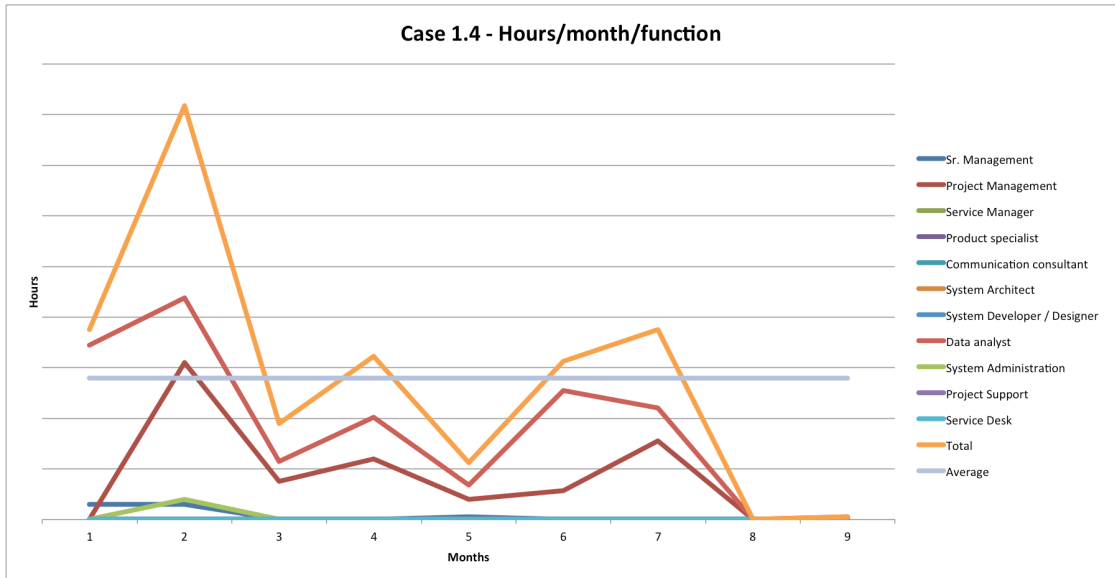
Figure 18 Hours/month/function – Case 1.4

