

# CHALMERS



## Factors that cause time delays in hardware development projects

A case study of a product development unit at Ericsson AB

*Master of Science Thesis*

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CHALMERS UNIVERSITY OF TECHNOLOGY

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## **Abstract**

A general problem in industry is that product development projects often suffer from time-delays, where it is not unusual with time-delays as great as 40 percent per project. To find the causes behind these delays is not usually a simple task. The objective of this report was to identify and present underlying factors causing time delay in hardware development projects. The report is based on a case study at a product development unit at Ericsson AB. The study identified issues related to four main-areas Technology maturity; Management, Ways of working and Communication. Semi-structured interviews based on white-books were held with the project leaders or sub-project leaders of the projects. During the interviews the interviewees were asked to grade the issues that had arisen in accordance to the degree of time delay that the issues had caused the project. In addition and adjacent to the interviews a questionnaire, with questions of qualitative nature, was completed by the interviewees and used as complementary information to the data found during the interviews.

One conclusion is that projects suffer from time delay not just of one factor; it is a combination of factors which cause time delays. During the study it has been seen that the projects affects by issues related to the pre-work to the execution phase, to management issues during the project, inconsistency in ways of working and that communication between members in the projects cause time delay. In the highest ranked sub-areas, "Uncertainty in Planning, Quality and Risk-management", "Work processes" and "Communication – Inside organization", the underlying factors causing time delay are identified and presented as: Immature technology, Inconsistency in work processes and Verbal communication.

**Keywords:** project development, knowledge management, organization learning

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# **1 Introduction**

Ericsson AB is a Swedish company and world-leading in telecommunication. The company offers end-to-end solutions for all major mobile communication standards. A central part of the telecommunication network is the microwave solution MINI-LINK that consists of a number of product solutions that enable flexible network rollout, provides gigabit capacity and carrier-grade availability. The main part of these products are developed at a product development unit (PDU) located in Mölndal.

The telecommunication sector is characterized by new inventions and rapid technology development where one of the greater challenges is to meet the ever-changing demands of the customers and to keep up with technologies and competitors on a dynamic market. Traditionally innovation has always been an important element of the culture at Ericsson and during the last years the focus on flexibility and efficiency in product development has increased in the organization.

A general problem in industry is that product development projects often suffer from time-delays, where it is not unusual with time-delays as big as 40 percent per project (Bellika et al., 2004). To find the causes behind these delays is not usually a simple task. Wheelwright and Clark (1992) states that learning from experience in development projects is crucial but also a complex task, where there often is pressure of time and resources spent on evaluating and learning from “yesterday’s problems” as the organization presses towards new projects. Even with great experience of project development and operation of a mature project management model in many years, time delays are common in the organization at Ericsson.

## **1.1 Purpose**

The aim with this master thesis is to identify the largest underlying factors causing time delays in hardware product development projects in a product development unit at Ericsson AB.

## **1.2 Delimitations**

Within the scope of this thesis a study will be made on hardware development projects at Ericsson AB in Mölndal. The hardware projects studied are by the company seen as characteristic for the development unit. Because of this reason not all development projects that have run during the set time frame will be included in the study.

The project data that will be analyzed will not be going more than thirty six months back in time since organizational and process changes have taken place and might lead to less relevance and accuracy in the analysis. Another aspect is that too old projects could be hard to remember for the interviewees.

The report will include recommendations with focus on the largest contributing factors in accordance with the study’s purpose and will therefore not cover all factors that might be found in the study.

Another aspect is that the study only focuses on time (i.e. time-delays) as one of the factors of productive product development. The other factors that could also have been included, if the purpose was to look at project effectiveness as a whole, are cost and quality. Weighing together and jointly study these three factors could provide a balanced overview of how the company

best could achieve project efficiency together with an understanding of how changes on one factor affect the other two.

Though, this would increase the complexity considerably as time and delays in the context is reasonably straightforward and practical to measure while cost and quality are likely to need to be studied from a broader perspective than what will fit within the frames of what is feasible for this study. For example, by necessary follow-up studies on the projects based on data that is not yet available, since in many cases too little time has passed since project release dates.

However, time-delay in product development has a close relationship to cost due to the fact that one of the biggest expenses during product development is linked with man-hours that will increase with time-delay. A consequence from focusing solely on time in the study is that the recommendations of the report will primarily target on how to overcome delays, even if the other factors are also indirectly affected.

### **1.3 Structure of the thesis**

#### **Chapter 1 – Introduction**

The chapter provides an introduction to the Master thesis that includes background description, states the purpose of the study and defines research questions, delimitations of and the thesis structure.

#### **Chapter 2 – Methodology**

The chapter describes the basic principles of the research design used to collect the information needed to answer the research questions together with a methodological discussion and criticism of method used.

#### **Chapter 3 – Theoretical framework**

The chapter provides a theoretical framework for the reader to be able to comprehend the analysis of empirical data and conclusions made in the study.

#### **Chapter 4 – Empirical data**

The chapter presents a general description of the empirical data findings together with a division of findings into sub-group areas for a better overview.

#### **Chapter 5 – Analysis**

The chapter presents an analysis of the empirical data findings with the support of and comparison to theories covered in the theoretical framework.

#### **Chapter 6 – Conclusion and discussion**

The chapter presents the conclusions drawn from the thesis work and holds a discussion around the outcome of the work.

## **2 Method**

This chapter describes the methods that have been chosen for data collection and analysis in the study with the aim to achieve an as objective research design as possible.

### **2.1 Literature review**

The main areas in the literature review for this study has been product development, operations management, organizational learning and knowledge management. During the review a number of books and articles have been read and literature relevant for the study has been stated in the theory section.

### **2.2 Research method**

According to Bryman and Bell (2011) and Yin (2003) the research method is the technique used to collect data. The section will explain the research method used in this study and described as well in more detail in chapter 4 when the empirical data is presented.

#### **2.2.1 Definitions used in the report**

An Issue - In the report the problems described in the lesson learn documents, final report and in interviews identified as causes to time delay are mentions as “issues”.

A Factor - Is an underlying pattern that can be seen in a group of issues and identified as a reason for time delay in the projects.

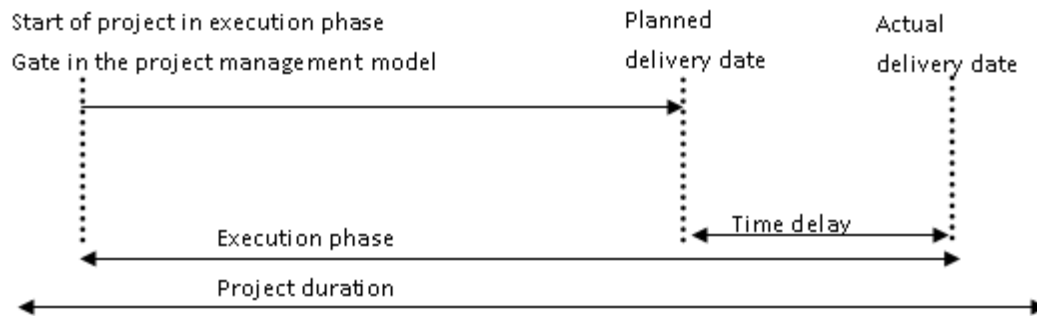
A sub-area -Is a grouping of issues that are considered related to each other.

A main- area - Is a grouping of sub-areas that are considered related to each other.

#### **2.2.2 Selection of hardware product development projects**

Since projects may vary in uniqueness and specific contexts it is important for the validity of the study to get a representative sample of projects (Bryman & Bell, 2011). Otherwise there is a risk the analyzed projects are outliers with the result that the findings and recommendations on actions from these findings will not be applicable to the broad mass of projects. All hardware development projects finalized during the last thirty six month were listed and the goal was to focus on at least fifty percent of the delayed projects during this time frame. The time frame was used for two reasons. First, all the hardware development projects used the same project management model during time. Secondly, too old projects could be hard to remember for the interviewees. A number of delayed project during the time frame were identified. The definition used in this study to decide if the project were delayed or not was stated as; the divergence between the planned project delivery date at the start of the execution phase, in the project management model, used in the project, compared to the actual project delivery date.

If there are more than one delivery date during the execution phase the last planned and the last actual date is used to set the time delay.



*Figure 1 shows the definition of time delay used in the study*

### **2.2.3 Analysis of content in organizational documents**

To increase understanding of what kind of issues could affect time in the projects, organizational documents such as lessons learned and final reports, written at the end of the projects, was read through. Other internal documents containing general information about the product development project and the project management model were studied to provide knowledge about the projects used in the study. This information together with information from literature was used to create the interview guide for the interviews and the questionnaire used in the study.

### **2.2.4 Interviews**

To get a broader perspective of the issues that affect the time delay in the projects, qualitative interviews with project managers were completed. The project managers were chosen to get a broader perspective of hard and soft issues in the project. In the cases the project manager had left the organization, the sub-project managers or other key personnel in the project were chosen. Semi-structured interviews were used during the study. The data collected during the interview was collected by an interview guide but with a level of flexibility that enables the interviewee to speak freely about the topic (Bryman & Bell, 2011). The interview guide was prepared from the information included in the lessons learned document or final report for the project. The interviewees were contacted and depending on availability they were given a verbal introduction about the purpose of the study, by phone or face-to-face. A written introduction with documentation material and meeting requests was sent by mail. This was done so the interviewee could prepare and refresh their minds for the interview. They were also asked to send or bring any additional information that they thought was relevant to the project.

During the interviews the interviewers and the interviewee were discussing the content in the document through the question and the issues that caused delays in the project. According to Guba and Lincoln (1985) it is impossible not to be influenced and affected in a situation as an interview, because the interviewer and interviewee interact with each other. By preparation before the interviews the authors have strived to minimize the unconscious influence during the interviews. In the study, all interviews have been conducted by two persons. Patel and Davidson (2003) state that if more than one person conducting an interview, they can compare their assessments and interpretations so the overall interpretation of the interview will be more accurate. All interviews were recorded. The benefit of recording the interviews, as an alternative of taking notes, was that the interviewer could listen to the interview again, which could be helpful in the analysis of the data collected. A disadvantage to beware of when recording interviews is if the interviewee feels uncomfortable in the situation of being recorded which

might affect the answers (Bryman & Bell, 2011). It was for that reason importance to create a comfortable setting to get the sufficient result of the data collection during the interview. During the interviews the issues were categorized, ranked and mapped on whiteboards. The procedure can be seen described in detail in section 0. Before the interviews ended, the interviewees were asked if they agreed upon the result of the mapping and if not, to make alterations until they felt pleased with the results on the whiteboard. After each interview about fifteen minutes were spend on writing down notes to describe possible disturbances to the interview or for example feelings of discomfort or tension that might affect have affected the answers given in accordance to (Bryman & Bell, 2011). It is important for the credibility of the data that interviewees are aware of issues that could influence data and reflect upon it (Patel & Davidsson, 2003). Photos were taken for documentation and during the following work the results were also written down on A1 sheets for the information to be easily overviewed and manageable during the coming analysis.

### **2.2.5 Questionnaire**

At the end of the interview the interviewee was asked to fill in a questionnaire with questions of a quantitative nature (Appendix 31). These questions are general for all the projects and designed when all the lessons learned documents and final reports for the collected projects had been studied. The questionnaire was created with the aim to capture the degree the issues had affected the projects in terms of time delay. In general the questions were asked on a form that had the responder mark the extent from one to five in the way that he or she thought best matched the project situation; see a more detailed description in the example in section 4.4.2 in Empirical Data.

## **2.3 Analysis of the empirical data**

The information from the interviews was used as a complement to understand the information stated in the content analysis of the organizational documents. The issues experienced in the projects, where listed and sorted into main-areas of issues and sub-areas of issues. These area-groupings of issues were chosen with the aim to try and capture the core of the issues. The groupings were made by help of theory, lessons learned documents and understanding from the interviews. The information was transferred from the A1-sheets to a spreadsheet which further helped to organize available details around each issue and make them more easily accessible through for example use of search-, sort- and filters functions in the spreadsheet. Some examples of information presented in the spreadsheet were issue description, project-belonging, project time-delay, type of project etc, see the procedure further described in section 4.4.2 in Empirical Data. The analysis procedure then consisted of clustering and analyzing of information from different perspectives to find possible correlations, patterns or emerging theories. This part of the analysis can be seen as inductive research as mentioned by Bryman & Bell (2010) where inferences are looked for in iterative tracking back and forth between theory and data. The conclusions from the analysis will be used as input for recommended actions to deal with the identified factors in the product development process.

## **2.4 Weighting and reduction of issues**

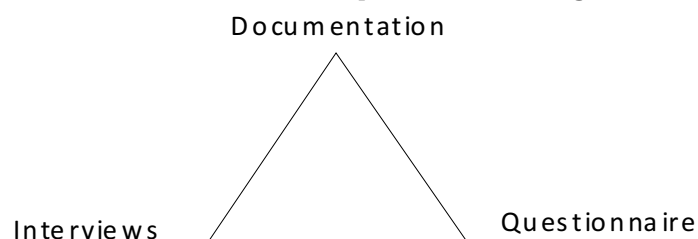
The projects contained varying amounts of issues mentioned in the lessons learned which also resulted in a varying number of issues in the created interview-guide and thereby also contributed to a varying amount of ranked levels of issues in each project, see Figure 12 in section 4.4.2 in Empirical Data. An interview-guide that would have resulted in equal amount of

issue-levels between all the projects was thought of but discarded. An example of how to achieve this could have been to have the levels to be fixed from for example 1 to 15 for all projects and then have the interviewee asked to sort the issues into each level. As this might have resulted in a more direct comparison of issues between projects, it would also have made the interviews more structured. Too much structure in this stage of the interview was considered to have resulted in a risk of loss of information where the interviewee is already trying to quantify qualitative information in some extent. As according to Bryman & Bell (2011) where a less structured interview may be perceived more natural by the interviewee. The decision to not put any more focus than necessary on the levels was later shown to be good whereas the issue-ranking in some of the interviews was perceived to have been met with a combination of carefulness and sometimes even slight reluctance from the interviewees.

This, however, resulted in the necessity to weight (normalize) the levels over all the projects for the possibility of comparison. The procedure is fully described in section 4.4.2 in Empirical Data. With the intention to find and focus on the issues and the underlying factors that, in alignment with the purpose of the study, cause delays the empirical data was seen necessary to be narrowed down for manageability. It was believed that all issues of significance to the projects could still be covered without leaving anything of importance out of the study through a reduction. The top two levels of issues were therefore looked into while the lower levels three and four were cut, which resulted in a reduction of issues from 162 to 100.

## 2.5 Criteria for evaluating the study

The conclusions and the recommendations of this study will be based on analyzing the findings with the theory. Therefore is it important that the data collected is trustworthy. The concept of trustworthiness consists of four different criteria; internal validity, external validity, reliability and objectivity (Bryman & Bell, 2011). To state the internal validity of the study respond validity and triangulation will be used. Respond validity means that the interviewee accepts the result of the interview. In the study this was done by asking the interviewee if they agreed to the interview results and were given time to make adjustments before ending the interview. Triangulation is when using more than one source of data collection and by this technique the data is crosschecked against each other (Bryman & Bell, 2011). Yin (2003) states that triangulation is when using multiple sources for convergence of evidence. These techniques are used to obtain a higher validity of the conclusions in the report. In the study triangulation was performed by using three different sources to capture data, see Figure 2.