Appendix D   Division of labour hours case group 2
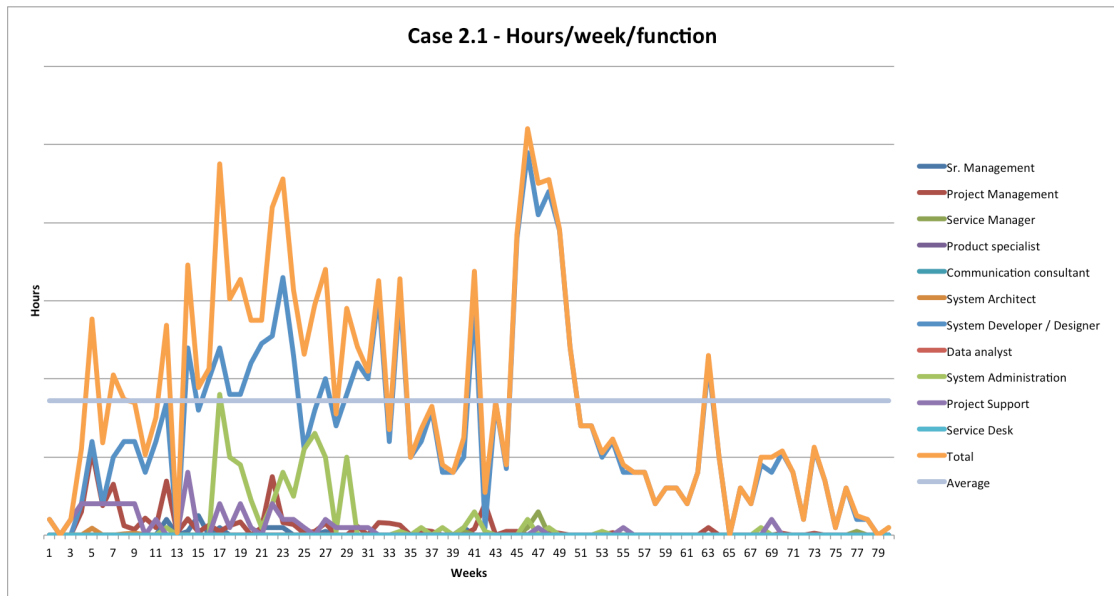
Figure 19 Hours/week/function – Case 2.1
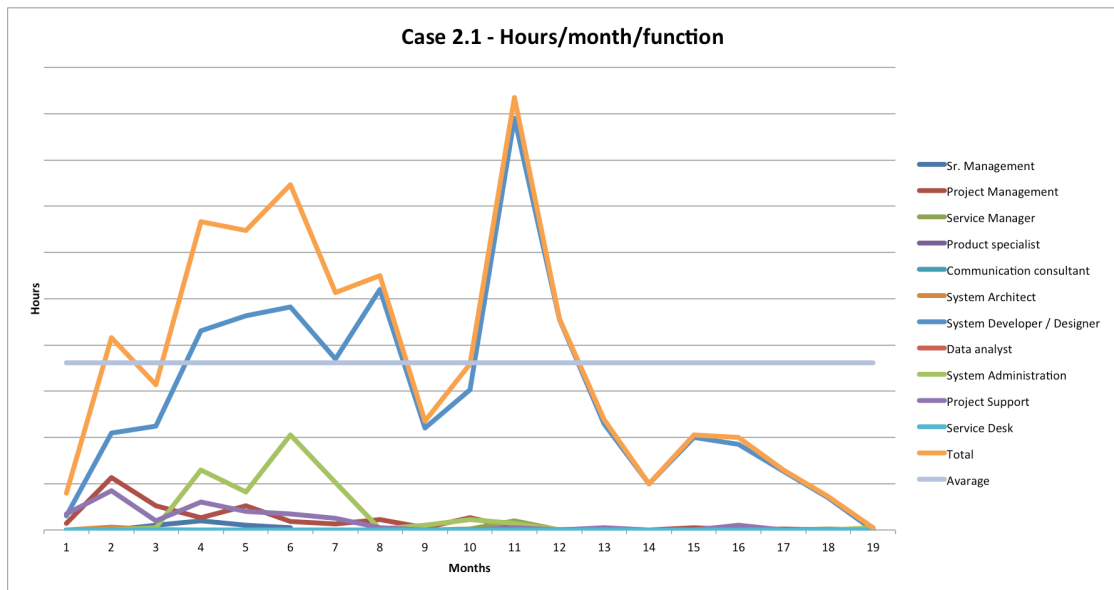
Figure 20 Hours/month/function – Case 2.1
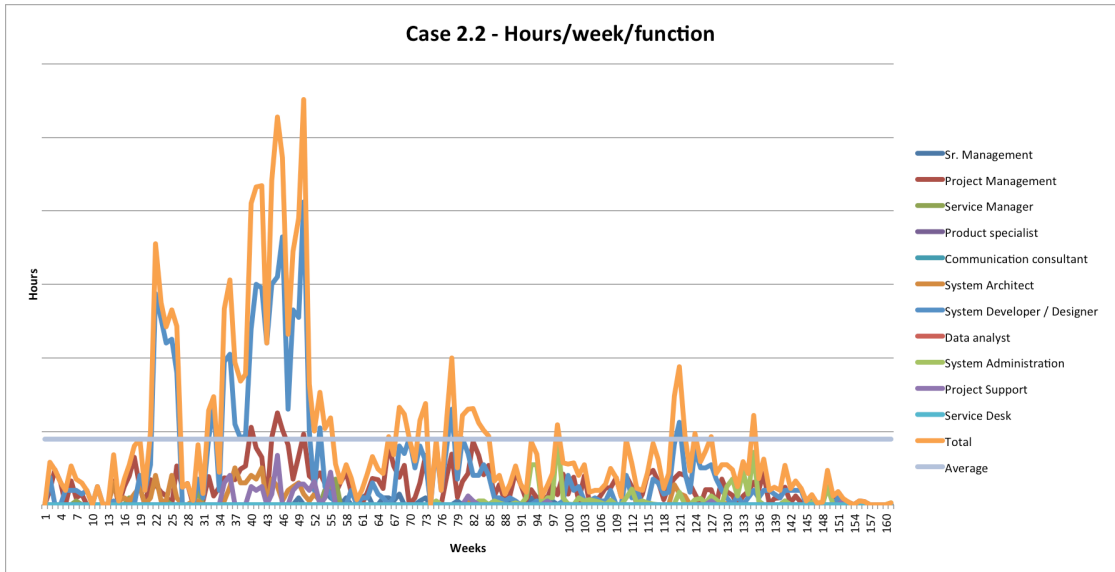
Figure 21 Hours/week/function – Case 2.2
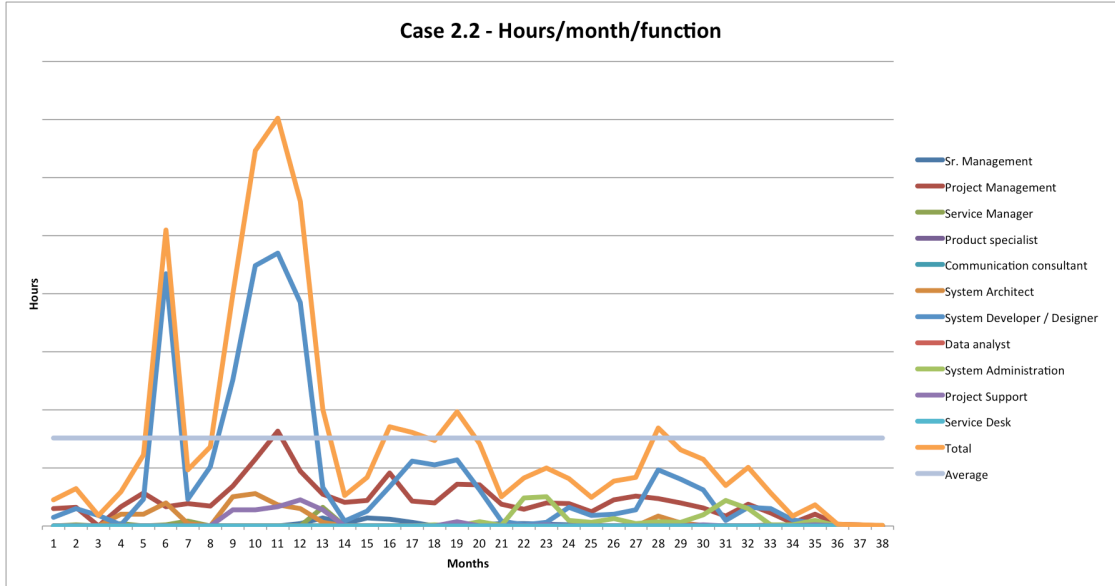
Figure 22 Hours/month/function – Case 2.2
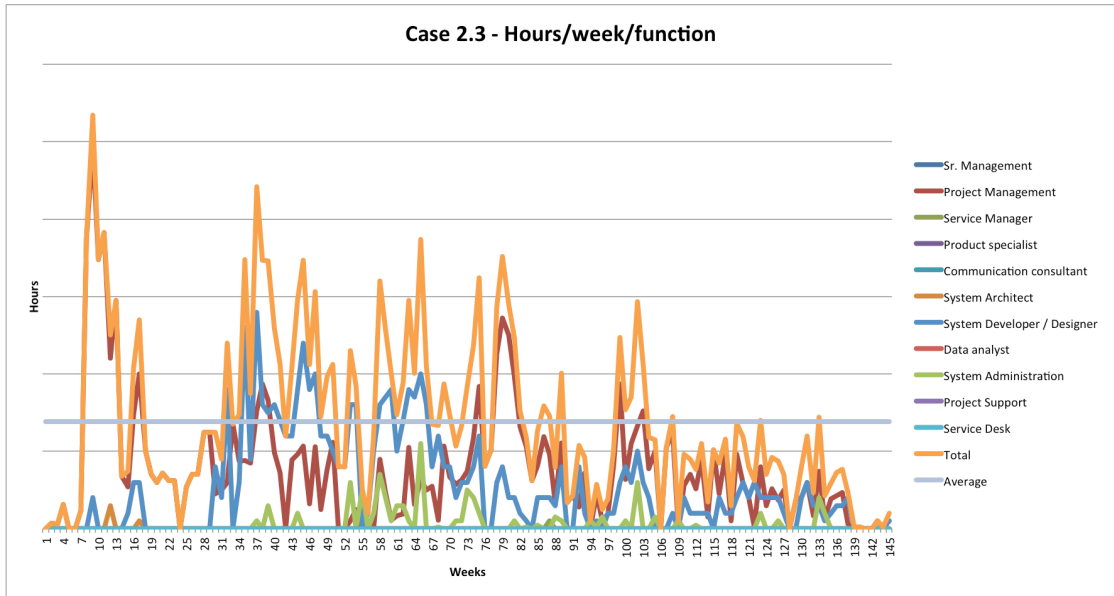
Figure 23 Hours/week/function – Case 2.3
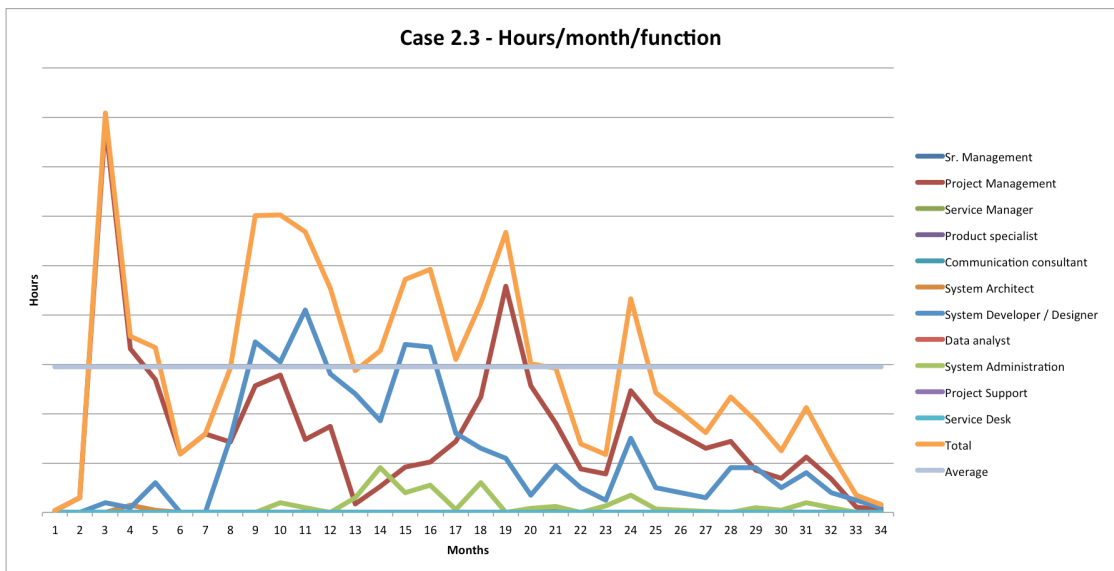
Figure 24 Hours/month/function – Case 2.3
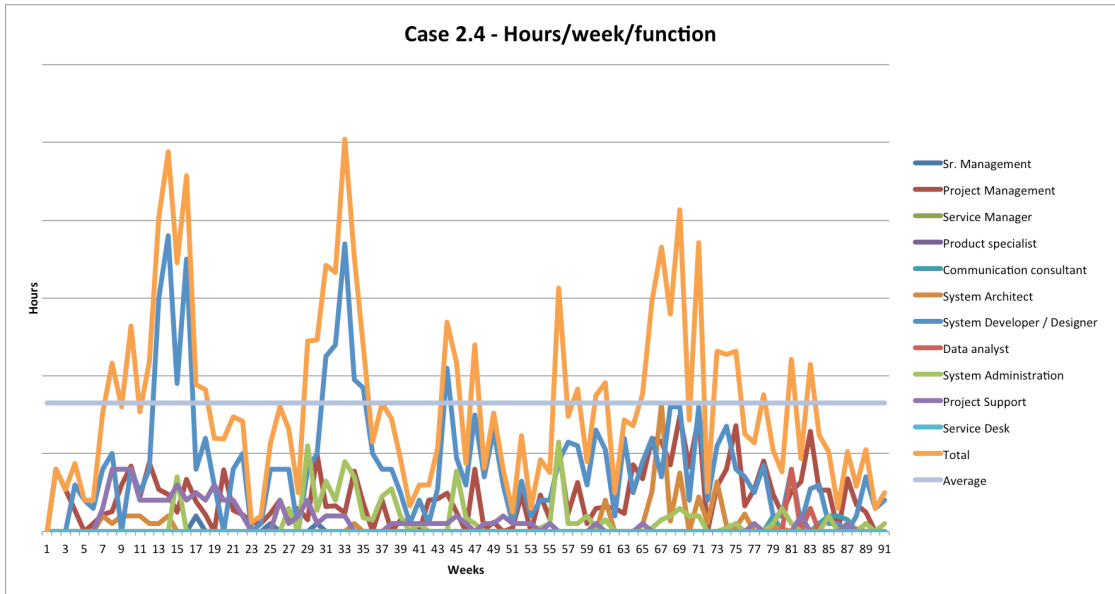
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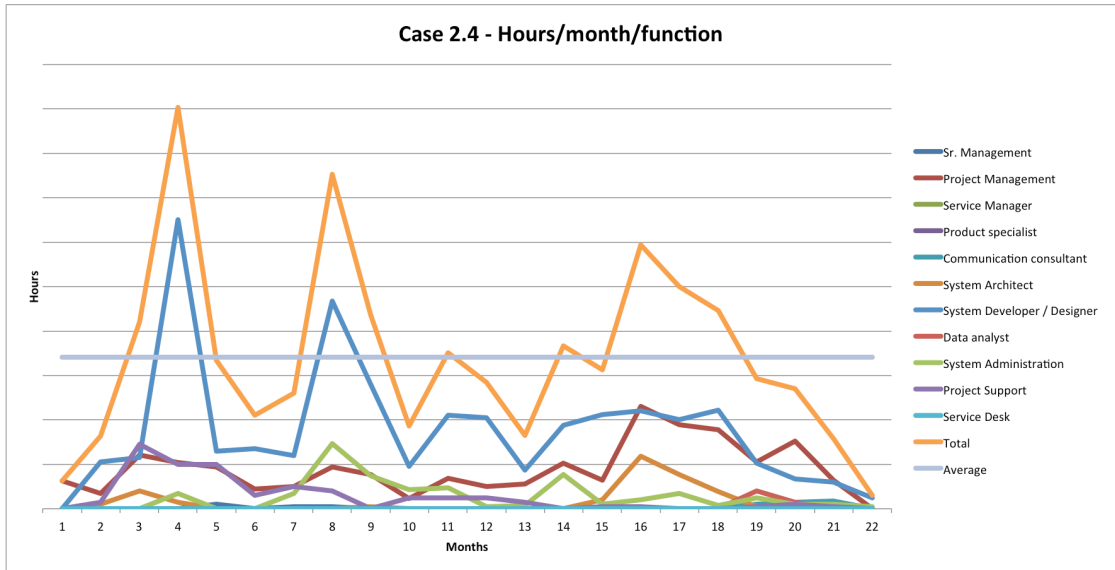
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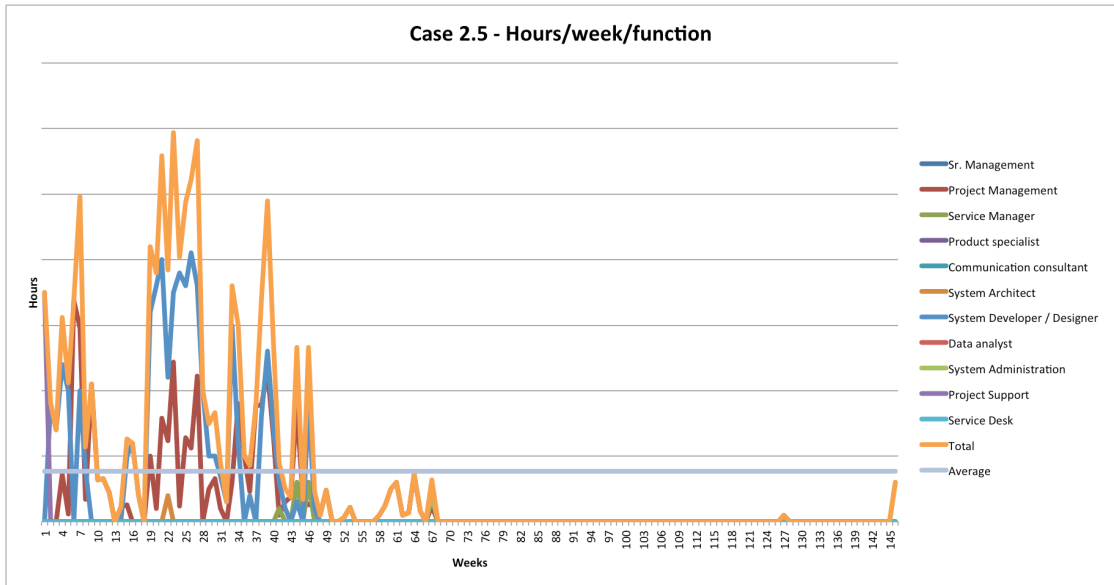
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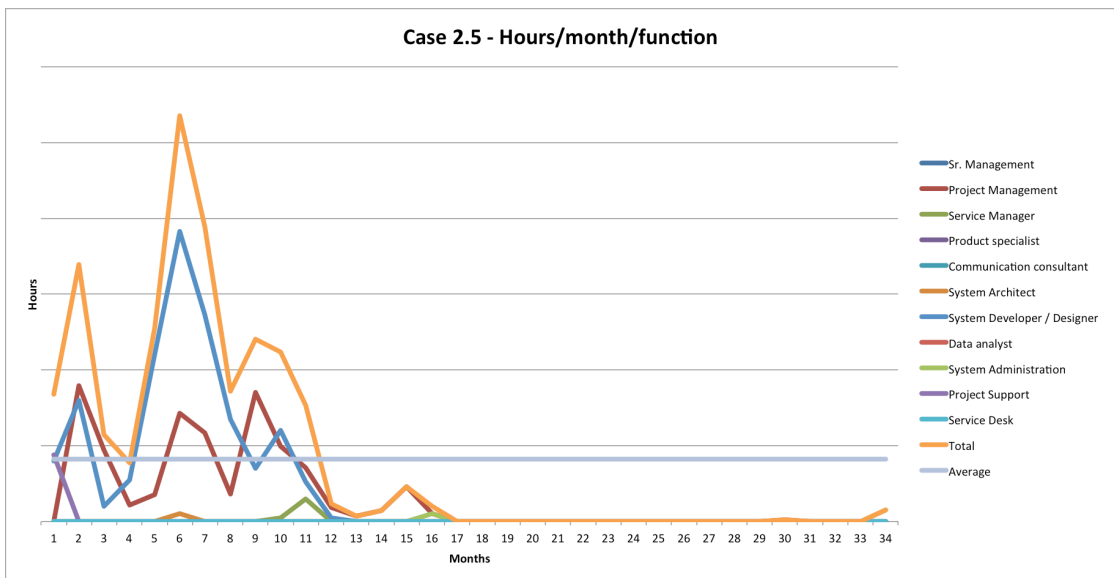
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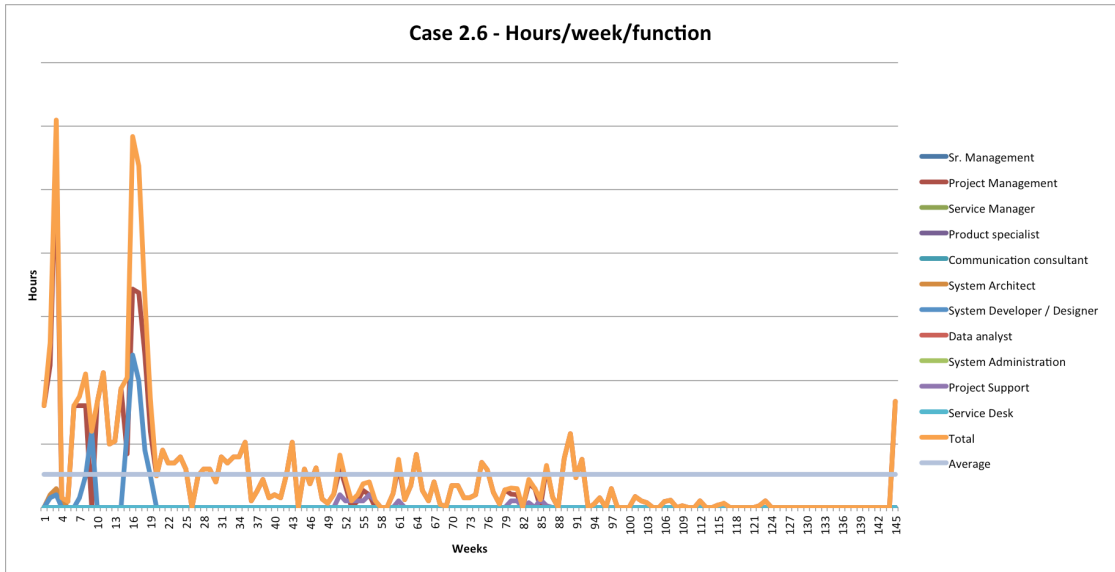
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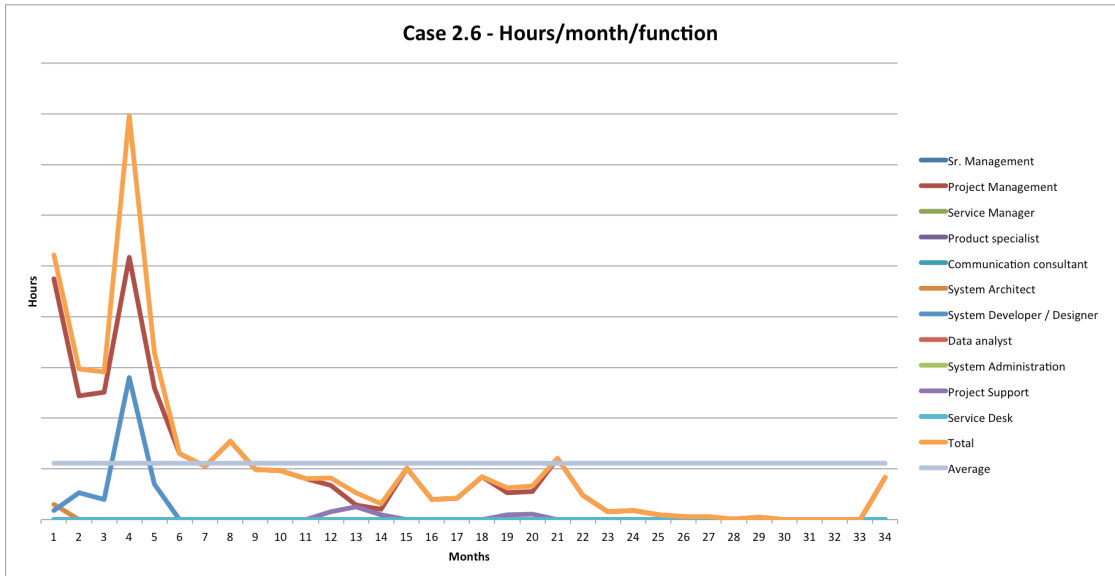
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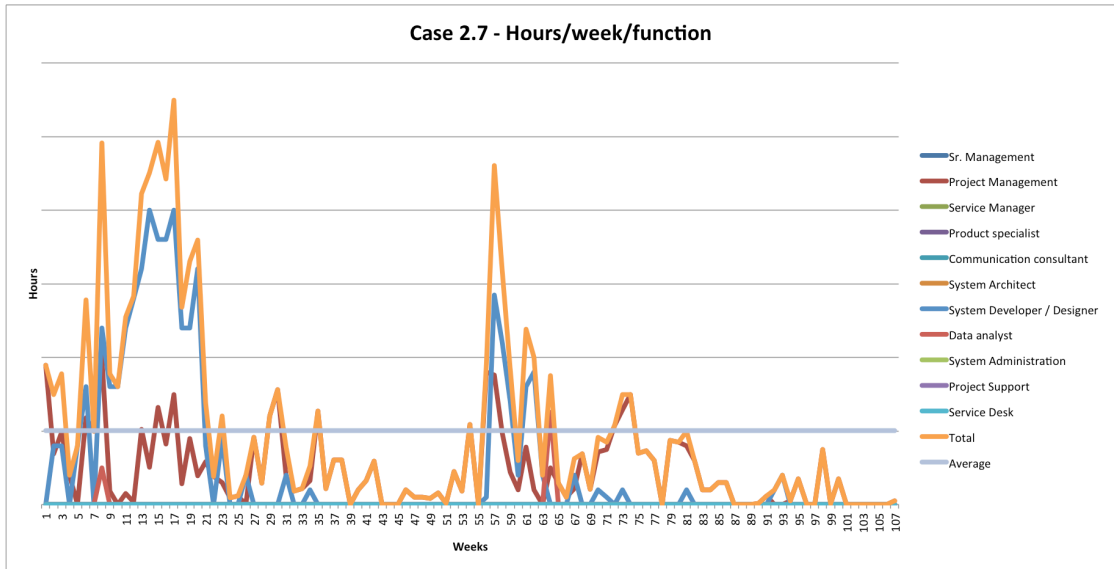
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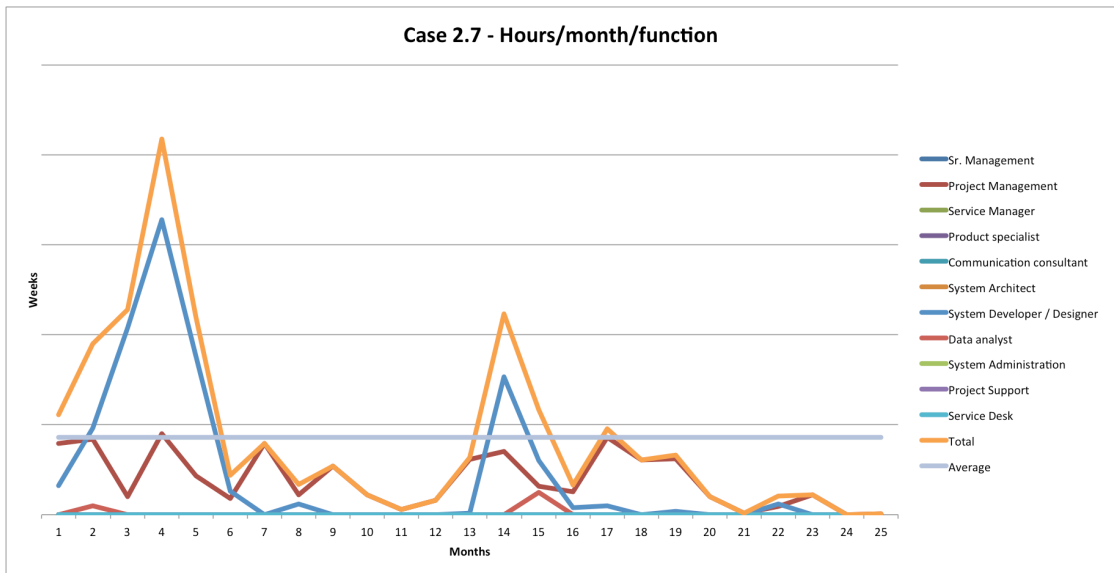
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Appendix E   Division of labour hours case group 3
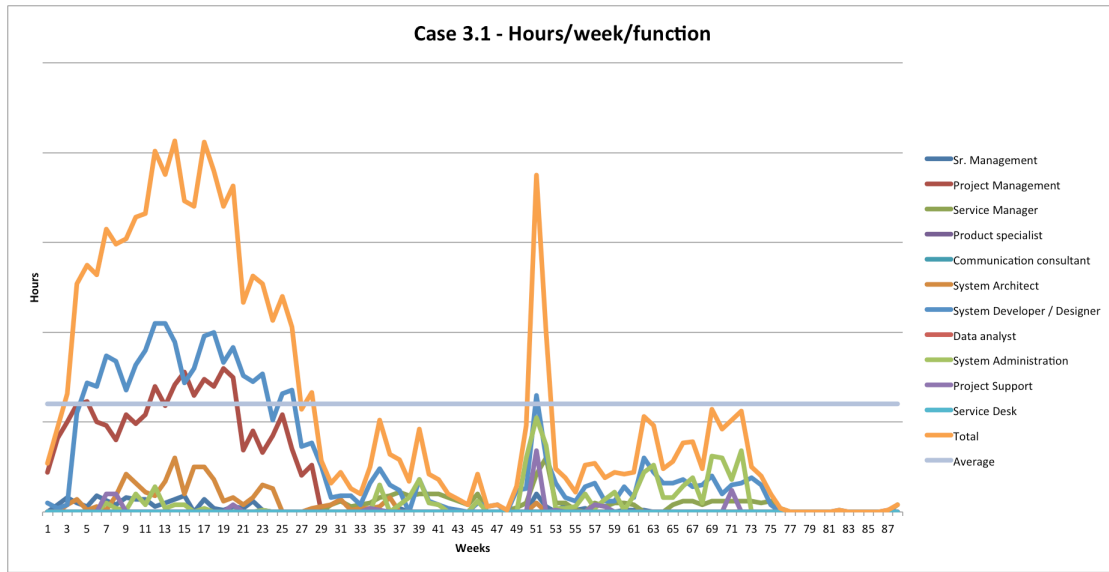
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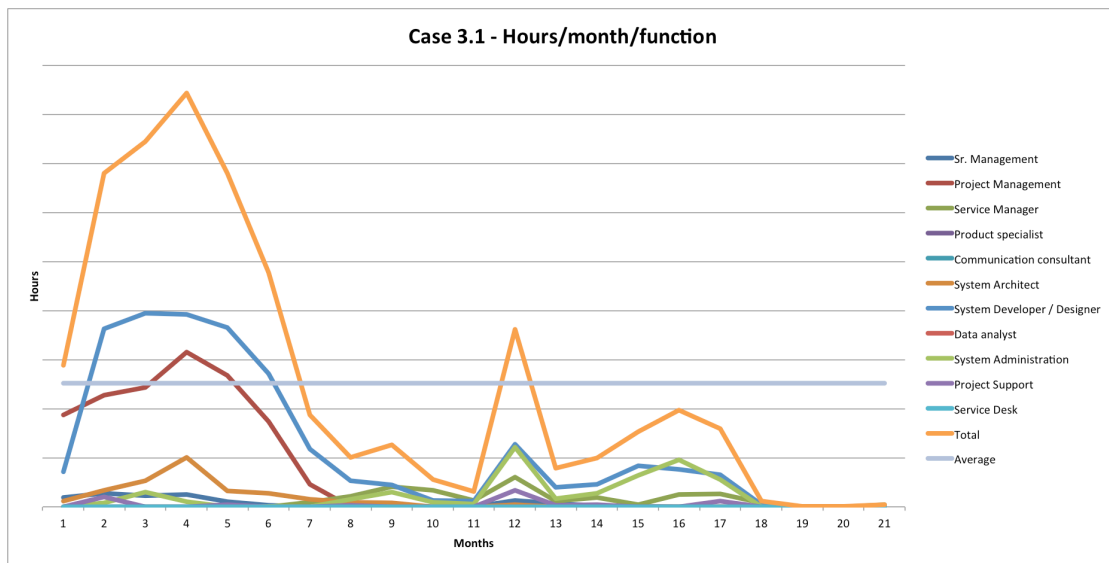
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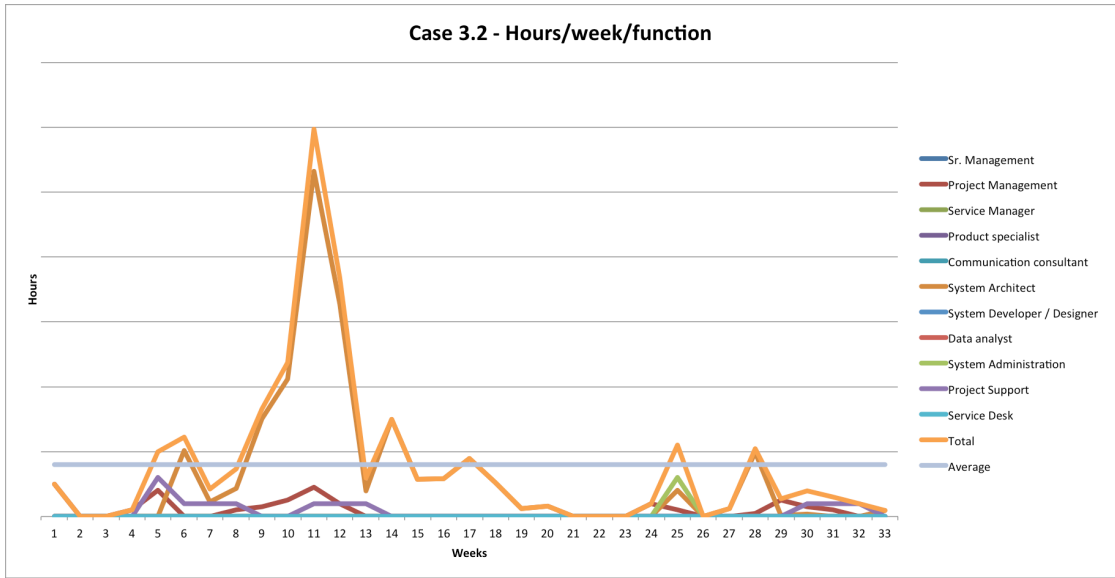
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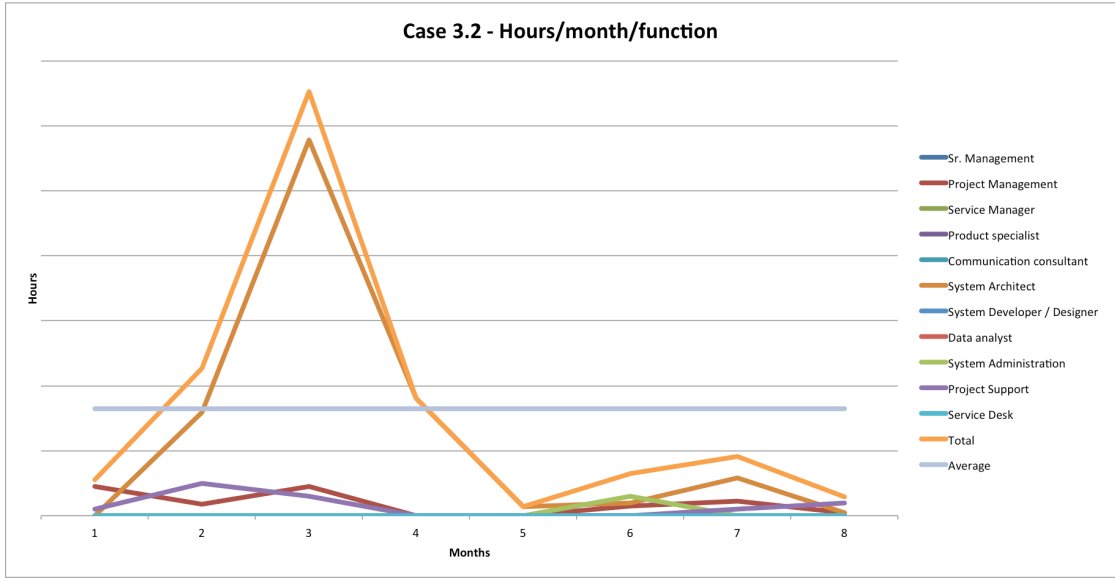
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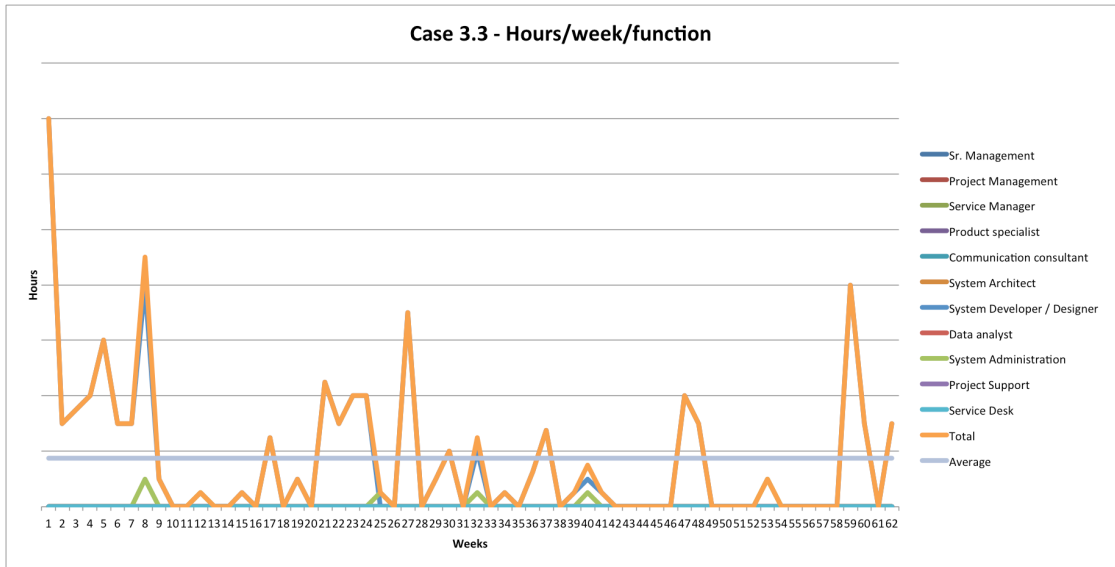
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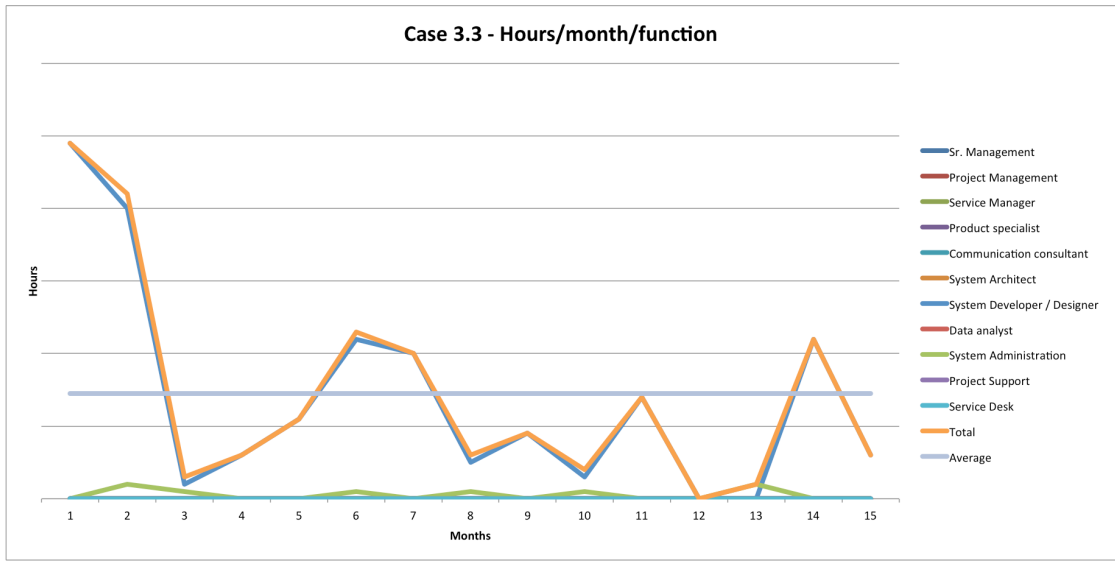
Figure 38 Hours/month/function – Case 3.3