**Figure 2 shows the data triangulation method used in study**

The external validity of a study ensures that the result can be generalized beyond the specific research context. Due to that a qualitative research often is not meant to be representative of a population. This matter could make the external validity of the case study findings problematic but in qualitative research the findings are generalized to theory instead of population (Bryman & Bell, 2011, Yin, 2003). Furthermore reliability or dependability is an important criteria for the trustworthiness of the study. The authors of the report should adopt an auditing approach to



ensure that the data collecting procedure is completed correctly. The data collected was kept in order to show that the general procedure of in the case study can be repeated with the same result (Bryman & Bell 2011, Yin 2003). The data used in this master thesis has been stored in a computer file system and the data collection process described carefully in the method chapter to enhance the reliability. However, collected data are always influenced and affected by the context in which it was collected and on the participant taking part in the study, therefore is it difficult to conduct a true replication of a qualitative case study (Bryman & Bell, 2011). Complete objectivity cannot be accomplished (Bryman & Bell, 2011); therefore is it important for the authors not to influence the study with personal values by the environment. For that reason time was spent both at the company and Chalmers during the work with this master thesis. According to Guba and Lincoln (1985) the degree of how the results can be considered neutral and not shaped by author's bias, motivation or interest, is of importance to be evaluated. One way to strengthen neutrality is to describe how data is collected and how the analysis has been carried out (Guba & Lincoln 1985). For that reason the method of collecting data and how the analysis has been described in this chapter. The way of conducting the study is further described in more detail in Chapter 4, when the empirical data is presented.

## **2.6 Criticism of method**

Effort has been made on making the result of this study as reliable as possible. In the section below sources have been identified that could impact of the result of the study. The matter will be further discussed in section 6.4.

### **2.6.1 Interviews**

The *documents* used to prepare the interview guide were written and structured in different ways. Some of the documents were very comprising while other less wide-ranging. This matter affects the structure of the interview guide even if the attempt was to make them equivalent. The experience of managing projects can be factors that affect the discussion during the interview. For example by interviewing sub-project managers or technical coordinators the interview got a more technical character. Aspects of how interviewee attributes and demographics may have affected the interview situation have not been taken in consideration in the study. Another issue is the *time aspect*. All projects in the study were ended during the last thirty-six month. Hence, the interviewees occasionally had difficulties to remember specific information asked.

### **2.6.2 Data collection**

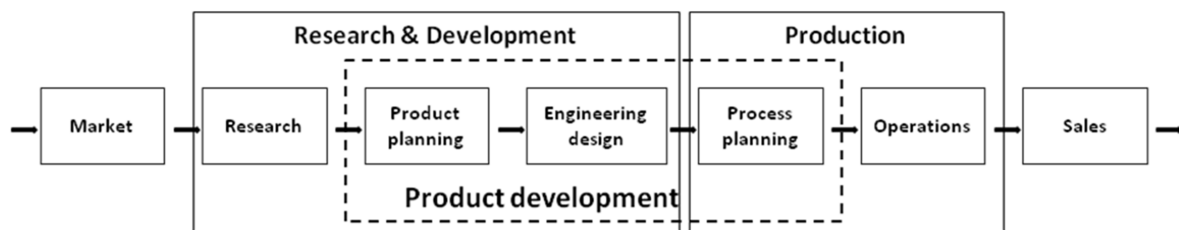
As mentioned, documents such as lessons learned are created by templates to serve as guides lines to cover all areas and issues that have appeared during the project. There might be a risk that there are issues outside these templates, and therefore has been left out even though relevant for the project learning. This is not something that the study has examined further.

### 3 Theoretical framework

*This chapter intends to describe the theory used in the thesis. First presented is a general description of the product development. After this the theory is divided in the sections; Technology maturity, Operation, Ways-of-working and Communication. The aim with these sections is to present the theory used in the different main-areas for analysis and for recommendations.*

#### 3.1 Product development - A general description

Product development is a large and dynamic area with years and years of literature material. Here the authors will try to cover the basics that are connected to the study. This means by narrowing down and presenting theory that focus on technological product development. To be further specific hardware development and aspects found relevant to product development projects from a time-based perspective. The product development process can be seen as a conversion process of materials, knowledge and customer needs into products ready to be sold on the market. The descriptions of the product development process are many and vary depending on what business area and type of development they are connected to. A model that was found to cohere with the thesis is a presentation of product development as part of the technological innovation process by Trygg (1991) presented in Figure 3.



*Figure 3 shows product development as part of technological innovation process*

The different parts are by Trygg (1991) described as follows: *The process of technological innovation* includes all activities from market, generation of ideas to commercial production and sales.

*Research* is defined by activities that are performed with the purpose to find new elements of technology that can be of use to the company in future.

*Product planning* is the search, analysis and choice of ideas for production that results in a product specification or implementation proposal where the most important requirements and characteristics are described.

*Engineering design* is an iterative process of problem solving in which the product specifications are transformed into concrete solutions in terms of drawings and specifications for production. The *engineering design* can be further divided into three different phases: feasibility study, preliminary design and detailed design. The feasibility study can be compared with what Priest and Sanchez (2001) refers to as the *requirements definition* phase in their view of development process. They state that the knowledge output from this phase is the product requirements specification documentation. The preliminary design is similar to what Priest and Sanchez (2001) calls conceptual design where possible designs are evaluated if they do meet the requirements from the feasibility study. These are often done with help of mathematical models, simulations and cost estimations before the detailed design is set. In the Priest and Sanchez

(2001) detailed design phase, examination of parameters and characteristic interactions is done. The analyses often include stress analysis, failure mode and producibility analysis. Where the later is closely related to the next stage, process planning.

*Process planning* also called *production planning* consists of activities with the purpose to prepare and adjust the production system including tools and fixtures. This stage should, according to Wheelwright & Clark (1992), be included early in the product development process. Sharing knowledge with the upstream engineers results in finding “downstream-friendly” solutions in the engineering design.

*Research and Development* includes the activities from *product development* except for process planning but also varies nature of research such as basic and applied research.

*Product development* as part of technological innovation process consists of *product planning*, *engineering design* and *process planning*. It includes all activities from market needs and technical possibilities to production designs. It often includes prototype production and test activities. Product development, specifically engineering design, will be focused on in this study in the form of a project perspective on factors that causes time delays.

Wheelwright and Clark (1992) state “the organization must have an effective way of defining products, must understand an appropriately deploy the mechanisms and tools for problem solving, and must understand and effectively deal with the issues involved in senior management review and control”.

### **3.2 Technology maturity – And road maps for the future**

Wheelwright and Clark (1992) states that managers and organizations lay foundation for a successful development project long before the project begins. Maps are one management tool that helps organizations to target the investments.

Roadmapping is a common way to help planning and cross-functional communication. It supports people at all levels in the organization to achieve milestones and to become committed to the overall process. Roadmapping also helps the organization to recognize in advance which new products and technologies that should be available and when. The planning horizon is depending on the product lifecycle, the technologies used in the industry and of course the lead-time in development. According to Kappel (2001) roadmapping can be used in four different areas; *Science/Technology*, *Industry*, *Product-Technology* and *Product*. The roadmapping process to use is depending on what purpose and can access different aspect of the planning problem (Groenveld, 2007).

The time interval at the roadmap depends on the type of products as well as aggregation level. Products with short life cycles will not cover more than three-to-four years, whereas roadmaps for generic products may extend to ten years (Groenveld, 2007). It is important to remember that the roadmap is a living document that should be updated continuously with the changed conditions for the organization.. A group of personal that represent relevant functions and competence in the organization is needed for planning the roadmap. Finally, it is important to ensure that the complexity within the planning does not grow to levels where the synchronization of competent competences becomes difficult in the planning groups (Karlsson, 2003).

### 3.2.1 Technology development and product development

Organizations can strategically lay more focus in one or several phases of development of ideas and opportunities to commercially produced end products. The phases are different in time perspective and come with different levels of uncertainty and technological maturity. The different phases of Research & Development from Aalto, Martinsuo et al. (2003) here presented in Figure 4.

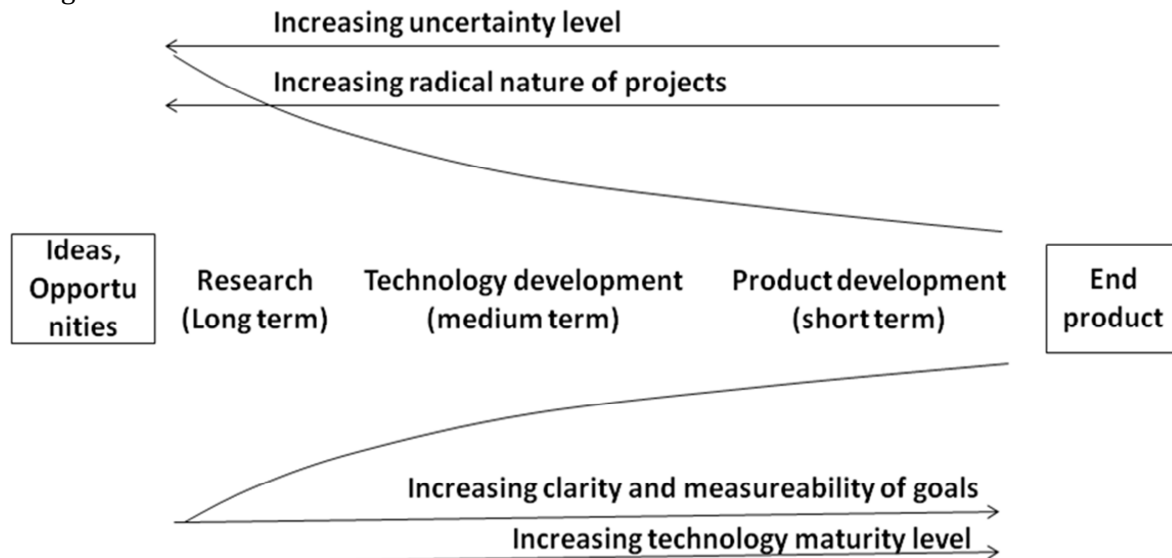


Figure 4 shows different phases of Research & Development from Aalto, Martinsuo et al. (2003)

The differences between technology development and product development can be further described in different dimensions. Högman (2011) presents examples of task characteristics in seven dimensions:

*Prerequisites.* Technology development is primarily exploration-oriented and problem focused with uncertain and unclear targets, while product development is primarily exploitation-oriented solution focused and with clearer market targets and resource requirements.

*Technical maturity.* In technology development, technology is evaluated and developed on a component level, while in product development focus is on framing and choosing of concepts on a system and integration level.

*Time horizon.* Technology development has more long-term goals and prepares for product portfolio of the future, while product development has more short-term goals.

*Competence needs.* In technology development the competence needs are often unclear and hard to schedule, whereas in product development they are clearer, project based and easier to foresee.

*Process repeatability* is often low in technology development with greater uncertainty, uniqueness and variation. Compared with product development the processes are of more routine nature and easier to formalize.

*Completion point* is often unclear in where the goals can be to build knowledge or explore. It present a feasibility level of technology while the completion point in product development is pre-decided and often ending with product launched to market.

*Development results* in technology development are mainly knowledge, competence and capability, while the product development results are mainly a product, service or manufacturing system.

### 3.2.2 Systems engineering and technology maturity

Systems engineering focus on capturing and analyzing customer needs and functionality requirements at an early stage in a development cycle. A holistic approach looks at the development as a whole and contains procedures going from specified requirements to design and system validation. Oliver et al. (1997) chose to divide the systems engineering process in two parts: a *Systems Engineering Technical Process* and a *Systems Engineering Management Process*. The Technical process includes evaluating available information, defining measurements of effectiveness, trade-off analysis, creation of structure model, build and test plan. The Management process focus on organization of efforts related to the technical process.

An important matter stated by NASA (2007) is the assessment of technology maturity in the early phases of system engineering. A newly invented technology (e.g. component, material.) is usually not ready to be incorporated directly into a system without first having been explored, tested and increasingly refined through iterations. Thomke and Fujimoto (2000) further claims that an organization can cut costs, reduce development time and free up resources by shifting the identification and solving of problems earlier in the product development process. A concept they define as front-loading. Which is supported by Dawson (2007) who states that a certain level of technology maturity is required, e.g. to gain a good understanding of technology status, transition possibilities, risk management and decisions related to technology funding.

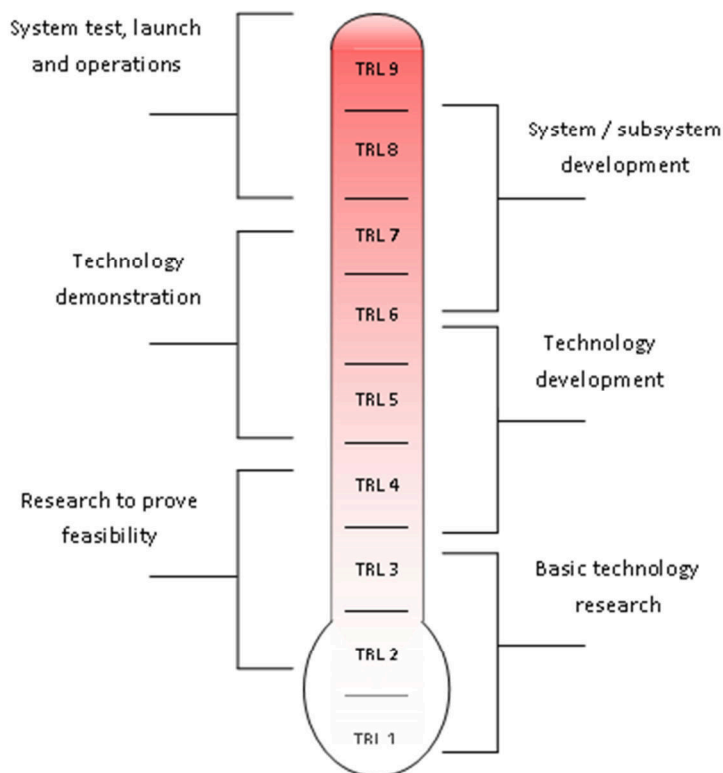


Figure 5 shows Technology Readiness Levels (Mankins 1995)

A model developed for technology maturity assessment is the Technology Readiness Level by NASA. The model is widely used in organizations and agencies beside NASA, such as U.S. Department of Defense, European Space Agency, U. S. Department of Energy and Federal Aviation Administration. There have been individual adaptations to the model by different agencies, some difference occurs but overall the model is similar.

The model used by NASA, presented in Figure 5, has been expanded by Mankins(1995).

The levels are defined as follows: **TRL 9** Actual system “flight proven” through successful

mission operations. **TRL 8** Actual system completed and “flight qualified” through test and demonstration (ground or flight). **TRL 7** System prototype demonstration in a target/space environment. **TRL 6** System/subsystem model or prototype demonstration in a relevant environment (ground or space). **TRL 5** Component and/or breadboard validation in relevant environment. **TRL 4** Component and/or breadboard validation in laboratory environment. **TRL 3** Analytical and experimental critical function and/or characteristic proof of concept. **TRL 2** Technology concept and/or application formulated. **TRL 1** Basic principles observed and reported. Dawson (2007) states that the use of technology readiness levels can help management in technology and development decisions, but there are challenges to consider. The readiness do not necessarily fit appropriately with technology maturity and when a product is judged mature with high readiness level in one setting does not mean that it is mature in another setting, e.g. different product systems or environments. The U.S. Government Accountability Office (GAO) also states in the Congressional Committees report (2008) that organizations have been running into costly and time-consuming difficulties by attempting to rush research into production, trying to move directly from TRL 3 to TRL 6.

### **3.3 Operations**

The following theory section will set the scene providing background theory, defining and explaining how components of operations strategy can be linked together. The theory will mainly be referred to in the analysis section of the report.

#### **3.3.1 Management - Leadership commitment and decisions**

Bergman and Klefsjö (2010) state that committed leadership is one of the cornerstones in total quality management. Leadership through credible, clear and good communication and role models can create commitment and engagement from the members in the organization. This is further supported by Wheelwright and Clark (1992) who states that senior management in the way they manage reviews, evaluations and modifies the project over time sends signals of the degree of responsibility delegated to those working on the project which creates powerful incentives and motivations, positive as negative, during the project time. They more state the importance of matters which may be seen as routine such as frequency, timing and format of reviews can have significant impact on the overall effectiveness of the project.

#### **3.3.2 Operations strategy**

“Operations strategy is the total pattern of decisions which shape the long-term capabilities of any type of operation and their contribution to overall strategy, through the reconciliation of market requirements with operations resources” (Slack & Lewis, 2008)

Slack & Lewis (2008) and Tan & Matthews (2009) state that there is no perspective that alone gives the full picture of what operations strategy is, but provides four perspectives that together may provide an idea on the contents of operations strategy: *Top-down*, *Bottom-up*, *Market requirements* and *Operations resources*.