110
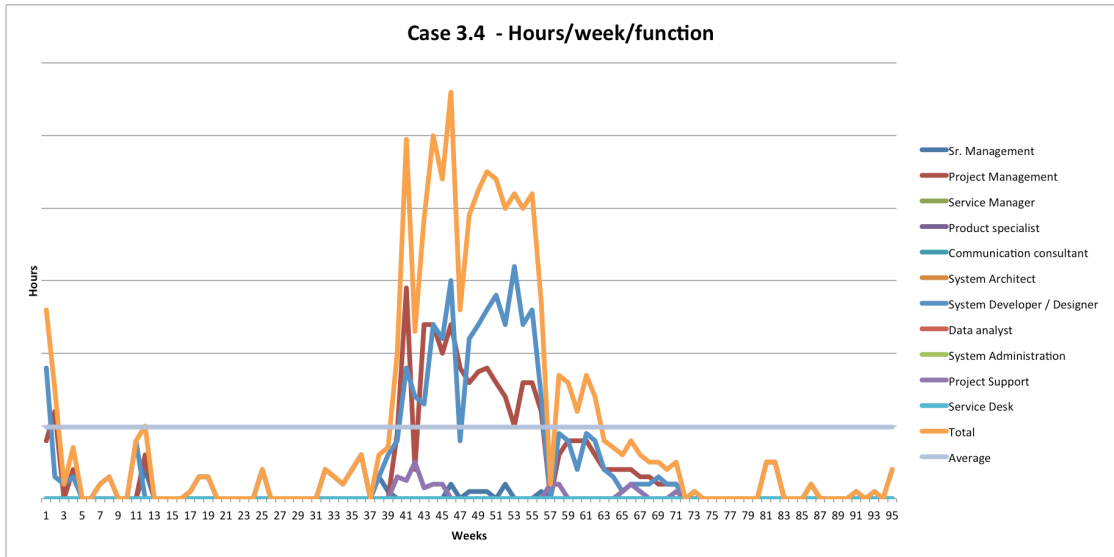
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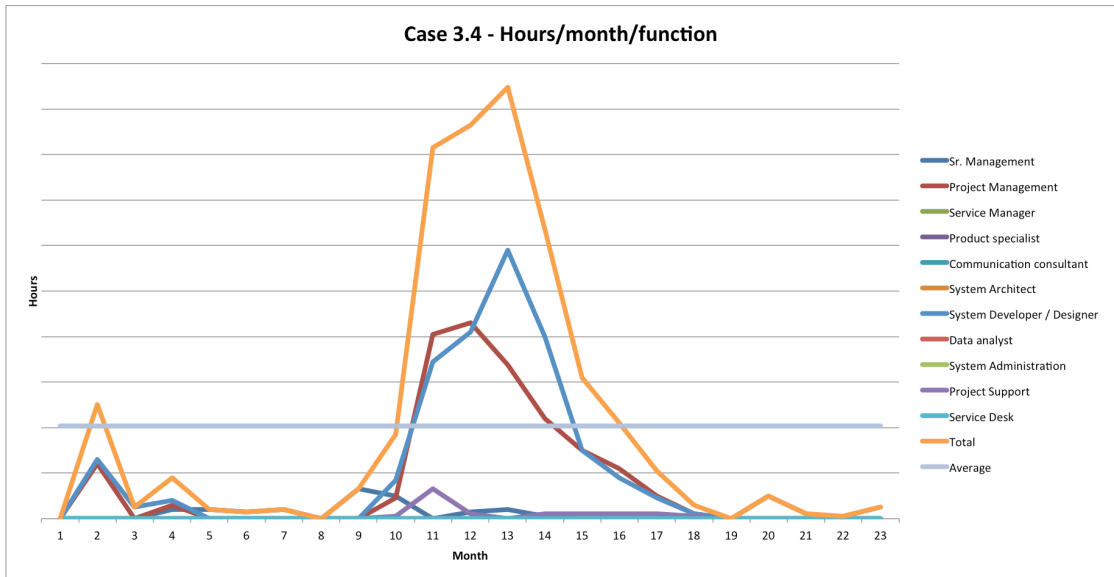
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Appendix F   Division of labour hours case group 4
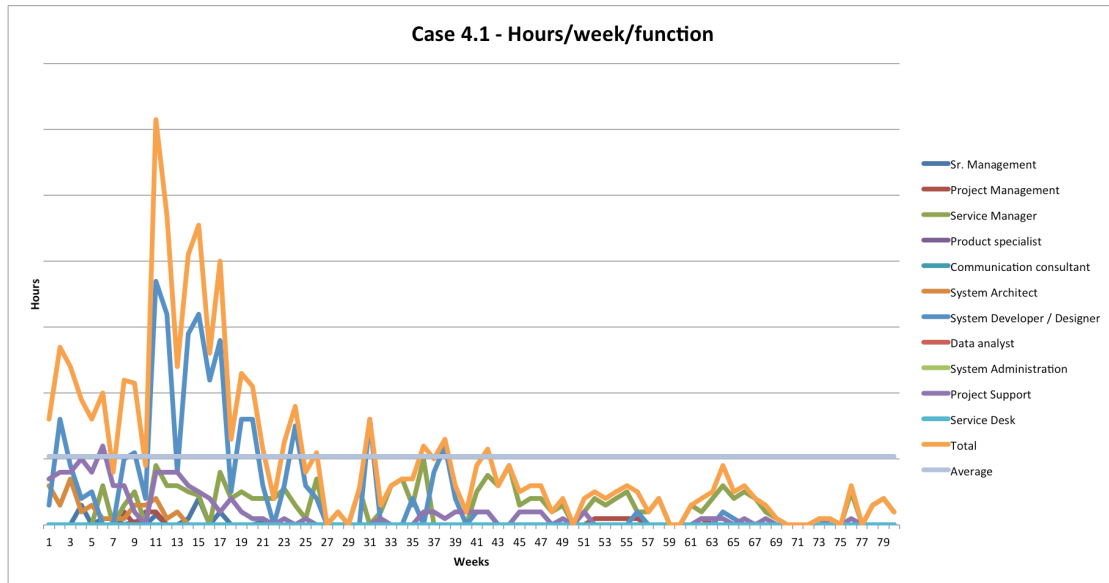
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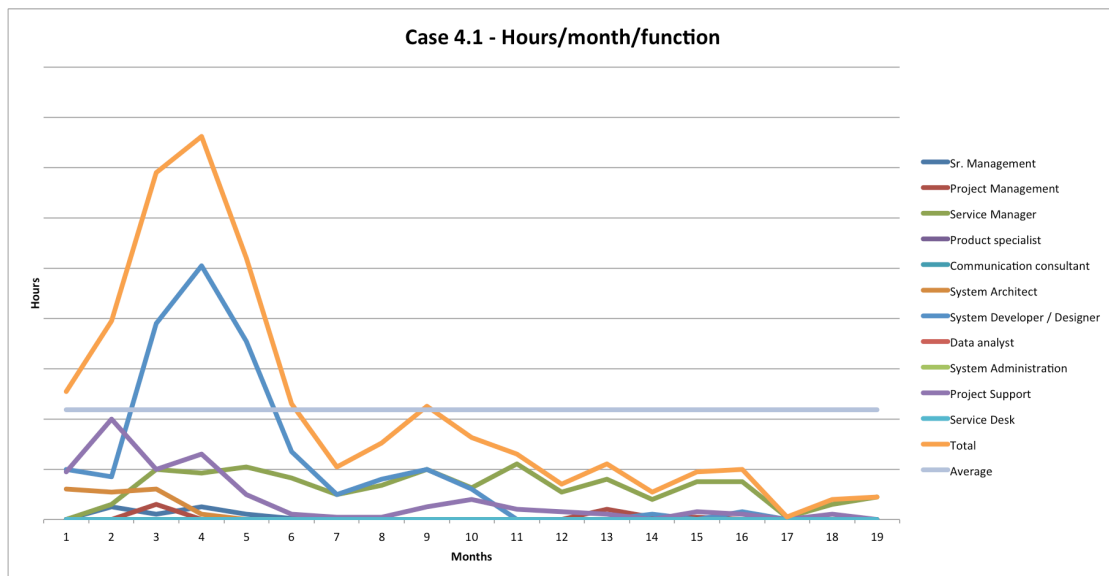
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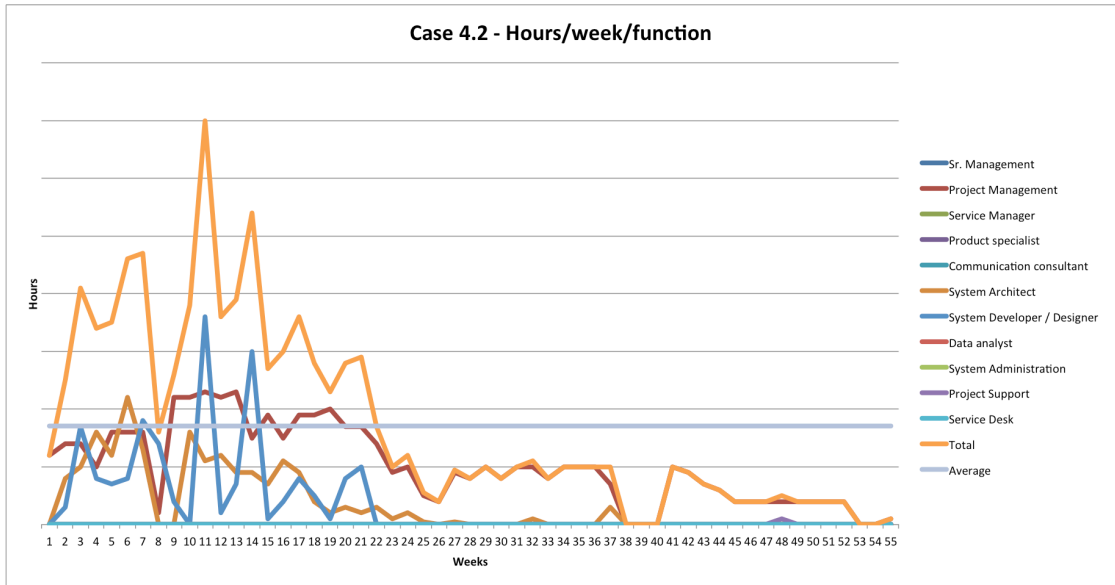
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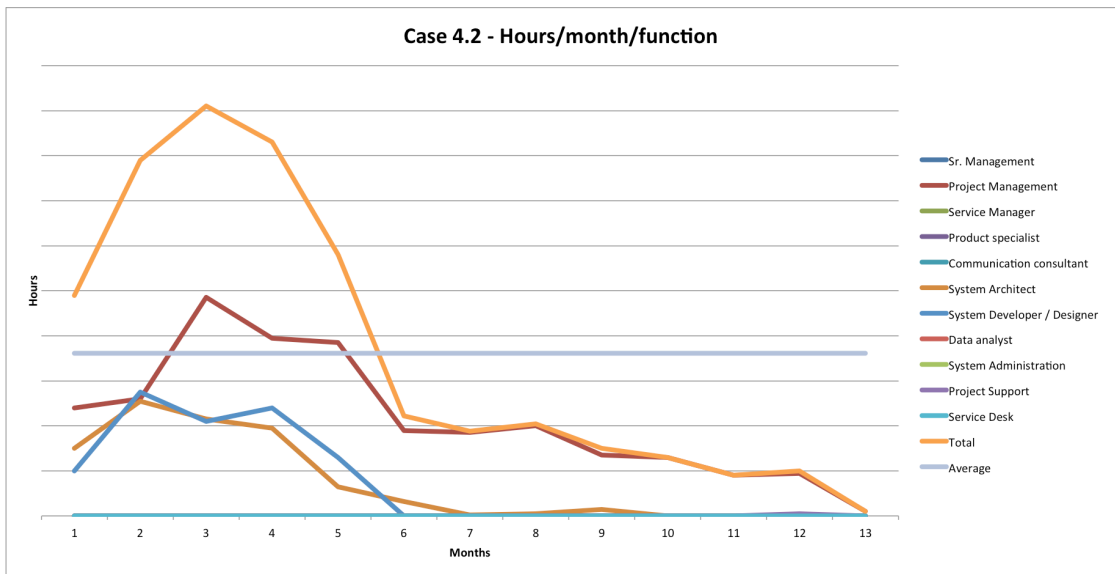
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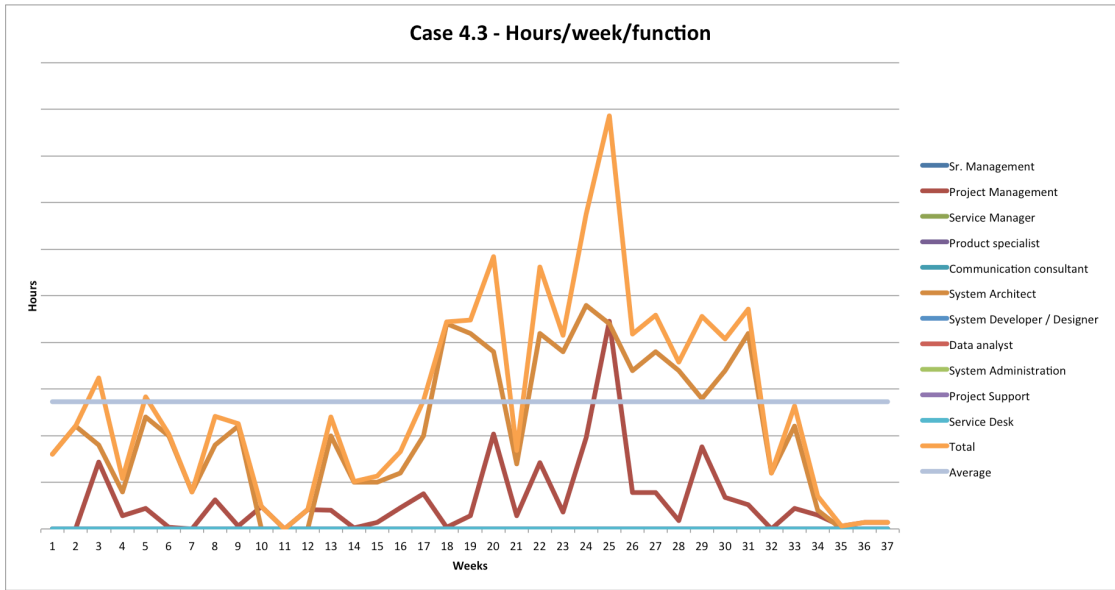
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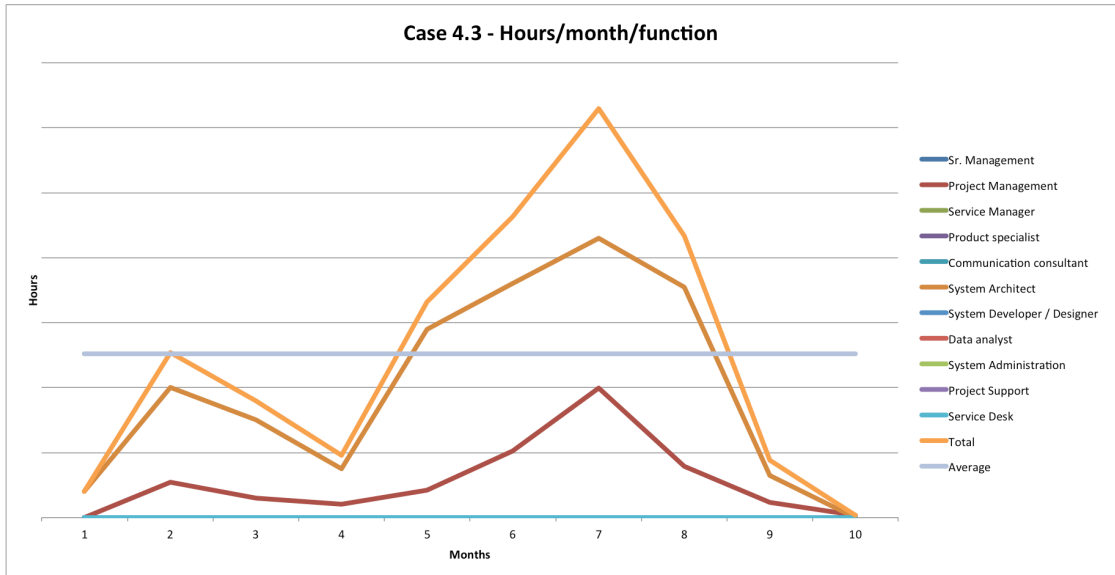
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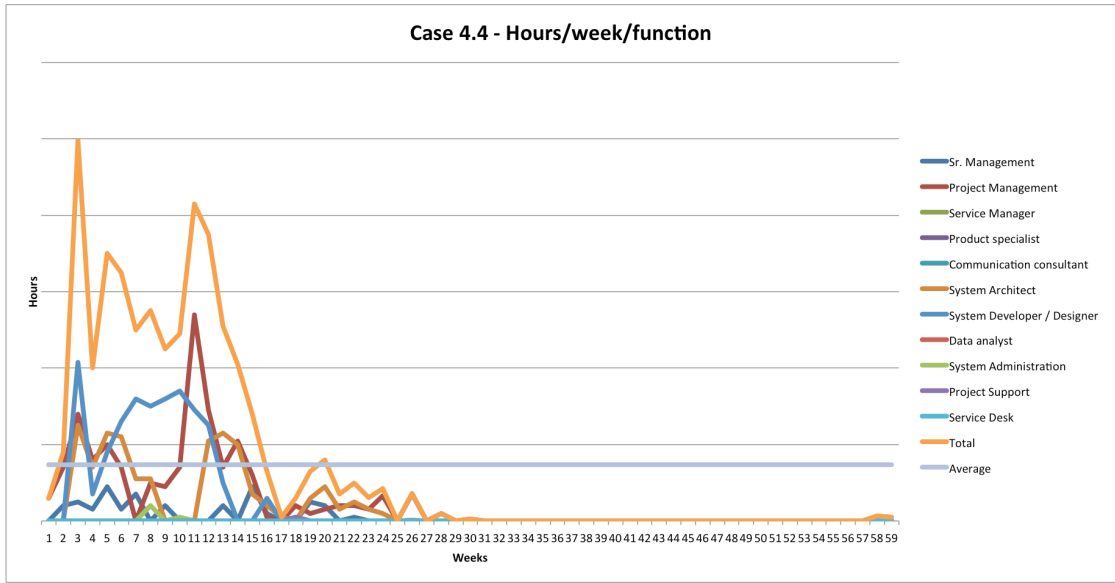
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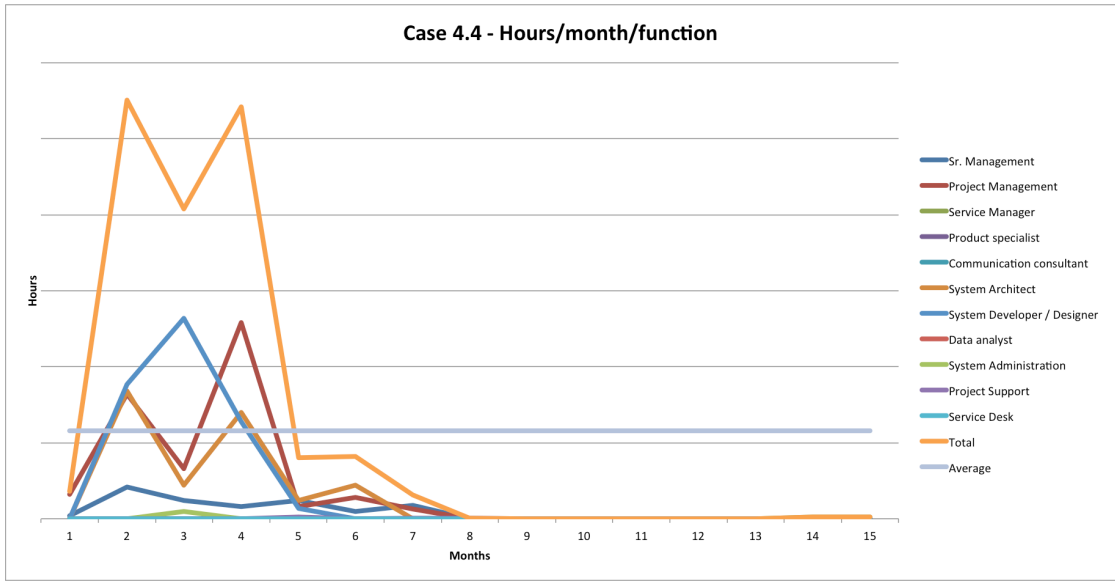
Figure 48 Hours/month/function – Case 4.4