A *top-down* approach involves decisions taken at the top of the organization, such as what type of business the organization wants to be in, where to operate geographically, what business to acquire or divest, how to divide costs and returns between the organization elements (Slack and Lewis, 2008).

The *bottom-up* approach where the principle is “shape the operation’s objectives and action, at least partly, by the knowledge it gains from its day-to-day activities”(Slack and Lewis, 2008).

The *market requirements* perspective involves translation of market requirements into operations decisions by asking how operations can help the organization to compete in its market place. Tan & Matthews (2009) state that market requirements as an element of operations strategy does not ask what can be sold but instead what is required.

The *operations resources* perspective involves exploiting the capabilities of operations resources in chosen markets (Slack and Lewis, 2008). Jenkins et al. (2007) state that an operational resource-based view on a firm can be appreciated how a company’s ability combines resources into capabilities. They further claim that it is an operation’s ability, not only to add value, but also add value to the company which allows continuous operation on a competitive market.

According to Slack and Lewis (2008) the content of operations strategy is the interaction between operation’s performance objectives and the decisions that it takes concerning resource deployment.

### **3.3.3 Performance objectives**

The performance objectives in this context are competitive factors that reflect dimensions of performance such as *Quality, Speed, Dependability, Flexibility* and *Cost*.

Quality can be divided into: *level of specification* for example high as quality end of market with luxury cars, *fit for purpose* meaning appropriate specification or *conformance to specification* for example how well the set quality level is achieved. *Speed* may for example be the time elapsed from customer order a product until it is delivered. *Dependability* meaning keeping delivery promises in aspects of time. Slack and Lewis (2008) presents dependability as equal to the due delivery time minus the actual delivery time, where a positive number shows on higher dependability. *Flexibility* can be measured as in systems’ ability to respond to changes in product, mix, volume and delivery. *Costs* can be divided into *Operating expenditure* such as labor and material etc., *Capital expenditure* such as land, facilities and machinery and *Working capital* meaning the gap between cash outflow and inflow, for example products produced but not yet paid for.

### **3.3.4 Decision areas**

The decision areas in the model are grouping of decisions that are stated to have a clear influence on an organization’s return of investments such as *Capacity, Supply network, Process technology* and *Development and organization*.

*Capacity* states the potential level of productive activity. Where having too much capacity, for example under-utilized resources, may give possibility in terms of flexibility to respond quickly to increased product demands, but requires investments that will drive cost-per-unit when they are not in full use. On the other hand having too little capacity may lead to limits the ability to meet customer requirements with risk of customers looking for alternatives for example by competitors resulting in loss of market shares. When looking at capacity as of human resources and in projects Adler et al. (1995) state that the efficiency of resources is adversely affected in relation to whether the resources would have been one hundred percent dedicated project meaning that there is loss in efficiency when sharing resources between activities and projects

which they call the congestion effect. According to Nobeoka and Cusumano (1997) there are also benefits of resource sharing. They argue that shared resources lead to better utilization of resources, reduction in required development hours, as well as better learning across projects.

*Supply network* can be seen as the strategic direction of an organization's relationship with customers, suppliers and their customers and suppliers in turn. Questions to be addressed are for example what activities should be done in-house and what activities to outsource?

Johnson et al. (2011) defines outsourcing as "the process by which activities previously carried out internally are subcontracted to external suppliers" and states that the argument for outsourcing to specialist suppliers is often based on strategic capabilities, where the activities outsourced are not part a central part of the organization's business.

If the activities are part of the core-activities, meaning activities that the company wants to keep control of or think is important to perform to increase knowledge within a specific area, and then it may be a reasonable alternative to keep the activities in-house. If the activities are not part of the company strategy or can be done with higher dependability or more efficient by a supplier, in terms of for example costs or quality, then there might be good reasons to outsource. The companies that are outsourced to are often specialized within the area with great capabilities and can therefore also achieve economies of scale.

According to Slack and Lewis (2008) the activities to outsource needs to be clearly defined and with contracts that cover what will happen if parts of the deal are not kept such as penalties if delays of delivery and quality defects etc. They further state that different types of supplier and customer relationships give different opportunities. By having many suppliers to choose from, may lead to the possibility to play supplier against each other and press prices. Long-term and close supplier relationships may lead to less focus on gaining the biggest part of the cake but rather focus on how to make the cake as big as possible. An example of this that Slack and Lewis (2008) mentions is "partnership supply", a relation between customer and supplier where partners "cooperate to the extent of sharing skills and resources to achieve joint benefits beyond those they could achieve by acting alone". Positives that may come out of more integrated activities are increased better informational flow (due to both increased communications and trust), joint learning and mutual investments.

Hallikas et al. (2004) highlights the risk of having only one supply option as a vulnerability "Companies should also avoid being too dependent on a single network or organization." They further state that network-cooperation brings benefits that, in addition to the benefits above mentioned by Slack and Lewis, increase the supplier responsibilities and can mean that investment risks may in some cases be transferred to the suppliers. But they also point out that an increased cooperation is likely to also increase dependency between the companies and with that become more exposed to the risks of the other company.. "The optimal strategy is to aim at share and balance rewards and risks between organizations."

*Process technology* can be defined as the "appliance of science to any operations process" and the strategy related to it as "the set of decisions that define the strategic role that direct and indirect process technology can play in the overall operations strategy of the organization and sets out the general characteristics that help to evaluate alternative technologies" (Slack and Lewis, 2008). The process technology concerns choice and development of systems, machines and



processes used to create a product. It can for example in manufacturing be the operations process that assemble a car, while product technology refers to for example components or design of the product such as the chassis or engine control steering system.

*Development and organization* is on how the organization make long-term or short-term decisions on how it should develop and for instance improve its operations processes over time, how resources should be organized projects or teams and other matters that are related with continuous improvements etc. As Slack and Lewis (2008) puts it "Even small advantages in product and service specifications can have a significant impact on competitiveness". There are basically two types of improvements: break through improvements and continuous improvements. The break through improvements mean big changes at a time and usually require high investments, interruption of production etc. whilst continuous improvements usually means more and smaller steps.

### **3.3.5 Trade-offs**

Trade-offs is an area discussed from different perspectives. In the context of product development, trade-offs involve focus on what manufacturing capabilities to develop to strengthen the company's position on the market in terms of decisions related to cost, quality, flexibility and delivery. According to Swink and Way (1995) the importance of these decisions and priorities between them is increasing with time referring to increasingly growing competitiveness of the market. Slack and Lewis (2008) can be seen supporting the statement on growing competitiveness of the market when they talk about the necessity for continuous improvements as the "Red queen" affect referring to a quotation from Alice in wonderland in which the queen tells Alice "Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else you must run at least twice as fast as that!"

Boyer and Lewis (2002) present three different perspectives on trade-offs. The first one is Skinner's trade-off model which proposes that the company needs to choose one of the priorities to get the most time and resources invested in, since the he means that the different competitive priorities requires different factory designs. Skinner means that there are limits for what can be done and that trying to be good in all areas comes with the risk and likeliness of not performing well in any of the areas. "For instance, no one today can design a 500-passenger plane that can land on a carrier and also break the sonic barrier"(Skinner, 1996).

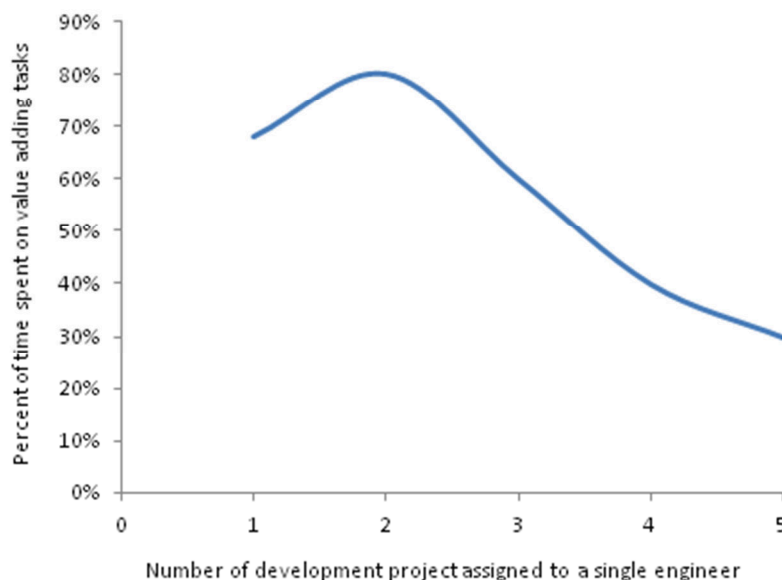
The second model is the cumulative that claims that trade-offs are irrelevant and that competitive priorities are complementing and helping each other in developing capabilities rather than competing with each other. This is also helped by increased use of advanced manufacturing technology (AMT) that allows factories to develop multiple capabilities. "Each successive capability becomes the primary focus once minimum levels of the preceding capabilities have been achieved" (Ferdows and De Meyer 1990).