Appendix G   Division of labour hours case group 5
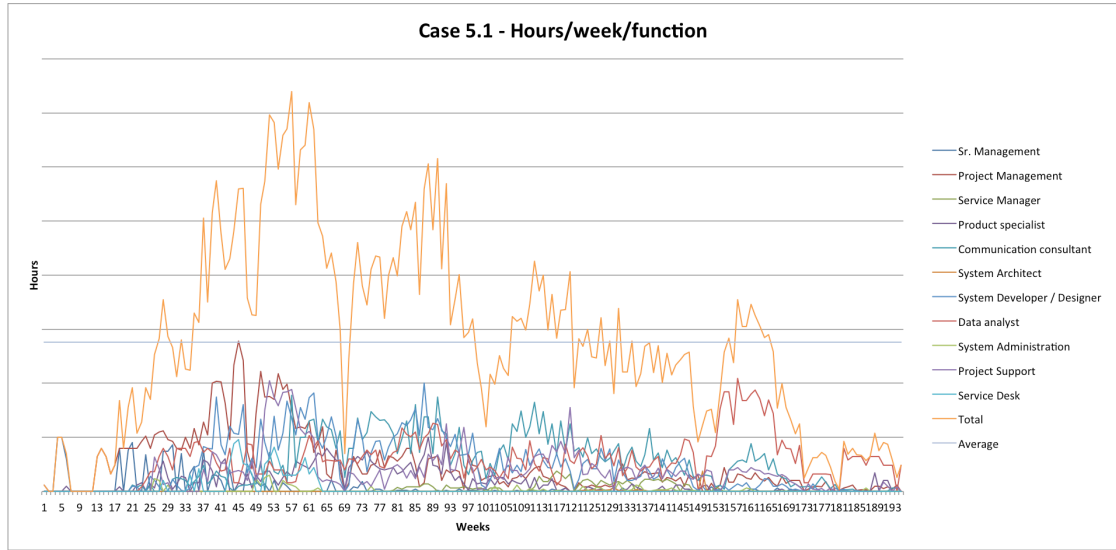
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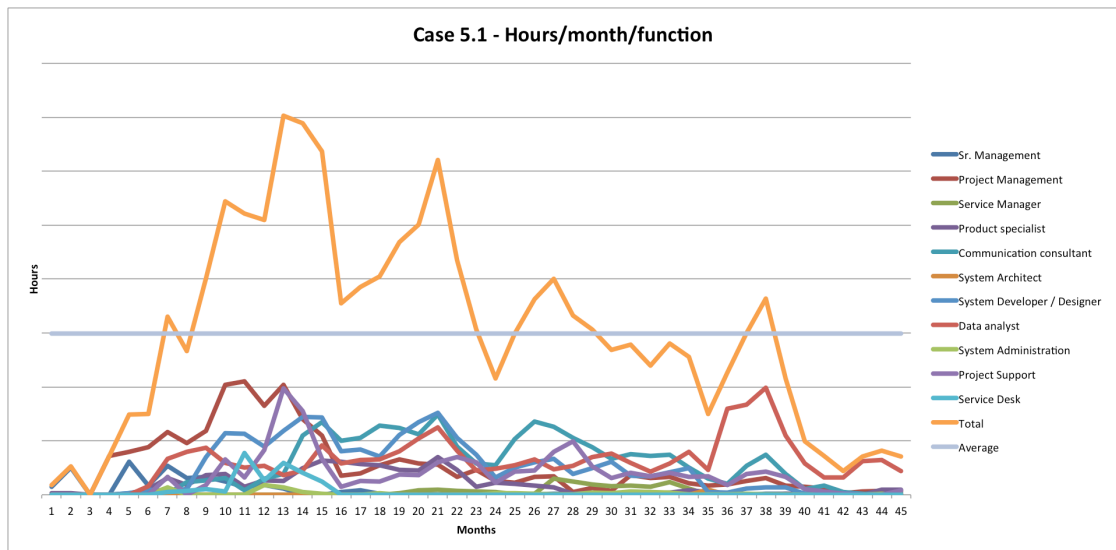
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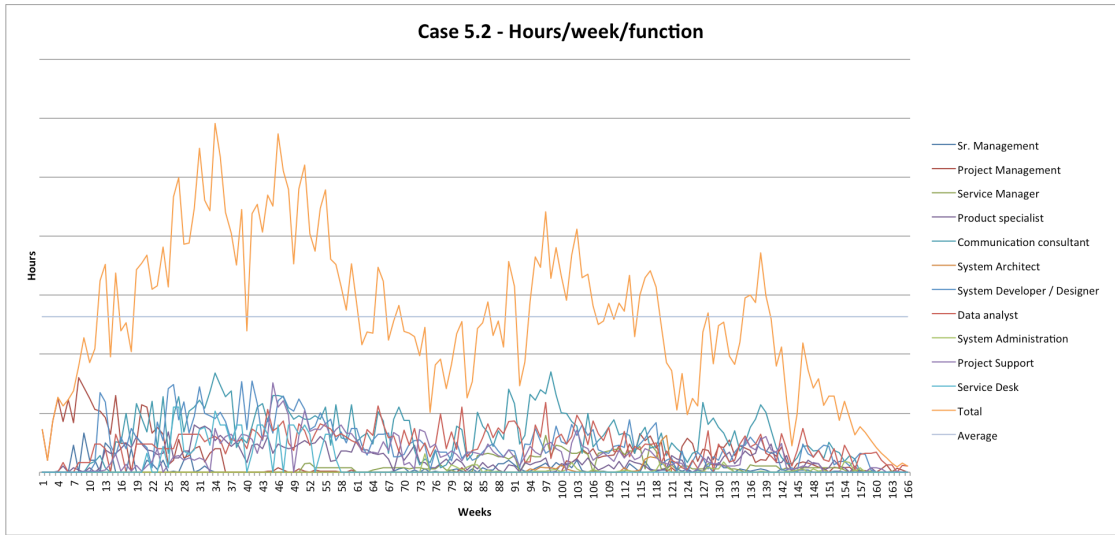
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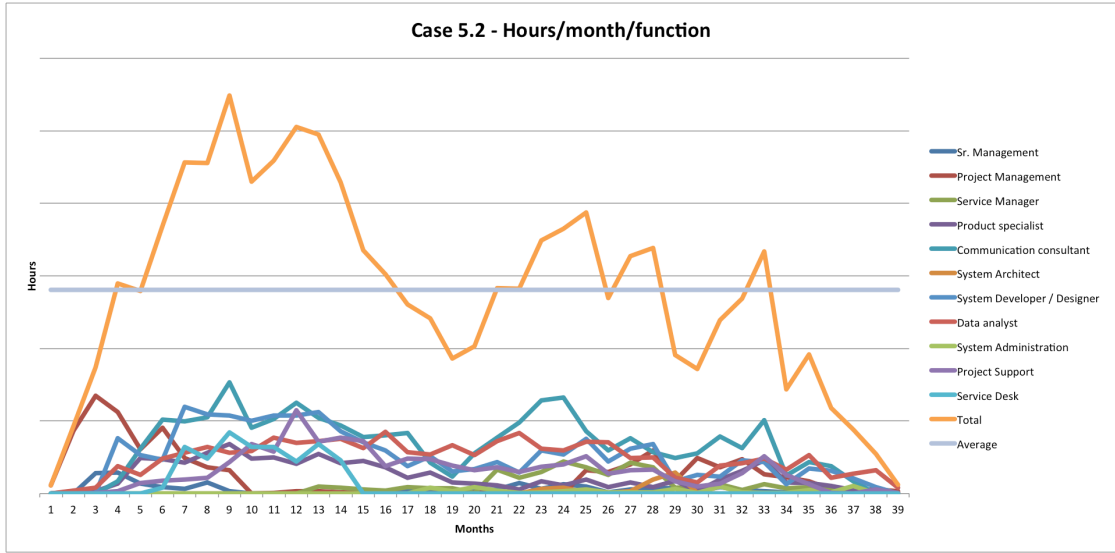
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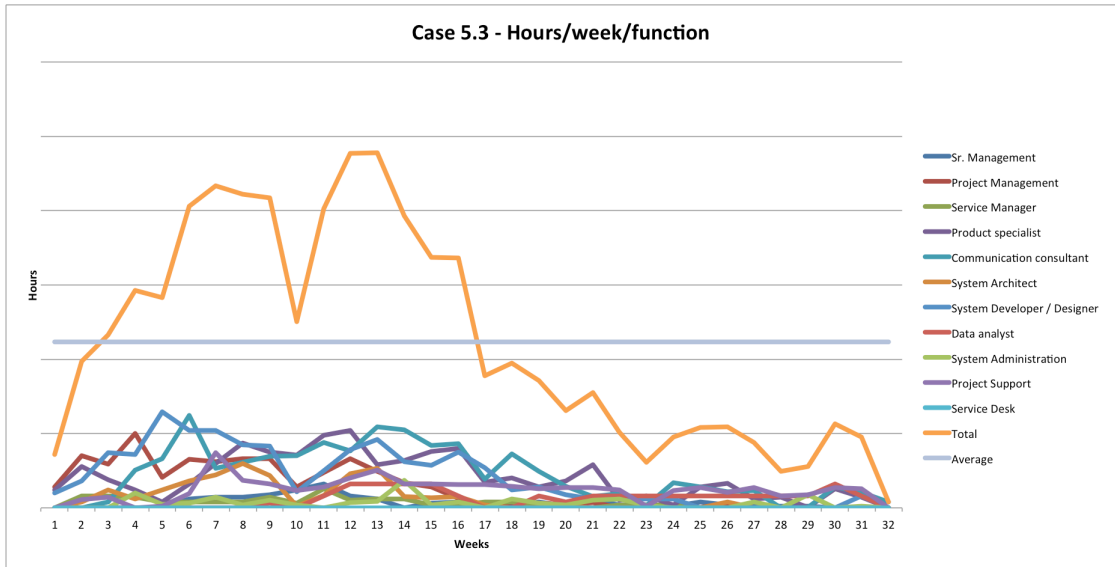
Figure 53 Hours/week/function – Case 5.3
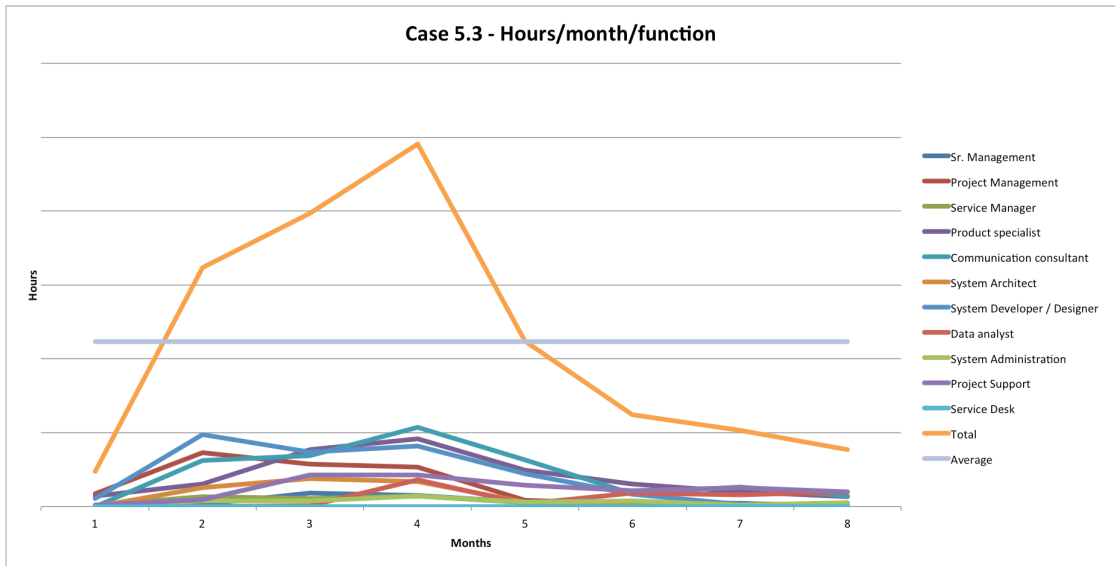
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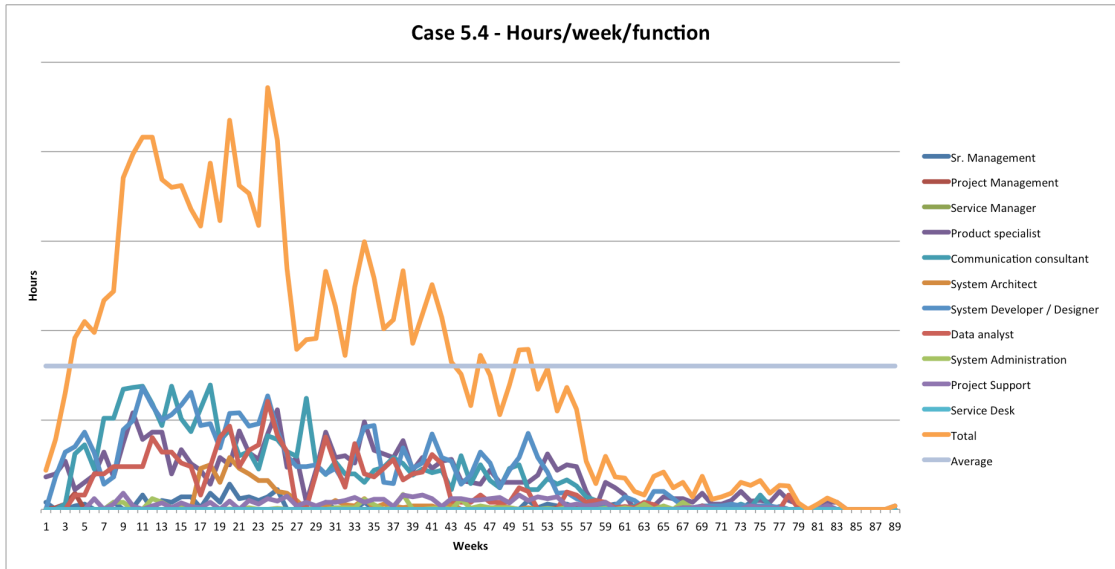
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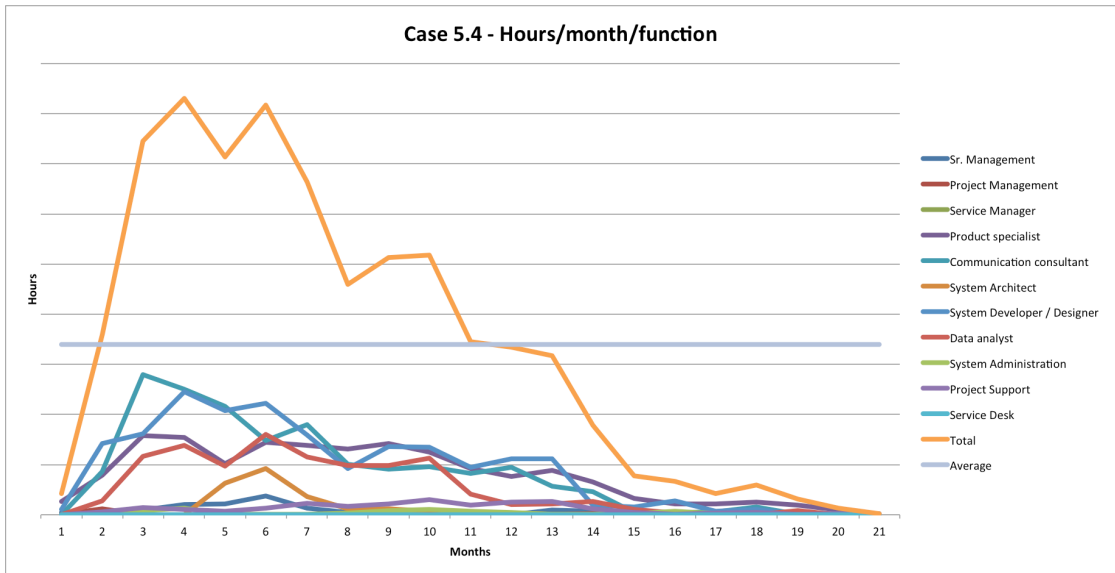
Figure 56 Hours/month/function – Case 5.4

Appendix H   Summarized results document analysis case group 1

Table 11 summarized results of the document analysis case group 1

Case	1.1		1.2		1.3		1.4	
Project size	Small		Very small		Small		Small	
Division of labour	Group #	Percentage	Group #	Percentage	Group #	Percentage	Group #	Percentage
	11	0,7%	11	0,7%	11	0,0%	11	2,6%
	10	34,4%	10	36,5%	10	14,0%	10	30,2%
	9	0,0%	9	0,0%	9	0,0%	9	0,0%
	8	0,0%	8	0,0%	8	0,0%	8	0,0%
	7	0,0%	7	0,0%	7	0,0%	7	0,0%
	6	0,0%	6	0,0%	6	0,0%	6	0,0%
	5	0,0%	5	0,0%	5	0,0%	5	0,0%
	4	63,6%	4	62,7%	4	86,0%	4	65,6%
	3	1,3%	3	0,0%	3	0,0%	3	1,6%
	2	0,0%	2	0,0%	2	0,0%	2	0,0%
	1	0,0%	1	0,0%	1	0,0%	1	0,0%
	Total	100,0%	Total	100,0%	Total	100,0%	Total	100,0%
Observations based on analysis Appendix C	- A peak of data analyst hour halfway the project. Project Management hours primarily in the first two weeks. - Not a constant workload over the time span, but short intervals.		- PM peak at initiation - DA hours increase from project initiation and reach a peak half way. - Primarily PM and data analyst hours		- Almost only DA hours - Large DA peak in just over half way in the project - Small PM peak at initiation		- One large peak at initiation of the project. After this peak activity remains relatively stable around average. - Almost only PM and DA hours. Ratio PM:DA is 1:2. - Closing of the project took approximately 2 months.	

Appendix I   Summarized results document analysis case group 2

Table 12 summarized results document analysis case group 2

Case	2.1	2.2	2.3	2.4
Project size	Average	Large	Large	Average
Division of labour	Group # / Percentage	Group # / Percentage	Group # / Percentage	Group # / Percentage
	11 — 0,8%	11 — 1,2%	11 — 0,0%	11 — 0,3%
	10 — 5,3%	10 — 28,7%	10 — 56,0%	10 — 26,2%
	9 — 0,4%	9 — 0,9%	9 — 0,0%	9 — 0,0%
	8 — 0,0%	8 — 0,0%	8 — 0,0%	8 — 0,0%
	7 — 0,0%	7 — 0,0%	7 — 0,0%	7 — 0,6%
	6 — 0,1%	6 — 5,0%	6 — 0,2%	6 — 4,4%
	5 — 80,2%	5 — 56,6%	5 — 39,3%	5 — 51,9%
	4 — 0,0%	4 — 0,0%	4 — 0,0%	4 — 0,7%
	3 — 8,6%	3 — 4,6%	3 — 4,4%	3 — 7,9%
	2 — 4,7%	2 — 3,1%	2 — 0,0%	2 — 8,0%
	1 — 0,0%	1 — 0,0%	1 — 0,0%	1 — 0,0%
	Total — 100,0%	Total — 100,0%	Total — 100,0%	Total — 100,0%
Observations based on analysis Appendix D	- Almost all hours were SD (group 5) hours (80%). - SD hours increase from start on and show a large peak in the beginning of second half. - Functions of other hours are only visible at the beginning of the project.	- The ratio of SD to PM hours is 2:1 (together >85%). - Two large SD peaks and one smaller PM peak at the beginning of the project. - After these peaks activity is stable - Other functions are only active in the beginning.	- More than 50% of the utilized hours were PM hours. - PM and SD account for >95% - A large peak in PM hours during project initiation. - Almost all SD hours were utilized during the second phase of the project	- PM and System Developer hours (ratio 2:1) are >75%. - Large System Developer peaks in the first half of the project - PM hours are relatively stable in the first half and increase to a small peak in the second half of the project

Case	2.5	2.6	2.7	
Total hours	Average	Average	Average	
Division of labour	Group # / Percentage	Group # / Percentage	Group # / Percentage	
	11 — 0,0%	11 — 0,0%	11 — 0,0%	
	10 — 38,1%	10 — 85,1%	10 — 45,9%	
	9 — 1,3%	9 — 0,0%	9 — 0,0%	
	8 — 0,0%	8 — 0,0%	8 — 0,0%	
	7 — 0,0%	7 — 0,0%	7 — 0,0%	
	6 — 0,4%	6 — 0,9%	6 — 0,0%	
	5 — 56,2%	5 — 12,2%	5 — 52,5%	
	4 — 0,0%	4 — 0,0%	4 — 1,6%	
	3 — 0,9%	3 — 0,0%	3 — 0,0%	
	2 — 3,1%	2 — 1,9%	2 — 0,0%	
	1 — 0,0%	1 — 0,0%	1 — 0,0%	
	Total — 100,0%	Total — 100,0%	Total — 100,0%	
Observations based on analysis Appendix D	- Almost only PM and SD hours in ratio 4:6 - Two peaks at the start of the project - A period of 1,5 years passed until closing	- In the first 5 months of the project the largest part of work was done. - The following months activity was very low or even none. - Almost only PM. SD hours are grouped around second peak.	- A large part of the hours are clustered around two peaks. Apart from these activity is very low. - PM hours are throughout the project while SD hours are only utilized in these peaks.	

Appendix J   Summarized results document analysis case group 3

Table 13 summarized results document analysis case group 3

Case	3.1		3.2		3.3		3.4	
Project size	Very large		Very small		Very small		Average	
Division of labour	Group #	Percentage	Group #	Percentage	Group #	Percentage	Group #	Percentage
	11	2,5%	11	0,0%	11	0,0%	11	5,0%
	10	27,7%	10	11,4%	10	0,0%	10	42,1%
	9	5,2%	9	0,0%	9	0,0%	9	0,0%
	8	0,0%	8	0,0%	8	0,0%	8	0,0%
	7	0,0%	7	0,0%	7	0,0%	7	0,0%
	6	5,6%	6	77,2%	6	0,0%	6	0,0%
	5	48,1%	5	0,0%	5	96,3%	5	50,2%
	4	0,0%	4	0,0%	4	0,0%	4	0,0%
	3	9,3%	3	2,3%	3	3,7%	3	0,0%
	2	1,6%	2	9,1%	2	0,0%	2	2,7%
	1	0,0%	1	0,0%	1	0,0%	1	0,0%
	Total	100,0%	Total	100,0%	Total	100,0%	Total	100,0%
Observations based on analysis Appendix E	- A large peak at the beginning and a smaller peak just over half the project. The five months in between the peaks were very slow. - Ratio functions PM:SD:others is approx. 2:1:1. At the beginning there are primarily PM, SD and SA hours. - Closing took approximately 3 months.		- Very mall project consisting almost only of SA hours. PM and PS have a small share - SA Peak in month 3 - Activity besides this peak is very low.		- Very small project consisting almost only of SD hours utilized over a time span of 14 months. - One large peak at initiation of the project (first 2 months). Activity is resumed at the half and the end of the project		- Work is centred around one large peak at the beginning of the second half of the project. - In a large part of the project there is no activity	

Appendix K   Summarized results document analysis case group 4

Table 14 summarized results of the document analysis case group 4

Case	4.1		4.2		4.3		4.4	
Total hours	Average		Average		Average		Average	
Division of labour	Group #	Percentage	Group #	Percentage	Group #	Percentage	Group #	Percentage
	11	1,7%	11	0,0%	11	0,0%	11	7,9%
	10	1,4%	10	59,6%	10	22,0%	10	33,2%
	9	29,1%	9	0,0%	9	0,0%	9	0,0%
	8	0,0%	8	0,0%	8	0,0%	8	0,0%
	7	0,0%	7	0,0%	7	0,0%	7	0,0%
	6	4,5%	6	19,9%	6	78,0%	6	24,2%
	5	45,4%	5	20,3%	5	0,0%	5	33,6%
	4	0,0%	4	0,0%	4	0,0%	4	0,0%
	3	0,0%	3	0,0%	3	0,0%	3	0,8%
	2	17,8%	2	0,1%	2	0,0%	2	0,2%
	1	0,0%	1	0,0%	1	0,0%	1	0,0%
	Total	100,0%	Total	100,0%	Total	100,0%	Total	100,0%
Observations based on analysis Appendix F	- Large SD peak in 3 to 5. - After the initial peak the hours remain relatively stable. - SD and PS primarily at start and Service Manager primarily in the second part of the project.		- PM, SA and SD hours in ratio 3:1:1. - Large peak in month 3. After this peak the hours reduce gradually until closing.		- Project consisting of System Architect hours (78%) and PM hours (22%) - One large peak in the second half of the project		- Almost all the hours are utilized in a three month time span (month 2,3 and 4) - Closing of the project has taken 8 months.	

Appendix L   Summarized results document analysis case group 5

Table 15 summarized results of the document analysis case group 5

Case	5.1	5.2	5.3	5.4
Total hours	Very large	Very large	Large	Very large
Division of labour	Group # / Percentage: 11 — 2,8% 10 — 18,0% 9 — 1,5% 8 — 6,3% 7 — 18,5% 6 — 0,1% 5 — 16,5% 4 — 21,1% 3 — 0,7% 2 — 12,6% 1 — 1,9% Total — 100,0%	Group # / Percentage: 11 — 1,9% 10 — 9,3% 9 — 3,6% 8 — 8,6% 7 — 23,8% 6 — 0,6% 5 — 18,3% 4 — 17,3% 3 — 0,7% 2 — 11,3% 1 — 4,5% Total — 100,0%	Group # / Percentage: 11 — 2,9% 10 — 12,1% 9 — 2,8% 8 — 18,3% 7 — 20,2% 6 — 6,0% 5 — 18,6% 4 — 5,3% 3 — 2,8% 2 — 10,9% 1 — 0,0% Total — 100,0%	Group # / Percentage: 11 — 2,2% 10 — 0,2% 9 — 0,0% 8 — 23,2% 7 — 24,6% 6 — 3,2% 5 — 26,9% 4 — 15,4% 3 — 1,0% 2 — 3,3% 1 — 0,0% Total — 100,0%
Observations based on analysis Appendix G	- In the first 12 months of the project the hours increase gradually to a very large peak -Three other peaks are clearly visible: month 21, 27 and 38.	- Large project over a long time span with a lot of fluctuations in the hours - There are approximately four peaks visible: month 9, 25, 28 and 33. In between the hours drop	- Efficient project: large amount of hours over a short time span - One clear peak in the middle of the project. Hours increase to that point and decrease from that point - All the function groups are relatively stable.	- Large peak at the beginning of the project, after this utilized hours decrease to the end. - Hours divided between Product Specialist, CC, SD and DA, but nu PM hours. - Closing has taken approx. 7 months.

Appendix M   Interview questions

Table 16 Questions for semi-structured interviews

Category	#	Question
Details participant (~5 min)	A-01	What is you exact role within the company?
	A-02	What kind of projects have you conducted in the past? (Specific projects or a large range of different projects)
	A-03	How many years of project management experience do you have?
	A-04	What is your background?
	A-05	What was your role/task in this specific project?
	A-06	Which part of the project have you been involved in?
Details project (~10 min)	B-01	Could you explain what this project has entailed? (Scope/deliverables)
	B-02	Who was the principal of the project?
	B-03	Can you give an overall idea of the tasks in the project over the time span of the project? Where did the team work on what? When were the deliverables?
	B-04	To what extent does this project resemble or differ from other projects within this organization?
	B-05	To your opinion: Has this project been successful?
	B-06	Which elements made this project successful/unsuccessful?
	B-07	Could you relate the success to: 1) Cost/budget, 2) planning/utilized hours, 3) Scope, 4) Quality?
	B-08	In hindsight, do you think the planning was realistic?
Novelty (~5 min)	C-01	To what extent was this project 'novel' for the company?
	C-02	Has a project ever resemble this one? If yes, which parts have differed?
	C-03	How do you think the novelty of the project is reflected in the work that needs to be executed during the project?
	C-04	How do you think the novelty of the project is reflected in the utilized hours? And in which part/phase is this visible?
	C-05	How new was such a project for the client/principal?
	C-06	To what extent has to 'novelty' at the client's side influence the requirements and changes of the scope during the project?
	C-07	How would this be visible when looking at the utilized hours?
Technology (~5 min)	D-01	What was the level of technology in this project?
	D-02	Where do you base this indication on?
	D-03	In case of High-Tech: In what part of the project are you able to see this in the resourcing?
	D-04	To what extent has India been involved in this project and which stages specifically?
	D-05	To what extent were there multiple iterations (design-build-test)?
Complexity (~20 min)	E-01	To what extent do you consider this project complex?
	E-02	Organizational: How large was the project team?
	E-03	Organizational: How experienced were the individuals in the team?
	E-04	Organizational: Have you worked with this team before? And have the individuals of the team worked together before?
	E-05	Organizational: Where there many different function groups working on this project simultaneously?
	E-06	Organizational: To what extent could this project count on the internal support of the company?