The third perspective presented is the integrate model that sees and tries to link the similarities of the two first models together meaning that one does not rule out the other but parts of both may be applicable and that plants have both an operating and an asset frontier.

Boyer and Lewis (2002) state that the most important issue when to reach good results is not what priority to emphasize but that the priority is supported with consistent decisions that helps to develop its capabilities into what is expected of it.

### 3.3.6 Planning and resource overcommitment of development capacity

There are many challenges in the planning of projects. Melton and Iles-Smith (2009) state that some of the common root causes to problems in generic planning in projects are: lack of contingency plans, lack of contractual obligations, integration of cost, time and scope issues, lack of communication, lack of understanding of team member responsibilities, poor scope management and control, and lack of understanding of what the project needs to deliver to enable expected benefits from the outcome. Problems in generic planning often result in as Wheelwright and Clark (1992) describe it, overcommitment of available development recourses. And they state that this is one reason for why cost of development increase, deadline passes and that pressure to cut corners increases. It also tends to mean that key personal frequently and at the same time as is used in different projects. One problem with this matter is that when the number of project is more than one the productivity first rise and then fall, after the second project the value adding time spent on each task decrease rapidly. The key recourse becomes a bottleneck in all projects assigned.



**Figure 6 Productivity of development Engineering Time (Wheelwright and Clark, 1992)**

A research study by Cooper, Edgett and Kleinschmidt (2004) shows also that multitasking maybe work to a specific level but with too much other work, to many projects and lack of focus, influence the outcome of the project. Therefore right resource allocation and focus is very important for time to market and for the quality of the execution of projects. Another theory related to resource performance is according to Herzberg's motivational needs theory: motivational and hygiene factors (Shani et al. 2009). Where if the motivational factors as achievement, recognition, work itself, responsibility and advancement are present in a work situation the individual's basic needs will be satisfied, that leads to job satisfaction and result in improved performance. The hygiene factors are factors that do not add any job satisfaction or positive feelings themselves but are so called dissatisfaction factors that if reduced will remove dissatisfaction and thereby improve performance. Such factors are, according to Herzberg, company policy and practices, supervision, interpersonal relations, physical working conditions, job security, benefits and salary. How to plan a project to avoid the above mentioned problems may not be a straightforward task. According to Howell and Ballard (1996) a classical way of

planning is to decide how many resources that are needed to perform certain tasks. They further state that this classical approach to planning produces waste in the lack of achievement of what was done against what should have been done. They mean that it is better for a project to be dynamic and to consider the concept of what can be performed to provide a yardstick. Then the planning process needs to involve a continuous adjusting between what should be done, to what can be done, to produce what will be done. An approach that will provide better knowledge on the process and through identification and correction of one weakness in the process another weakness is likely to show. So the work of continuous improvement will proceed.

### **3.3.7 Time to market**

According to (Pawar et al., 1994) *time to market* is the *strategy* when focusing on reducing the time between that a product being conceive until the product is introduced to the market. *Time to market* can also be defined as the length of time it takes to develop a new product from the product definition in the early stage of the development process to the time the product is ready for manufacturing release (Vesey 1992, House and Price 1991). Smith and Reinertsen (1991) state that development time or *time to market* is the time between the first opportunity someone started working on a development program and the first time a final product is available on the market.

Smith and Reinertsen (1991) present also four key objective; *development speed, product cost, product performance and development program expense*. The objectives are important because it is very hard to reach all of them at the same time. In some situations it is possible to reach more than one objective, but in most cases trade-off must be made between the objectives. Therefore is it important to make the right decision. For most companies it is to maximize product profitability which not always is an easy task. To make wise trade-off decisions it is important to have knowledge about the real meaning of the four objectives and the consequences of the decision.

The impact of product development cycle time on the profit is one issue to address when talking about time delay in product development projects. Patterson (1993) and Smith and Reinertsen (1991) address four different scenario impacting the profit before-tax; *six month delay in product introduction; ten percent increased in product cost; a ten percent decreased in unit sale due to reduced product performance; fifty percent overrun in development cost*. The conclusion was that the profit was most impacted negative when delaying the product introduction. Meaning that increasing the development investment by fifty percent to keep the project on schedule was a good business decision. According to Blackburn (1991) product development that overruns fifty percent in cost to keep time is still more profitable than six month delay in time for the project.

## **3.4 Ways of working - Continuous improvement and learning in organizations**

The following section present and introduce theory mainly used in the chapter Ways of working in the analysis.

### **3.4.1 Continuous improvement**

Continuous improvements mean according to Dean and Bowen (1994) a constant examination of technical and administrative processes in search of better methods. Continuous improvement is one of three principles in total quality which states that constant customer satisfaction can be attained by improvement of processes that create products and services. The principals are implementation in an organization through a set of practices and supported by a wide array of techniques. Examples of practices for continuous improvement are process analysis and the

PDCA (Plan, Do, Check, Act) cycle while flow charts and fishbone diagrams are techniques associated with the principles for continuous improvement. When mention customer it can both be external customer outside the organization and internal customers in the organization (Dean and Bowen, 1994). The improvements can be directed towards different processes in an organization and the implementation is a useful way of working for leaning (Eklund, 2000).

Practices:	Process analysis Reengineering Problem solving Plan/Do/Check/Act
Techniques:	Flowcharts Pareto analysis Statistical process control Fishbone diagram

**Table 1 Practices and Techniques in continuous improvements (Dean and Bowen, 1994)**

Learning cycles as the PDCA cycle, introduced by Edward Deming, is a method or practices that can be used in the improvement process in an organization (Bergman and Klefsjö , 2008) and in projects for inter-project learning or intra-project learning (Kotnour, 1999). The PDCA cycle can be used for short term or long term change and to achieve continuously improvements within identified improvement areas (Bergman and Klefsjö , 2008).

To understand the processes are of great importance, therefore the key is to gain knowledge about the process; this can be done by illustration the process in a flowchart. A cause-and-effect diagram, which is also called fishbone diagram, is one technique used for finding the root cause in a systematic way. The cause-and -effect provides an basis for problem solving (Bergman and Klefsjö , 2008). The importance of finding the root cause and a general solution for the problem, instead of putting a remedy to the symptoms, is crucial in improvement work. If the solution is specific and only invented to solve the immediate problem the same type of problem will occur again. The knowledge can be useable when moved in to the organizational level and being standardized. This creates a good change and learning which benefits the organization (Alänge, 1994).

### **3.4.2 Organizational culture**

Schein (1992) classifies organizational culture in three levels: artifacts, espoused beliefs and values and basic underlying assumptions. Artifacts are the visible culture at the surface such as language, visible behavior patterns, technology and products. The espoused beliefs and values are externalized in expressed organizational values and strategies. These visibly levels of the organizational culture identifies what is important for a specific group and the members in the group are consciously aware of these values. The basic underlying assumptions are invisible. These assumptions are taken for granted and are unconsciously deep-rooted values and beliefs which determine people's perception, thoughts and feelings. They have impact on how people behave in an organization. However, according to Schein (1992) the basic underlying assumptions have more influence on the behavior than the artifacts and espoused beliefs and values in an organization. A metaphor often used when describing culture is an iceberg; whereby the assumptions which the culture is based on stay invisible. Only a small part of the culture is visible such as artifacts, behavior, rituals and written rules (Friedman and Berthion, 2005).