	E-07	Organizational: How much pressure from other projects was there on the project team?
	E-08	Environmental: Were there many stakeholders involved in the project?
	E-09	Environmental: To what extent was the client involved in the development process and how have you experienced this?
	E-10	Environmental: Was the client a new client for the company?
	E-11	Environmental: Were there many different suppliers involved in the project?
	E-12	Environmental: Were these suppliers new to the company?
	E-13	Environmental: Was the project at stages dependent on stakeholders for the progress and how have you experienced this?
	E-14	Technical: How large was this project (compared with the entire portfolio of projects)?
	E-15	Technical: How clear were the goals/requirements and scope at the beginning of the project? Did they change a lot over time?
	E-16	Technical: Could you give an indication how many different tasks there are in such a project? And are they dependent on each other?
	E-17	Technical: Were all the required skills for the project available or did parts of the development need to be outsourced?
Pace (~5 min)	F-01	To what extent was this project fast-paced?
	F-02	Was the project team mainly working on this project or was it a project that ran alongside other projects?
	F-03	Was the project team (at stages) totally dedicated or even autonomous to this project?
R&U (~1 min)	G-01	To what extent do you think that these questions could be answer front-end of the project?
Hours (~20 min)	H-01	I have graphs of the utilized hours during the project. Could you try to explain the different peaks and lows during the project?
Planning & Resourcing (~5 min)	I-01	Do you consider project planning an important (or event essential) tool in this company?
	I-02	To what extent are risks and uncertainties currently incorporated in the project planning and how do project managers do this?
	I-03	To what extent do project managers look back on the initial project planning during execution and are they adjusted for future prognoses?
	I-04	Do you think that there is still an efficiency gain (company wide) possible by improving the project planning and resourcing?
	I-05	To what extent do you think that the company is prepared to use an extra planning tool (simple to use) in the project planning?
Closing (~2 min)	J-01	Is there still something you would like to bring to the table?
	J-02	This was it! Thank you very much for your cooperation! I will make minutes of our conversation. Would you like to receive a copy of these?

Appendix N Case specific remarks on projects

Case 1.1 - Hours/month/function

Read up, writing PID, changes in PM. Also technical issues that needed attention.

Performing the measurements and vacation time.

Analysing data, reporting and reviewing.

Took a very long time before the client accepted the report.

Figure 57 Comments on case 1.1

Case 1.2 - Hours/month/function

Change in PM, initiation, installation of the system and performing the measurements.

Analysing the data and reporting of the findings.

Several rounds of feedback, both internally and with the client.

Figure 58 Comments on case 1.2

Case 1.3 - Hours/month/function

Long discussions with client, setting the scope clear, initiation (PID), installation and performing measurements. Also vacation time.

Data analysis and reporting of findings.

Revisions of the report.

Figure 59 Comments on case 1.3

Case 1.4 - Hours/month/function

Started the work on basis of a sales planning instead of doing an intake check by a PM

Scope redetermined with the client.

A lot of fluctuations in the work. Resources were only limited available

An internal deadline was set on the project to increase the speed. Extra resource joined the team.

Residual questions by the client took a bit longer to close the project

Figure 60 Comments on case 1.4

128

Figure 61 Comments on case 2.1

Figure 62 Comments on case 2.2

Case 2.3 - Hours/month/function

A different project manager initiated the project. This took a lot of effort.

Designing of the system and a lot of software development. Did not go as planned, more than average amount of client interaction was required.

A new project manager took over. A lot of managerial attention was needed to get the system in order within the deadline.

Acceptation phase of the software. Let to a list of alterations that needed more effort.

Long tail after the acceptation. Some software parts still needed attention. Also installations of the panels started.

Figure 63 Comments on case 2.3

Case 2.4 - Hours/month/function

Setting the requirements for the project and the new back-end system

System is being developed at the outsourcing partner.

The delivered system had several bugs. Many things still needed to be done in-house.

First rollout of the cluster. Led to rework and new functionalities needed to be added.

Development continued on the system while work was done on the rollout of the new clusters of displays.

Figure 64 Comments on case 2.4

130

Figure 65 Comments on case 2.5

Figure 66 Comments on case 2.6

Case 2.7 - Hours/month/function

| Designing of the system, ordering parts, making prototype, development of firmware and software (partly outsourced) | Outsourced production of the displays | Acceptation and installation | Installation of the remaining displays. |

Figure 67 Comments on case 2.7

Case 3.1 - Hours/month/function

Designing of the system, ordering parts, making prototype, development of firmware and software (partly outsourced)

Delivery of phase 1.

Delivery of phase 2.

Final delivery.

A different PM started this project. A lot of technical development work in this phase.

The project should have officially been finished and reports were made to wrap things up.

The rollout of the first tunnel did not go as planned and a lot of on-site work needed to be done to get everything fixed.

Second tunnel went live and this once again led to rework.

Reporting and a lot of discussion with the client.

Figure 68 Comments on case 3.1

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Case 3.2 - Hours/month/function

Ordering of parts and initiation.

Designing of the technical system, developing a plan for the outsourcing partner.

At this phase it should have been at the service side already. Instead there were some of problems with the outsourcing

Last minute problems that came up from the client side that had to be addressed.

Figure 69 Comments on case 3.2

Case 3.3 - Hours/month/function

First deadline after this peak. Setting the requirements and coordinating the outsourcing partner.

Second deadline. This was an update of the system. This peak is coordination of the outsourcing team.

The second update of the system.

The third update of the system.

Figure 70 Comments on case 3.3

133

Figure 71 Comments on case 3.4

Figure 72 Comments on case 4.1

Simply a lot of (internal) software development.

Integration with the hardware. Furthermore it is unknown where the large tail comes from. It could be an administrative mix up with case 4.1.

Figure 73 Comments on case 4.2
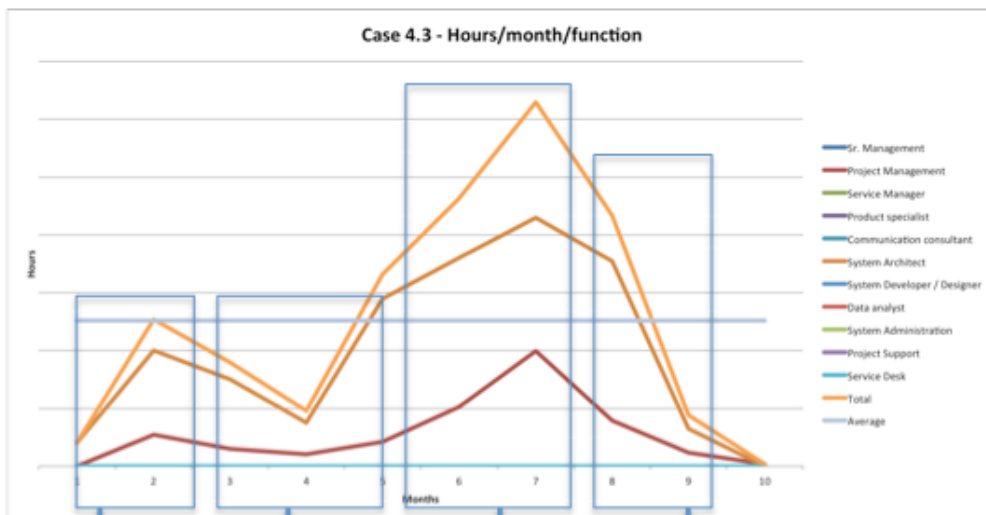
Initiation and designing of the system.

Outsourcing partner works on the system. Initially there are many questions, but this decreases over time.

Software is delivered by the outsourcing partner was not up to par. A lot of last minute development in-house has to be done.

Certification of the system, client acceptance and installation of everything.

Figure 74 Comments on case 4.3

Case 4.4 - Hours/month/function
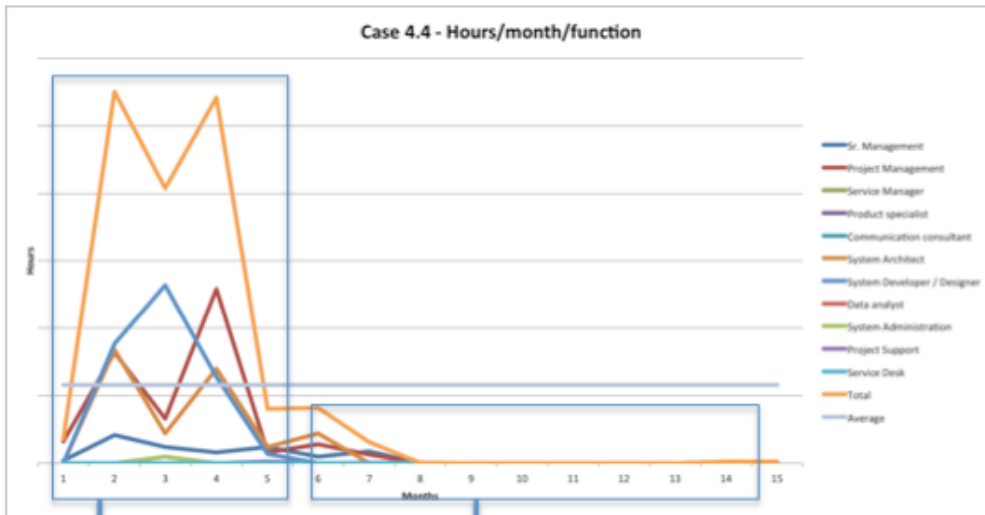
All the development work. The deadline was very fast and all the work had to be done at once.

Unknown where the tail comes from.

Figure 75 Comments on case 4.4

Case 5.1 - Hours/month/function
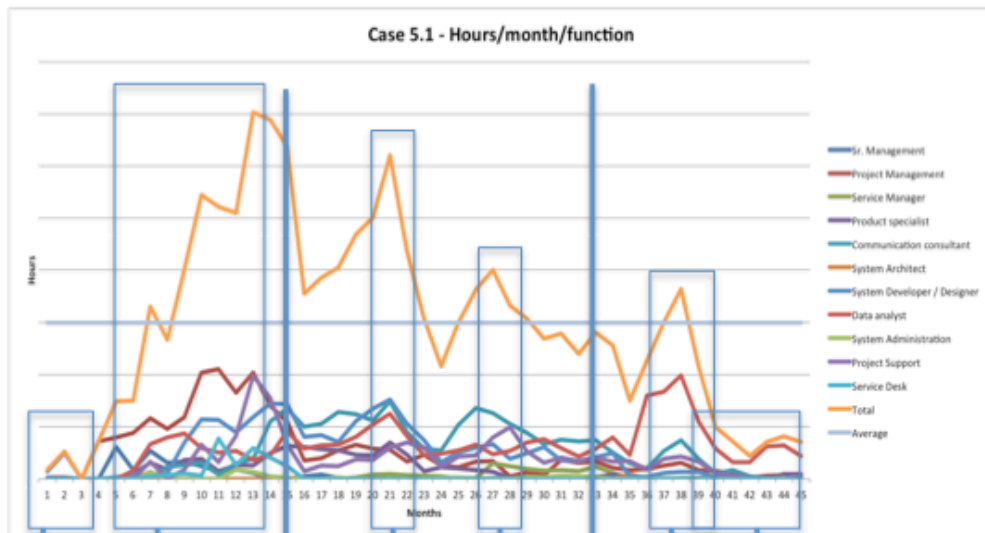
Dynamic initiation phase. Several project managers started.

First technical rollout went live.

All preparation and development work for the first rollout. Was far more work than anticipated. More and more resources joined the project team.

Second technical rollout.

Second phase of the project starts.

New project manager takes over the project.

Technical adjustments of system.

Reporting phase.

Figure 76 Comments on case 5.1

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Case 5.2 - Hours/month/function

A lot of development work.

Dynamic initiation with 2 project managers who stopped after a short time.

Test phase

System went live

Client expectation of interaction was high.

Second project manager took over

Delivery of a new phase.

Verification of the system for the client.

Subproject of case 5.2. It was a new technical system.
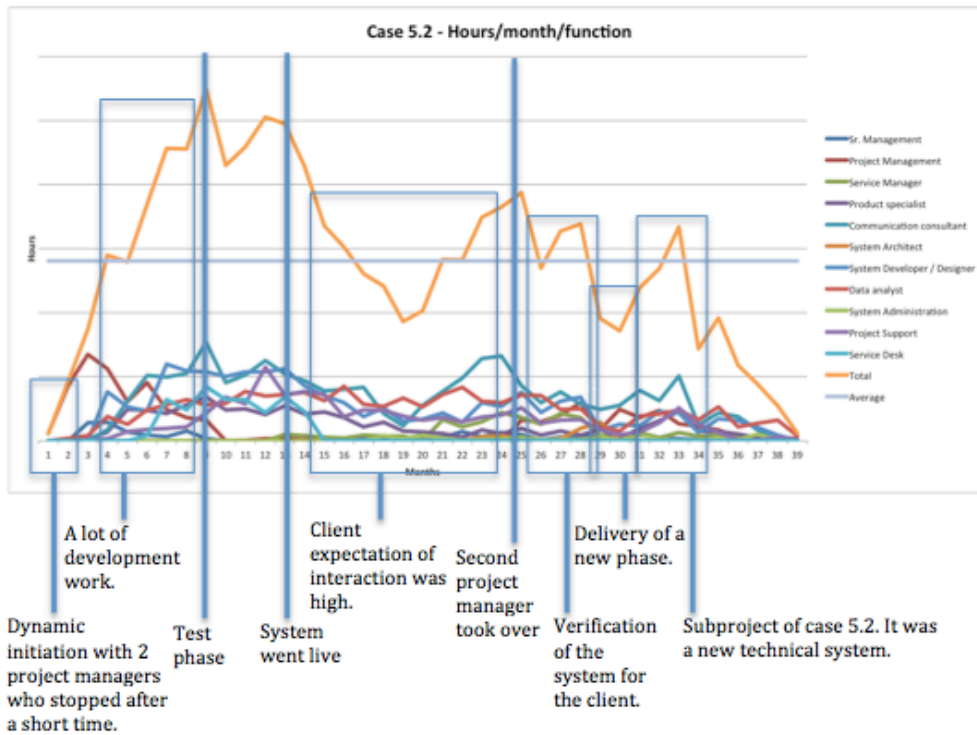
Figure 77 Comments on case 5.2

Case 5.3 - Hours/month/function

All the development work was done and preparations are done.

Rollout of the system.

Primarily maintaining the system and a few adjustments.
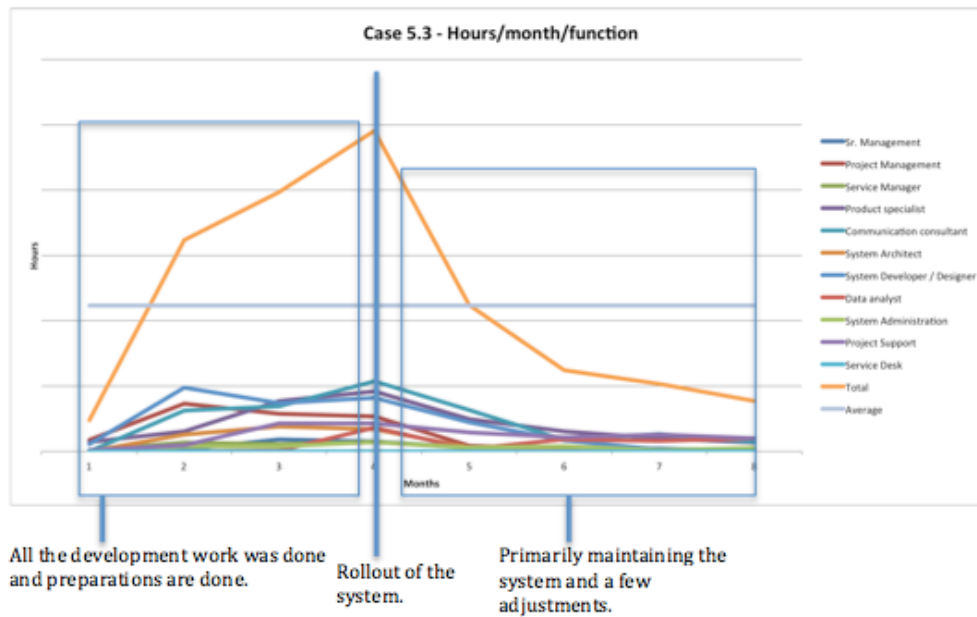
Figure 78 Comments on case 5.3

Case 5.4 - Hours/month/function

Legend:
- Sr. Management
- Project Management
- Service Manager
- Product specialist
- Communication consultant
- System Architect
- System Developer / Designer
- Data analyst
- System Administration
- Project Support
- Service Desk
- Total
- Average

Project missed a normal initiation. A lot of effort in managing the client. High documentation standards.

Rollout of the system.

Execution of the project. Development in this phase was aimed at automating manual processes. Also still a lot of client management by the project manager.

Reporting, data analysis work and some discussion about administrative issues.

A lot of communication work. Finding participants; marketing etc.

Development of the next phase.

Figure 79 Comments on case 5.4

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Appendix O Factors mentioned in interviews

Table 17 Factors mentioned in interviews

#	Technical complexity; Mentioned factors	Projects	Organizational complexity; Mentioned factors	Projects	Environmental complexity; Mentioned factors	Projects	Novelty Mentioned factors	Projects	Technology Mentioned factors	Projects	Pace Mentioned factors	Projects
1	Total size of the project	2.2 (-), 2.3 (-), 5.1 (-), 5.2 (-), 5.3 (-), 5.4 (-)	Changes in project management over time	1.2 (-), 1.3 (-), 2.1 (-), 2.3 (-), 2.6 (-), 3.1 (-), 5.1 (-), 5.2 (-), 5.3 (-), 5.4 (-)	Project management consultant hired by the client	2.1 (o), 2.3 (-), 4.2 (o), 4.3 (o), 5.1 (-), 5.2 (-), 5.3 (o), 5.4 (-)	Completely new elements incorporated in the scope	2.1 (-), 4.3 (-), 5.1 (-), 5.2 (-), 5.4 (-)	Product development as part of the scope	5.1 (-)	Fast paced	1.3 (-), 2.2 (-), 2.4 (-), 2.5 (-), 3.1 (-), 4.4 (-), 5.1 (-), 5.2 (-), 5.3 (o), 5.4 (-)
2	Broad scope (lack of focus)	5.1 (-), 5.2 (- -)	Size of the project team (# employees)	5.1 (-), 5.2 (-), 5.3 (o), 5.4 (-)	Overall attitude of the client towards contractor	5.2 (-), 5.3 (+ +)	Scope does not resmble anything done before	1.4 (- -)	Off-the-shelf technology: no development	1.1 (+), 1.2 (+), 1.3 (+), 2.6 (+)	Large panalty clauses involved if the deadline were not met	2.2 (-), 2.4 (-)
3	Soft deliverables' part of the scope	5.1 (-)	Not clearly defined project team	5.1 (-), 5.2 (-)	Many different suppliers	2.6 (-), 2.7 (-), 3.4 (o), 4.1 (o), 5.1 (-)	Familiar scope, but with new requiremements or alterations	1.3 (-), 2.3 (-), 2.4 (-), 2.5 (-), 2.7 (-), 3.2 (-), 3.3 (-), 4.2 (-), 4.3 (-), 5.3 (-)	Technical system was familiar, but had new requirements	2.1 (-), 2.4 (-), 2.5 (o), 2.7 (-), 3.2 (-), 3.3 (-), 4.2 (-), 4.3 (-), 5.3 (-)	No (external) deadline given	1.4 (-), 4.3 (o)
4	Scope changes during execution	1.1 (o), 3.1 (-), 4.1 (+), 4.2 (+), 5.1 (-), 5.2 (-)	Number of different function groups	5.1 (-), 5.2 (-), 5.3 (o)	New suppliers	2.6 (-), 4.1 (o), 5.1 (-)	The way the project will be executed is new for the organization	5.1 (-), 5.2 (-)	Completely new technical elements needed to be developed as part of the scope	2.3 (-), 5.4 (-)	Pace increase due to external factors (e.g. Measurement dates)	1.2 (o)
5	The need for physical presence to build in parts	2.1 (-), 3.1 (-), 5.1 (-)	Availability of human resources	4.1 (-), 5.1 (-), 5.2 (-)	Large amount of external stakeholders	2.6 (-), 3.4 (-), 4.1 (-), 4.3 (-), 5.1 (-), 5.2 (-), 5.3 (-), 5.4 (-)	Scope was relatively new for the organization	3.1 (-), 3.4 (-), 4.4 (-)	Resource went to outsourcing company to manage the development work	5.3 (+ +)		
6	Unclear scope	1.3 (-), 3.4 (-)	Experience of the resources	5.1 (o), 5.2 (o)	Co-development by another contractor	2.2 (-), 2.3 (-), 2.4 (o), 3.4 (o), 4.1 (o), 4.2 (o)	Technical system is off-the-shelf but not implemented often	1.1 (o)	Unable to do real live tests of the system	4.3 (-)		
7	Unfamiliar with the location	1.3 (-)	(Almost) dedicated project team	4.4 (+ +), 5.3 (+ +)	Organizational changes at clients side	3.4 (- -)	Nothing new. Completely off-the shelf	2.6 (+)				
8	Responsibility of acquiring permits and licenses	1.1 (o), 1.2 (o), 1.3 (o)	Experience of the project manager	1.1 (-), 1.2 (-), 1.3 (o), 1.4 (o), 2.1 (-), 3.3 (o), 4.1 (o), 5.4 (-)	Dependencies on several stakeholders for the progress	1.3 (-), 2.5 (-), 2.7 (-), 4.2 (-)						
9	Very high demands on quality	3.1 (-), 4.3 (-)	Lack of internal support	1.3 (o), 1.4 (-)	Client demanded a lot of project management attention	2.3 (-), 2.5 (-), 3.1 (-), 5.1 (-), 5.2 (-), 5.4 (-)						
10	Not all knowledhe in-house	3.1 (-)	Many different tasks need to be executed by project team simultaneously	5.1 (-), 5.2 (-), 5.4 (-)	New client	2.2 (-), 5.3 (o)						
11	Supplied hardware system was unknown to company	2.1 (-)	Project manager unfamiliar with resources	5.1 (o), 5.2 (o)	Clear stakeholder management focus	5.3 (+)						
12	Chosen hardware design led to difficulties	2.7 (-)	Project disliked by the project team	2.5 (-), 3.4 (-)	Foreign client - communication diffificulties	3.2 (-)						
13	Lack of experience of the outsourced development team	2.2 (-), 2.4 (-), 3.1 (-), 3.2 (-), 4.3 (-)	Problems with the transfer of the project from sales to operations	3.4 (-)								
14	Large number of interrelating technical parts that need to be developed	3.1 (-), 5.1 (-), 5.2 (-), 5.3 (-)	Lack of technical background by project manager	1.1 (o), 1.2 (o)								
15	Clear development task for outsourced company, easy to communicate	1.1 (+), 1.3 (+), 1.4 (+), 3.3 (+), 5.4 (+)	Two project managers in the team; internal and external	5.3 (+)								
16	Experienced outsourced project team	3.3 (+), 4.2 (+)	Technical development work outsourced to multiple suppliers	3.2 (-), 5.1 (o), 5.2 (o), 5.3 (-)								
17	Combination of hardware and software development and system integration	2.7 (-), 4.4 (o)										
18	Task was very difficult to communicate with outsource company	2.1 (-)										

Legend

+ +	: Mentioned explicitly as a positive factor
+	: Mentioned as positive
o	: Mentioned, but had no influence on the project
-	: Mentioned as a negative effect
- -	: Mentioned explicitly as a negative effect

Appendix P   Overview of the uncertainty-based planning tool

Sheet 1/8

Assessment of the potential uncertainty of a project
September 2013
Developed as part of a graduation project

This excel workbook is developed as a tool to assess the (potential) uncertainty a project is susceptible to. It is developed by analysing 23 completed projects. All (unforeseen) factors that have influenced the result of these projects are incorporated in this tool. This tool will relate the potential uncertainty of the project qualitatively to the planning of a new project. It will not develop a generic project planning, but it will give qualitative advice on how to incorporate buffers (in hour overrun or time overrun) in the project planning and can therefore be an aid for a project manager during a project initiation.
The tool is divided over 7 sheets:
    - Novelty: determine the level of this dimension - 1 factor
    - Technology: determine the level of this dimension - 1 factor
    - Pace: determine the level of this dimension - 1 factor
    - Technical complexity: will be determined on basis of a list of factors - 16 factors
    - Organizational complexity: will be determined on basis of a list of factors - 11 factors
    - Environmental complexity: will be determined on basis of a list of factors - 10 factors
    - Overview: will give an overview of the potential uncertainty and a summary of the given advice
All questions can be answered using a multiple-choice box. Some factors may not apply to a specific project. The zero (0) option should be used in these cases. For the factors that may apply the most appopriate level should be chosen.

Novelty

Definition: The extent to which the scope and requirements of a project are new to the contractor and the client(s).

Explanation: There are four different levels for this dimension determined. Choose on basis of the explantions of the levels which level applies to the project. An advice regarding the project planning will appear in the right column on basis of the anwer provided.

#	Level	Explanation	Options	Consequences - Advice on project planning
1	Roll-out	This level represents rollout projects. The specific solution/product has been implemented very often in the past and no alterations need to be done. It can directly go to implementation.	1 - Roll-out 2 - Familiar, but new requirements 3 - Completely new elements 4 - Never done before	These projects are, as far as the dimension novelty goes, reltively clear and are not susceptible to a lot of uncertainty. The resources usually understand the requirements and the tasks that accompany these requirements. They are therefore able to estimate the amount of hours and required time relatively accurate. However, these project may be suceptible to uncertainty that arises from the other dimensions.
2	familiar, but new requirements	This level represents projects that rely on a well-known principal, but in which specific parts need to be altered on the basis of the wishes of the client.		
3	Completely new elements	This level respresents projects are very novel either in one of two ways. 1) The concept of the solution/product is known by the contractor, but the system needs to be (almost) completely altered on the basis of the requirements set by the client or 2) the concept of the solution is completely new, but the scope of the project includes some parts that are known to the contractor.		
4	Never done before	This level represents projects that are completely new to the world. The concept of the solution needs to be developed from scratch as goes for the individual parts of the system. In these projects it is very difficult to determine the precise scope and requirements in an early stage.		

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Technology

Definition: The technological uncertainty of a project that arises due to the (technological) development of parts as part of the scope.

Explanation: There are four different levels for this dimension determined. Choose on basis of the explantions of the levels which level applies to the project. An advice regarding the project planning will appear in the right column on basis of the anwer provided.

#	Level	Explanation	Options	Consequences - Advice on project planning
1	Roll-out	This level represents technological rollout projects. These projects rely of 'off-the-shelf' technologies and systems; No development has to done.	1 - Roll-out 2 - Low-Tech to Med-Tech 3 - Med-Tech to High-Tech 4 - High-Tech to Super High-Tech	The uncertainty that aris due to the technology in this poject is limited. It should be possible to make a realtively good estimation of the hours and time that are needed for the development work (either in The Netherlands or India). The amount of iterations (design-develop-test) will be limited.
2	Low-Tech to Med-Tech	This level represents projects that require minor technical development. The required technological knowledge is limited and the resources are experienced in the technical procedures.		
3	Med-Tech to High-Tech	This level represents projects that involve many interrelating technical parts of which many have to be (partially) developed. The projects often involve both hardware and software development and a great deal of system integration.		
4	High-Tech to Super High-Tech	This level represents projects that involve the technical development of completely "new-to-the-world" technical products or parts. These projects can't rely on previously developed technology.		

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Pace

Definition: The technological uncertainty of a project that arises due to the (technological) development of parts as part of the scope.

Explanation: There are four different levels for this dimension determined. Choose on basis of the explantions of the levels which level applies to the project. An advice regarding the project planning will appear in the right column on basis of the anwer provided.

#	Level	Explanation	Options	Consequences - Advice on project planning
1	Low-paced	These are gap-filling projects for the resources. These projects have no real deadline and there is no pressure on the organization and the resources to finalize the projects.	1 - Low-paced 2 - Medium-paced 3 - High-paced 4 - Blitz	High paced projects require fast action and high priority from the project team. The work of the resources should be shifted, as much as possible, to the beginning of the project in order to reduce the pressure around the deadlines. It is advisable to clearly define the project team at initiation of the project and keep the team as small as possible. This way less time will be required for communication and coordination. Priority from this team for the project, or maybe even a dedicated team (has been shown to be very positive for the project result), will be required.
2	Medium-paced	These are projects in which either internal or external deadlines are set, but the pressure on the resources to meet the deadline is limited. Also the consequences when missing the deadline are limited.		
3	High-paced	These are fast-paced projects in which clear deadline(s) are set. The organization and resources are forced to make this project a priority in order to meet the deadline. Failing to meet the deadline will have consequences for the success of the project.		
4	Bliz	These are the fastest-paced projects. In these projects the project team has to autonomous in order to meet the deadline. Failing to meet this deadline will lead to the direct failure of the project.		

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Complexity - Technical complexity

Definition: Uncertainty that arises due to the clarity of (technical) goals and requirements and dependencies on parts, location and (outsourcing) partners.

Explanation: This dimension will be determined on the basis of 16 questions with multiple choice answers. Please fill in the answer that is most applicable to the specific project. All the questions are currenlty filled in on the zero option. The zero option should be chosen only if such a question can't be answered at this moment or does not apply to the project. In the most right column an advise will appear per category on basis of the answers given. When the given answers do not require a specific advice (because the category is not susceptible to the project) a "-" will remain in this cell. When all answers are given, check the box in the bottom of the questionnaire and a general advice will appear.

#	Category	Factor	Question	Options	Advice on project planning regarding the category
C-T-01	Project	Size	How large is this project relative to the portfolio of the projects in terms of budget?	0 - Does not apply 1 - Small 2 - Medium 3 - Large	Larger projects are more difficult to oversee front-end. Therefore larger projects rely much more on estimations than calculations than smaller projects. In this case the project is medium sized. A small hour buffer for all the resources throughout the project is adviced.
C-T-02	Scope	Clearity	How clear in the scope of the project? Is there room for ambiguity or different interpretations?	0 - Does not apply 1 - Completely clear 2 - Elements are unclear 3 - Very unclear scope	-
C-T-03		Focus	Is the scope very broad or clearly focussed. Does it incorporate many aspects or just one?	0 - Does not apply 1 - Clear focus 2 - Multiple elements are incorporated 3 - Very broad scope	
C-T-04		Possible changes	Is it likely that the scope is susceptible to changes in the course of the project?	0 - Does not apply 1 - Not likely 2 - Likely	
C-T-05		'soft' deliverables	Does the scope incorporate soft (difficult to measure) deliverables?	0 - Does not apply 1 - Not incorporated in scope 2 - Incorporated in scope	
C-T-06		Demands on quality	How large are the demands on quality for the project? Are they clear to the project manager?	0 - Does not apply 1 - Regular 2 - High 3 - Very high	
C-T-07	Location	Unknown location	Is/Are the location(s) known to the project manager? Has work been executed on the location(s) before?	0 - Does not apply 1 - Known 2 - Unknown	There are multiple elements in this project that can lead to uncertainty regarding the location. This can have a large impact on the hours that are required in especially the installation and testing phase. Required physical pressence can make the work very iterative and off course a lot of time (depending on the remoteness of the location) is required for transportation. This uncertainty should be planned in the form of a buffer in the resource hours and time span during the installation and testing phase.
C-T-08		Need for permits and licenses	Are there permits or licenses needed for the work on location? Are the part of the scope of the project?	0 - Does not apply 1 - No or not part of the scope 2 - Yes part of the scope	
C-T-09		Need for physical presence	Is there necessity for physical pressence for testing or modifications of the system?	0 - Does not apply 1 - No 2 - Yes	
C-T-10	Technical system	Combination software/hardware	Is the to be developed technical systme a combination of hardware and software or solely software?	0 - Does not apply 1 - Only software system 2 - Software and finished hardware 3 - Soft and hardware development	Uncertainty that arises due to the complexity of the technical system can have a severe impact on the development hours that need utilized during a project. This project has a few elements that lead to such uncertainty. It will have an impact on the amount of hours needed for the development work in the Netherlands and/or the amount of hours needed to coordinate the outsourced development work in India. Since there are only limited elements in this case a small buffer should be incorporated on these hours.
C-T-11		Interrelating parts	Does the system consists of many (small) interrelating parts?	0 - Does not apply 1 - No, one system 2 - Few interrelating parts 3 - Many interrelating parts	
C-T-12		Familiar with hardware	Is the (supplied) hardware in the technical system known to the project team? Has it been used previously?	0 - Does not apply 1 - Yes 2 - No, not familiar	
C-T-13		Knowledge available	Is all the knowledge for this project in house (or in India) available? Will it be necessary to outsource parts of work?	0 - Does not apply 1 - Yes, it is available 2 - No, outsourcing is required	
C-T-14	Development	Outsourced: clearness of task	Is the outsourced development work clearly understable and easy to communicate?	0 - Does not apply 1 - Single task, easy communication 2 - Multiple tasks with dependecies 3 - Very difficult set of tasks	-
C-T-15		Outsourced: Experience of team	Is the development team that will do the development work experienced and experienced with the task?	0 - Does not apply 1 - Highly experienced team 2 - Relatively experienced team 3 - Inexperienced development team	
C-T-16		Outsourced: Number of organizations	Is the development work outsourced to one or multiple organizations?	0 - Does not apply 1 - One 2 - Multiple	

Is the questionaire on the potential technical complexity completely filled in? ☑ Yes, completely filled in

Overall advice regarding project planning on basis of the technical complexity

Technical complexity (low/medium/high):   Medium

Advice: There are several elements in this project that lead to technical uncertainty in this project. This will have primarily an influence on the amount of development or technical coordination hours that are required in this project. To lesser extent it will also have an influence on the project management hours in this project. More information on where specific buffer should be placed can be found in the advice per category.
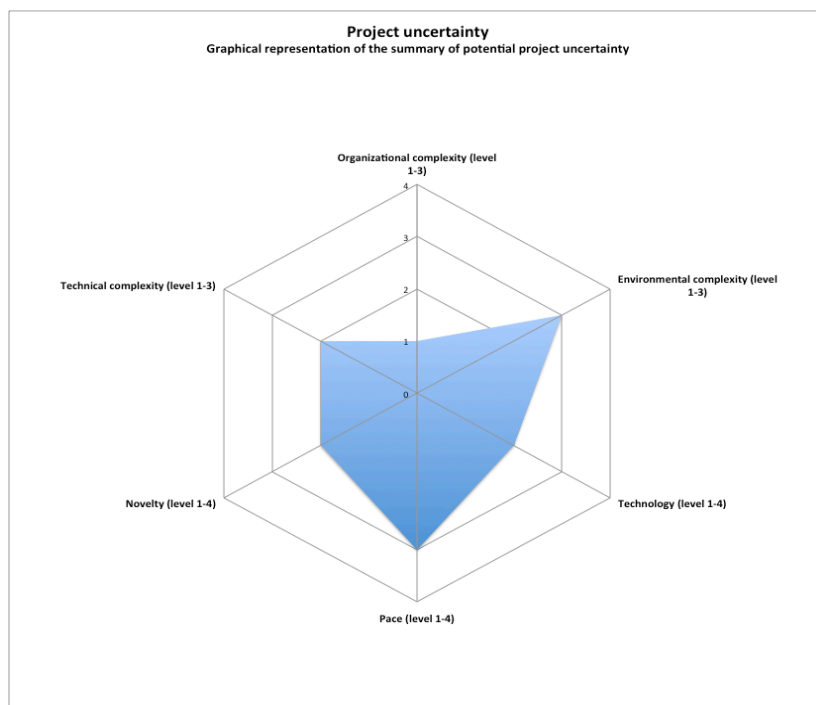
Complexity - Organizational complexity
Definition: Uncertainty that arises due to the amount of, availability of, dependency on and experience of internal resources.
Explanation: This dimension will be determined on the basis of 11 questions with multiple choice answers. Please fill in the answer that is most applicable to the specific project. All the questions are currenlty filled in on the zero option. The zero option should be chosen only if such a question can't be answered at this moment or does not apply to the project. In the most right column an advise will appear per category on basis of the answers given. When the given answers do not require a specific advice (because the category is not susceptible to the project) a "-" will remain in this cell. When all answers are given, check the box in the bottom of the questionnaire and a general advice will appear.