According to De Long and Fahey (2000) is culture both intangible and tangible and is reflected in the elements values, norms and practices. Values are tacit embedded preferences about what the organization should strive to attain and how to do so. They also state that values is often difficult to articulate and even more difficult to change. The norms are easier to observe and identify than the values for the people in the organization. The visible symbols are the practices of the culture and a way of understanding any set of repetitive behavior. All these three elements influence the behavior in the organization.

To what extent the culture is built on the knowledge is identified by existing norms and practices in the organization. Values then lies within individual creativity and not in leveraging past experiences and reusing knowledge. In another aspect, a norm that rewards individual knowledge or accumulated knowledge is used to reach individual reward. To get the individual to sacrifice themselves for the better of the organization require sacrifice (Long and Fahey 2000).

Black et al (2001) describes a common strategy used in companies to fix problems late in the development cycles. It is called “fire fighting” and describes the work of company heroes that solves problems when they occur late in the product development cycle. The firefighters often have an expertise needed in other projects and drain the company of competence. It is also a strategy that often spreads out in the organization. “Firefighting is not a complement to a more structured approach to new product development, but is, instead an organizational pathology that left unchecked can significantly degrade on organizations ability to create high quality products”. (Black et al, 2001 s.46) Oosterwal (2010) describes “firefighting” as common syndrome in product development projects in a universal perspective. The project leader often has the thought of having to solve problems as a “fire-fighter” or through a “fire-fighter”. A competitive and complex reality creates the need of firefighting at project level due to the environment the product development works in.” Fire-fighting” is rewarding according to the “fire-fighter” but hazardous for the organization as a whole. Managers tends to react to problems until the problems are emergent (Wheelwright and Clark, 1992). It is important that the managers instead of reacting to problems prevent them. In both project level and on manager level the importance of preventing problems before they occur is less successful than letting problems grow and escalate.

### **3.4.3 Roles and responsibilities**

The project organization is focused on the assignment, the goal setting and goal fulfilment, making changes if it is necessary and to continuously reporting about the state of the project. The project organization is also responsible for the budget and that the time schedule is kept for the project (Kerzner, 2001). According to Meredith and Mantel (2012) the project manager has the responsible for what needs to be done, when in time and what resources is required to get the work done.

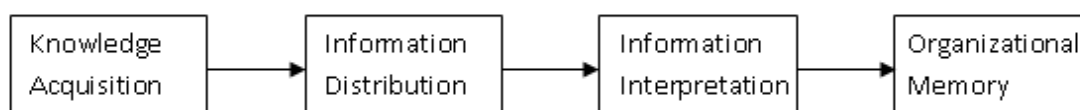
The line organization or the functional management, on the other hand, is responsible for accumulating competences and resource allocation for the projects in the organization, the employees and equipment needed for the project. The line organization is also responsible that the work is carry out in a professional way, investment and for the long term planning for the development (Kerzner, 2001). Who will do the work required in the project and how the work will be accomplished in a technical point of view is the responsible for the line organization (Meredith and Mantel, 2012).

#### 3.4.4 Learning in organizations

In literature the relationship between *individual* and *organizational* learning is debated and is dominated by two groups of theories (de Weerd-Nederhof et.al, 2002). First, learning occurs when individual members of the organization assimilate new experiences. Secondly, organizations learn because of their process capability is equivalent or identical to those processes by individuals. In summary, learning in the organization occur when the organization capture individual learning and institutionalize the learning in to the organization (de Weerd-Nederhof et.al, 2002). Another aspect is that individual learning is important for an organization but it is significant to understand and remember that organization learning is not simply the sum of each members learning in the organization (Fiol and Lyles, 1985). Kim (1993) also claims organization learns via individual learning, therefore is it fundamental that the individual learning is transferred into the organization. He also states that in a new enterprise organizational learning is the same as individual learning. An organization comprises of a small group of members and has a minimal structure. When the organization grows a difference between individual and organizational learning develops and the need for a system capturing the learning of its individual members. Argyris (1999) defined organization learning as “a process of detecting and correcting errors” and the organization do not itself perform the actions that produce the learning. Learning occurs when individuals act as agents of the organization that produce the behavior. Learning occurs in two conditions. First when an organization achieves the result as intended or when a mismatch is turned into a match. According to Argyris (1999) single loop learning occurs whenever a match is created or when the failure is corrected without questioning the underlying values of the system. Double loop learning occurs first when individuals examining and change the value system before corrective actions are

#### 3.4.5 A model of organizational learning processes

One of the most cited model for organization learning is a four stage process model by Huber (1991) there he states that usability of the learning depends on the effectiveness of the organization's memory (Figure 11). In this model learning is depending on *knowledge acquisition*, *information distribution* and *information interpretation*. To create an *organizational memory* is important for the idea of organizational learning according to Huber. The learning must be stored in an organizational memory and be able to be fetched when needed.



**Figure 7 shows the processes associated with organizational learning according to Huber (1991).**

The four stages in the model are described as:

*Knowledge acquisition or information acquisition*, the process by which knowledge is obtained for example by direct experience learning which is improved by the analysis of feedback about cause-effect relationship between organizational action and outcome or by gain knowledge or information by reading magazines and articles or by listening to the information shared during the coffee break (Huber, 1991, de Weerd-Nederhof et.al, 2002 ).

*Information distribution*, the process which information from different sources in the organization is shared and combined so new information and understanding obtains.

*Information interpretation*; the process by which distributed information is given meaning. It is important to remember the fact that the information is not uniformly framed when distributed, uniform interpretations are less likely to be achieved.

*Organizational memory* is the way which knowledge is stored for future use. Huber (1991) states that the organizational memory is affected by membership attrition, the information distribution, the organizational interpretation of information, the norms and methods for storing information and the methods for locating and retrieving stored information. The construction of the organizational memory is important for the idea of organizational learning (Huber, 1991). The knowledge in an organization can be embodied in different ways. The organization learning occurs through the organizational memory which embodies the knowledge via databases, procedures or processes. While the team learning embodies via reports, products, team-specific expertise. The knowledge from the team learning is linked to the organization learning via post-projects reviews as lessons learned according to Zedtwitz (2002).

#### **3.4.6 Explicit and Tacit Knowledge**

According to literature there exist two different types of knowledge: *explicit and tacit knowledge*. Explicit knowledge can be expressed in words and number and can easily be transmitted between individuals in a formal and systematic language (Nonaka, 2007). This knowledge can be stored and retrieved easily through various mechanisms such as plans, reports, meetings or computer systems (Ernst and Kim, 2002). Tacit knowledge on the other hand is highly personal, and based on experience which makes it hard to formalize, codify and communicate with others. People acquire it through observation, imitation and practice. The diffusion requires apprentice-type training and face-to-face interaction (Ernst and Kim, 2002, Nonaka, 2007). Tacit knowledge can be seen as a part of human body as skills or the capacity how human interact in and interpret their environment but also as routines in organizational practice or as basic assumptions, beliefs and norms in an organization. According to Nonaka and Konno (1998) tacit knowledge can be transferred into explicit knowledge to be understood by others. In practice the transfer is made in two different steps. The first step, involves techniques that help to express images, ideas, concepts and visuals. The second translates the tacit knowledge into explicit forms that are easy to understand. Different types of tacit knowledge have different degrees of difficulties in transfer between people (Ernst and Kim, 2002).