#	Category	Factor	Question	Options	Consequences - Advice on project planning
C-O-01	Project management	Experience	How many years project management experience does the project manager has relative to other PMs?	0 - Does not apply 1 - Experienced 2 - Relatively inexperienced	-
C-O-02		Possible changes	Are changes in project management during the execution of the project likely or possible to happen?	0 - Does not apply 1 - Not likely 2 - Likely	
C-O-03		Familiar with project team	Has the project manager worked with the resources of the project team before or are they new to one another?	0 - Does not apply 1 - Yes, familiar with resources 2 - No, new to the project manager	
C-O-04	Project team	Clearly defined	Is the project team clearly defined or are the exact resources to be used in the project unknown?	0 - Does not apply 1 - Project team in completely known 2 - Some known, some unknown 3 - It will be determined along the way	There are one or two elements that lead to uncertainty in the project team in this project. This uncertainty will result in extra coordination hours and less efficiency in the work. These extra hours needed in the planning are required for the complete project team.
C-O-05		Dedictated	Is the project team (almost) dedicated for this project or are they currently working on several projects?	0 - Does not apply 1 - No, low priority project 2 - No, but it has high priority 3 - Yes, (almost) dedicated	
C-O-06		Size	How many (main) resources will there be working on this project?	0 - Does not apply 1 - Few (<5)) 2 - Larger team (5-8) 3 - Large (8<)	
C-O-07		Amount of functions	How many different function groups will be working on this project?	0 - Does not apply 1 - Limited 2 - Many	
C-O-08		Experience	How experienced is the project team of this project?	0 - Does not apply 1 - Very experienced 2 - Different amounts of experience 3 - Limited experience	
C-O-09		Availability	Is it likely that the resources will be limited available during the project?	0 - Does not apply 1 - Not likely 2 - Availibility could be a problem	
C-O-10	Internal support	Project team	Is the project team enthusiastic about the project at hand or are individuals sceptical?	0 - Does not apply 1 - Yes, support among the team 2 - No, the project is not liked	-
C-O-11		Management	Is this project considered important by the organization's management?	0 - Does not apply 1 - Yes 2 - No, no priority	

Is the questionaire on the potential technical organizational completely filled in?   ☑ Yes, completely filled in

Overall advice regarding project planning on basis of the organizational complexity
Organizational complexity (low/medium/high):   low
Advice: This project scores low on organizational uncertainty. The amount of chaos and unforseen elements that arise internally in the organization are limited. Apart from the adice given on the specific categories no additional (general) advice will be presented.

Complexity - Environmental complexity
Definition: Uncertainty that arises due to the amount of and dependency on stakeholders and the managerial pressure arising from these stakeholders.
Explanation: This dimension will be determined on the basis of 10 questions with multiple choice answers. Please fill in the answer that is most applicable to the specific project. All the questions are currenlty filled in on the zero option. The zero option should be chosen only if such a question can't be answered at this moment or does not apply to the project. In the most right column an advise will appear per category on basis of the answers given. When the given answers do not require a specific advice (because the category is not susceptible to the project) a "-" will remain in this cell. When all answers are given, check the box in the bottom of the questionnaire and a general advice will appear.

#	Category	Factor	Question	Options	Consequences - Advice on project planning
C-E-01	Client	New	Is the client new to the organization or have there been project in the past conducted with this client?	0 - Does not apply / 1 - No / **2 - Yes, it is a new client**	There are several elements that lead to uncertainty at the side of the client. This will lead to additional (external) project management hours to manage the client. A buffer should be incorporated for the project management hours throughout the project. Even more hours should be invested at the start of such projects. Managing the clients expectations at the start of the project can overcome some of the problems that may arise later on in the project. Depending on the size of the project it might even be helpfull to have an external and an internal project manager on this project.
C-E-02		Project management outsourced	It the project management from the client outsourced to an external organization/individual?	0 - Does not apply / 1 - No / **2 - Yes, to a known party** / 3 - Yes, to an unknown party	
C-E-03		Attitude	Is the attitude of the contact person from the client suspicious or goal-oriented?	0 - Does not apply / 1 - Goal-oriented client / **2 - Regular** / 3 - The client is Likely to be suspicious	
C-E-04		Managerial attention	Is it likely that the client will demand a lot of managerial attention?	0 - Does not apply / 1 - No / **2 - Yes**	
C-E-05		Foreign	Is the client Dutch or foreign?	0 - Does not apply / **1 - Dutch** / 2 - Foreign	
C-E-06	Stakeholders	Amount of stakeholders	Is there a relatively large amount of stakeholders in this project?	0 - Does not apply / 1 - Few / **2 - Medium** / 3 - A difficult web of stakeholders	Stakeholders create dependecies and require project management effort. The dependencies can result in delays, because the progress is slowed by a stakeholder. Extra required project management effort will lead to extra hours that need to be utilized to manage the stakeholdes. In this case there are several elements that lead to uncertainty surrounding the stakeholders. Large buffers for both consequences mentioned should be added to the planning.
C-E-07		Amount of suppliers	Are there many different suppliers in this project?	0 - Does not apply / **1 - No or few** / 2 - Many different suppliers	
C-E-08		New to the organization	Are one or more stakeholders new for the organization?	0 - Does not apply / 1 - No / **2 - Yes, one or more are new**	
C-E-09		Dependecies on stakeholders	Is the project strongly dependent on multiple stakeholders?	0 - Does not apply / 1 - No / **2 - Yes**	
C-E-10	Development	Development partner	Is the project developed along with a development parter?	0 - Does not apply / **1 - No** / 2 - Yes, a known partner / 3 - Yes, a new partner	-

Is the questionaire on the potential Environmental complexity completely filled in?   ☑ Yes, completely filled in

Overall advice regarding project planning on basis of the environmental complexity
Envrionmental complexity (low/medium/high):   High
Advice: There are several factors that lead to environmental complexity in this project. Therefore this project scores high on this dimension. This can have a severe effect on the required amount of project management hours in this project. Depending on the size of the project it might be beneficial to have a project manager solely for the external task. Dependencies on stakeholders may also lead to delays during the project execution. This should also be incorporated in the project planning.

Overview of potential project uncertainty

Explanation: This sheet will proviced a summary the potential uncertainty that may arise in the project on basis of the 4 dimensions. It provides: 1) the level, 1-4 in the case of novelty, technology and pace and 1-3 for the dimensions of complexity and 2) the general advice already as also given in the individual sheets

Dimension	Level	General advice
Novelty	2 (out of 4)	These projects are, as far as the dimension novelty goes, reltively clear and are not susceptible to a lot of uncertainty. The resources usually understand the requirements and the tasks that accompany these requirements. They are therefore able to estimate the amount of hours and required time relatively accurate. However, these project may be suceptible to uncertainty that arises from the other dimensions.
Technology	2 (out of 4)	The uncertainty that aris due to the technology in this poject is limited. It should be possible to make a realtively good estimation of the hours and time that are needed for the development work (either in The Netherlands or India). The amount of iterations (design-develop-test) will be limited.
Pace	3 (out of 4)	High paced projects require fast action and high priority from the project team. The work of the resources should be shifted, as much as possible, to the beginning of the project in order to reduce the pressure around the deadlines. It is advisable to clearly define the project team at initiation of the project and keep the team as small as possible. This way less time will be required for communication and coordination. Priority from this team for the project, or maybe even a dedicated team (has been shown to be very positive for the project result), will be required.
Technical complexity	2 (out of 3)	There are several elements in this project that lead to technical uncertainty in this project. This will have primarily an influence on the amount of development or technical coordination hours that are required in this project. To lesser extent it will also have an influence on the project management hours in this project. More information on where specific buffer should be placed can be found in the advice per category.
Organizational complexity	1 (out of 3)	This project scores low on organizational uncertainty. The amount of chaos and unforseen elements that arise internally in the organization are limited. Apart from the adice given on the specific categories no additional (general) advice will be presented.
Environmental complexity	3 (out of 3)	There are several factors that lead to environmental complexity in this project. Therefore this project scores high on this dimension. This can have a severe effect on the required amount of project management hours in this project. Depending on the size of the project it might be beneficial to have a project manager solely for the external task. Dependencies on stakeholders may also lead to delays during the project execution. This should also be incorporated in the project planning.

Project uncertainty
Graphical representation of the summary of potential project uncertainty

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Appendix Q   Overview interviews for external validation

Questions prior to presentation:

1. Can you explain in a few sentences what the organization (Damen/InteSpring) does?
2. Can you explain what your role is within this organization?
3. How long have you been in this role and can you give an indication of the amount of projects you have led?
4. If allowed: To what extent does the front-end project planning (time and resource hours) correspond with the execution in a typical project? Do you experience difficulties with this? If so, where do you expect these problems originate from?
5. To what extent does it occur that unforeseen factors (uncertainty) influence the outcome and/or the success of a project
6. If allowed: Can you give a rough indication on the percentage of a typical project budget that originates from human resource hours?

Short presentation about the thesis research:

- Introduction of the applied theoretical framework
- Short summary of the results
- During presentation question 7 & 8

7. To what extent is the framework applicable to this organization? To what extent do projects within this organization range on the 4 dimensions presented?
8. To what extent might the results be of use to the organization? Do the results of a specific dimension apply more than other dimensions?

Questions after presentation:

9. To what extent would it be of interest to this organization to make a front-end assessment of a project's uncertainties?
10. Thank you very much for you time. Would you be interested in receiving a (public) version of the thesis report?

Appendix R   Minutes of meeting with Rogier Barents for external validation

Date: 6-9-2013
Location: Office InteSpring, YesDelft!, Delft
Present: Rogier Barents, Armand Hersbach

Table 18 Minutes of meeting with Rogier Barents

#	Answer
1	Engineering firm specialized in building prototype products for companies based on gravity balancing by means of suspension systems. The company is still relatively small with 9 people on permanent staff.
2	General director. Within this role Rogier is responsible for structuring the organization and making it financially healthy. Besides his role as general director he is also project manager for the organization.
3	Rogier is one of the founders of InteSpring and founded the organization 7 years ago. Since 2009 the projects within the organization got structure and therefore he has 4 years of real project management experience.
4	The problem that a planning does not correspond with the execution is very familiar to Rogier. There are many unforeseen factors that influence the execution of projects.
5	They do. Very often.
6	Roughly 80% of the budget of a company is contributed to resources.
7&8	The results of all different dimensions were presented and Rogier gave feedback on how there are similarities with InteSpring and where there are differences: - Novelty: The definition of novelty as it is given can very good be applicable to this organization. We got all levels of novelty, except for rollout projects. There is always something different in a project. But we also got completely new product that we need to make, which are new to us, but also not yet known outside this organization. Off course we try to use the gained knowledge in these projects in new projects, in order for the next project to be in level 2 or 3. It is very difficult to make profit with level 4 projects. - Technology: Rogier can relate the definition for the dimension of Technology to the practices of InteSpring. However, they do not have projects that are High-Tech or higher. At most projects are Med-Tech. Usually it are modifications of a technology that we already have developed. However, we do claim that our products are High-Tech, which they are, but there is simply no major development during the projects. Usually the technology is Rollout or Low-Tech to Med-Tech. The effects on project planning will probably be comparable at InteSpring. - Pace: Also for this dimension Rogier can relate the definition to InteSpring. InteSpring has projects ranging in all 4 levels of Pace. Rogier completely agrees with the results regarding pace. He has the same experience among his team and in his organization. - Technical complexity: Some feedback on the different categories of factors in the technical complexity dimension:

		o Project size: definitely has impact on the uncertainty of projects at InteSpring
		o Scope: Can also relate to this category. When the scope is not clearly set he always has problems during the execution of the project and especially towards the end of such projects.
		o Location: Whole category is not applicable to InteSpring.
		o Technical system: Also not really applicable to this organization. They sometimes have to work with new parts, but there are usually not a lot of problems because of this.
		o Outsourced team: They do outsource parts of their projects. This has been a learning trajectory. They have found organizations that they can rely on and some organizations they will never work with anymore. Now they don't experience any large problems with this.
		- Organizational complexity: Once again some feedback on the categories of factors:
		o Project manager: They are a very small organization so they don't have the same problems. But there are some factors that do lead to problems. For example it is difficult to precisely define the responsibilities per function. There is too much overlap since the team is so small. There is therefore no specialization. This often leads to difficulties
		o Project team: They can't really relate to this category, but Rogier does recognize that when a project team is not clearly defined during the execution, you don't get the support needed.
		o Internal support: Among the management it is a known problem at InteSpring. If one of the managers does not agree with a project, or something similar, the process will get a lot more complicated.
		- Environmental complexity:
		o Client: This is a well-known issue at InteSpring. There is a lot of difference in the attention that is required. There are major differences between public and private parties in their case.
		o Stakeholders: Assessing the amount of stakeholders and the dependencies between them is very important. This will determine how good the agreements at the start of the project should be with all these parties. If you don't do this you will have problems along the way, and it will cost a lot more effort
		o Co-Development: this happens in many of the InteSpring projects, but it has never led to major problems. It is usually co-development because of the lack of knowledge in a required field. They always do business with individual freelancers and they always do their job correctly, because for them such assignments are very important.
9	Yes, this would be very interesting since we do experience the same problems with the project planning. The framework that is developed is very interesting and can be used. However the factors of complexity are not completely the same. Therefore alterations would be required if we want to use this.	
10	-	

Appendix S   Minutes of meeting with Jos Govaarts for external validation

Date: 10-9-2013
Location: Office Damen Shipyards, Gorinchem
Present: Jos Govaarts, Armand Hersbach

Table 19 Minutes of meeting with Jos Govaarts

#	Answer
1	Slogan Damen "Wherever there is water there is Damen". Damen constructs a large range of ships, does repair & maintenance of ships and constructs parts required in shipbuilding. The company works according to a standardised design formula where they have many parts in stock. This way they can guarantee high quality, a good price but most of all fast delivery. Off course there is room for requirements by the client.
2	Jos is a project manager and specifically for the high-speed crafts within Damen Gorinchem. These ships are often patrol boats. His specific task is to make sure the boats are delivered within budget, time and the required specifications.
3	Jos has been working at Damen for 2,5 years of which 1 year as a project management trainee and now 1,5 years as project manager. During this time he has managed approximately 10 projects.
4	This is a familiar problem. They have been putting a lot of effort in making this process better and more reliable. To do this they have implemented an ERP system (IFS software) and resourcing now becomes better coordinated. Nevertheless the problem is familiar.
5	This indeed happens quite often.
6	The general rule is that approximately 1/3 of the budget contributes to labour hours at Damen. That being said, a lot of very labour intensive parts are outsources to other parties.
7&8	The dimensions will be discussed individually: - Novelty The definition as stated is very applicable to Damen and the projects of Damen. He can define 3 levels of novelty in his projects: o Rollout: these are ships that are built from stock and still have no client. They are built according to a standard specification/requirements. Nothing new in these projects. o Familiar but new requirements: projects started as rollout projects but got a client along the way who has some specific requirements for his ship. o Completely new elements: These are prototype ships build to specific requirements of the client. Often it is something very new for Damen and can serve as a new model for future production. The fourth level (never done before) does not apply to Damen, because all projects are ships and the concepts are very much alike. The results on project planning for novelty seem like they are very applicable to Damen. - Technology This is a bit more difficult. Damen is not a complete project based organization, but more in the direction of a matrix organization. They have an R&D department disconnected from the projects. Therefore the real high-tech projects are in R&D. During projects there is just rollout and low-tech to

med-tech. med-tech to high-tech is done in the R&D department and there is no such thing as super high-tech in shipbuilding.

- Pace
  Damen has projects in all levels of pace and the definition as well as the levels is very applicable to Damen. This also goes for the results of the research. For Jos the dedicated teams and the commitment are very familiar.
- Technical complexity
  The definition could very well be used in the projects of Damen. Some comments on the individual factor categories:
    o Project size: This definitely is a factor for complexity, but the budget is not linear to complexity.
    o Scope: Unclear scopes are not really applicable, but changes do appear if a client want some modifications in a ship that was already build for a large part from stock. This has a large influence on the execution
    o Location: Is a very big issue at Damen, but maybe not in the same way as in the case of the research. Damen has yards all over the whole world and if a ship is build in let's say Vietnam, a lot more issues arise which influence the execution of the project.
    o Technical system: Not very much applicable at Damen, but we do sometimes have complexity due to computer controlled equipment (happens more and more). There are always issues with versions and such. This is something that needs to be assessed front-end.
    o Outsourced development: We outsource a lot of parts, but we always have long-term relationships with our contractors. Therefore we never experience such issues.
- Organizational complexity
  The definition also sounds familiar. The last couple of years Damen has been growing very fast. Therefore a lot of attention has been going to how to manage a growing research pool and how to make the organization as flat as possible. Teams are put with each other on the same floor. Project managers are at the same place in the building, but on different floors and so on.
    o Project Management: Due to all the effort invested in this by Damen, we do not experience a lot of problems with this.
    o Project team: This also goes for the project team. The size of the project team is always constant in their projects and responsibilities are clearly set, therefore not a lot of complexity there.
    o Internal support: Yes, this is experienced. Although Jos feels that the moral among the team is very high, there are however projects that are not favoured or don't have priority in the organization.
- Environmental complexity
  This is very applicable to Damen. Experiences a lot of complexity due to stakeholders.
    o Client: The whole category, including all factors, plays a large role in the complexity of projects at Damen. The project management at the client's side is also often outsourced which is terrible and some clients demand a lot more attention than others.
    o Stakeholders: There are many other stakeholders that we need to take in account. Examples are organizations that give out 'flags' and certify ships. They have a large range of different requirements a ship needs to deal with.

	o Development partner: This is not the case in the projects of Damen. There are however partners in for example R&D (TU Delft is a very important partner).
9	A risk (and uncertainty) assessment is indeed very important for a project manager. But it also takes a lot of time. Considering the time pressure on projects this often is not executed properly. It would be very helpful if there were a general tool in which a project manager was aided to make such an assessment. So, yes: interested.
10	-