#### **3.4.7 Codification and personalization**

According to Antoni et al (2005) knowledge can be transferred by code and people i.e. through documents and people. Hansen et al (1999) presents two similar concepts; codification and personalization. Codification refers to codifying knowledge sharing from people to documents or storing knowledge in databases, with focus on reusing the information. Codification transfers individual knowledge to organizational knowledge by the use of databases which makes it possible to share the knowledge between individuals in an organization (Magnusson, 2004). Personalization is based on the assumption that a dialogue is necessary for sharing knowledge and experience between people (Hansen et al, 1999). The main perception is that codification is suitable for capturing explicit knowledge while personalization is more suitable for capturing tacit knowledge. There are of course limitations in codification of knowledge; there is always a risk of loss of knowledge or information when codify. It is important for the source of the knowledge to know how the user is and how the information will be used to make the codification efficient. No interaction or communication between source and user is a critical issue for the codification. Usually the one who writes the document has no idea who will use it,

when or if the information will be useful to the user (Chen and Ghaedian, 2012). To use only one of the concepts is not enough to capture needed knowledge. The personalization concept is easier to capture, often in an informal way, therefore a more formal and systematic way of working to create meetings and interaction between employees could be useful for caption knowledge i.e. create networks between employees in the organization (Chen and Ghaedian, 2012). According to Chennanmaneni et.al (2011) there are different kinds of tacit knowledge. First the knowledge that is entirely unconscious and inaccessible for introspection, while another type of tacit knowledge is conscious and accessible if captured and triggered in suitable way. It would be a mistake to consider knowledge as strictly tacit or explicit, the degree of tacitness specifies how the knowledge is accessible or not. Knowledge with low degree of tacitness can be transferred by mechanisms like expert systems, lessons learned and protocol analysis. Knowledge with high degree of tacitness is accessible with transfer mechanisms as direct observation, apprenticeship and mentoring. The knowledge with medium degree of tacitness can be captured by mechanisms such as concept mapping, fishbone diagrams where the knowledge is visualized and captured by others. However, Goffin et al. (2010) also states that tacit knowledge is possible to capture to explicit by codification in certain aspects by suitable codification schemes and mechanisms. Goffin et.al (2010) has identified different mechanisms for generating and sharing explicit and tacit knowledge,

Explicit knowledge	Tacit knowledge
Codification Documentation Databases Search engines Blogs Intranets	Practice Personal and team reflection Drawing mental maps Apprenticeships Social interaction and mentoring Story-telling and metaphors Converting some elements of it into explicit knowledge

*Table 2 Mechanism for generating and sharing explicit and tacit knowledge (Goffin et.al. 2010)*

while Chennanmaneni et.al (2011) present mechanisms to transfer tacit knowledge between people.

Low degree of tacitness	Medium degree of tacitness	High degree of tacitness
Expert system and Case Based Systems Neutral Networks Brainstorming Structured expert interviews Protocol Analysis Lessons learned Best Practices	Metaphors and story-telling Analogies Concept – and process mapping Repertory grid Fishbone Prototype Brainstorming Apprenticeship Mentoring	Observation Apprenticeship Mentoring

*Table 3 Mechanism to transfer tacit knowledge (Chennanmaneni et.al ,2011)*

Treating knowledge as if it is synonymous with information is common in many organizations. This matter makes many organizations ignore the tacit dimension, even if tacit knowledge is one of the most critical recourses and competitive advantages when managing tacit knowledge in the company (Goffin et al., 2010).



### 3.5 Communication

The following section present and introduce theory mainly used in the chapter Communication in the analysis.

#### 3.5.1 Patterns of communication

Transferring information and interaction between people in projects, departments or functions are elements that impacts the duration of time in product development. Weelwright and Clark (1992) describe communication patterns between groups in four dimensions, see figure 13;

*Richness of media:* the ability of the medium to communicate and transfer a message. A medium can be documents or computer network which has a sparse level of transferring messages while face-to-face interaction have a rich ability to transfer massagers.

*Frequency:* the frequency of the information batches between groups. One batch communication is a low frequency while piece-by-piece is high frequency communication.

*Direction:* one-way or two-way direction of communication where one-way is a monologue while two-way is a dialogue between people.

*Timing:* the time during the project information is shared. The timing can be late or early, with late is the work is completed when sending the information forward or early when sending preliminary information during the entire project.

In the best of worlds the information is shared face-to-face, frequently piece-by-piece, in a two-way direction early in the process. In what level the organization or project team makes these choices influence the cross-functional integration in the project (Weelwright and Clark, 1992).

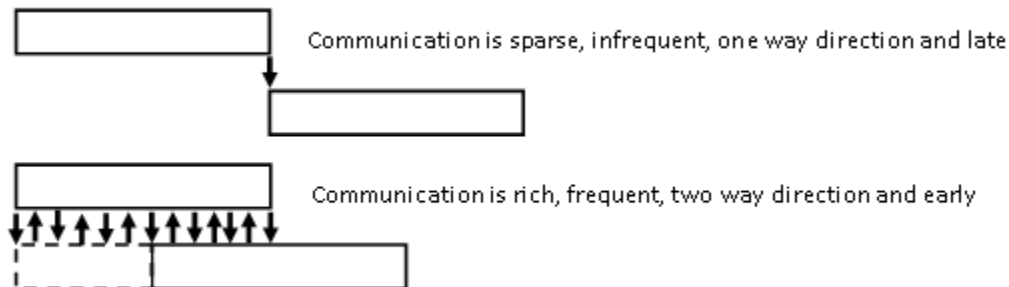


Figure 8 shows pattern of communication and interaction (Wheelright and Clark, 1992)

Smith and Reinertsen (1991) states that it is important to overlap the transfer of the information between activities in small batches but also that the communication must be in a two-way direction to provide feedback and to get the possibility to ask question about the information. Communication face-to-face is affected by several factors. The interpretation of the receiver is affected by feelings, attitudes, experiences, knowledge and personalities. That makes the use of feedback communication essential to manage to communicate and reach an understanding that comes close to the interpretation of the sender. (Maltén, 1992) Verbal communication face-to-face has the benefit of direct response. Body-language adds a dimension of communication that cannot be communicated in writing. Smith and Reinertsen (1991) describe the importance of regular, preferably daily, team meetings to share information but they should be short and informal. The daily meetings can be an important factor for the team members start to thinking about making daily progress in the project. Co-location of members in the project is also one factor that simplifies communication during product development.

Working in projects the informal communication can be beneficial and useful (Smith and Reinertsen, 1991). But looking upon the organization as a whole the informal communication is non-beneficial and should be hindered and formal arenas for communication is important. According to Vuuren and Elving (2008) the informal communication in the organization “threats, destroys or disturbs all kinds of formal communication

### **3.5.2 Barriers**

There are different barriers for integration and communication in product development for example language, status between department or functions, culture, geographical distance and time pressure. Traditionally when refers to language barriers it is when people do not communicate in their native language but it could also be differences between language in different functions or departments in an organization depending on education and vocabulary used at daily work. As culture differences can also be divided in two aspects according to different countries, different functions in the organization or different organizations (Trygg, 1992).

### **3.5.3 Visual communication**

An approach to visual communication is to use visual panning. According to Olausson and Bergren (2010) a planning approach including an interactive visual communication in public arenas, facilitate rapid interaction, problem discovery, shared understanding, and cross-functional decision making. Visual communication and visual planning are concepts that have its origin in the concept of Lean (Parry and Turner, 2006). The visual planning makes *communication* possible through face-to-face interaction between team members and through the visualization of information on a board (Lindlöf and Söderberg, 2011). They also state that combination of frequent meetings and the visualized overview provides an ability to *coordinate* the tasks in the project. One of the principles in this way of working is that the frequent meetings keep short and that if further discussion is needed, these will be discussed with the people concerned.

Sebestyén (2006) describe visual communication as a concept supporting interaction and team work in projects. The face-to-face interaction, the visualization of information and the team work during the meeting, facilitate communication, but also a shared understanding and a shared point of view of the project. By visualizing information it becomes concrete communication and the team members can see what is communicated (Sebestyén, 2006). The gain with visual approach in planning on boards is according to a study by Lindlöf and Söderberg, (2011) that the communication is build up on real time information. There is a belief in that the analogue and visible format of the method make it easier for the members of the project to talk and listen more actively to each other during the meetings. The difficulties with using the method is when teams are scattered over multiple sites, how to tracking all links between the activities discussed on the board and how to saving the data related to the progress of the project.

*In Chapter 3 the theory used in this master thesis was presented. The sections including technology development, product development, project management, operations strategy, organizational culture, organizational learning , knowledge management and communication has been useful for the analysis of the thesis, while the sections about technology maturity, continuous improvement, knowledge management and communication has been useful for the recommendations.*

## 4 Empirical Data

*The chapter describes how the data was collected by going through lessons learned-documents; performing interviews and having interviewees answer questions in a questionnaire. Further how the data was sorted, weighted by impact relevancy on the projects in terms of time delay, reduced into a manageable form and presented in main-areas.*

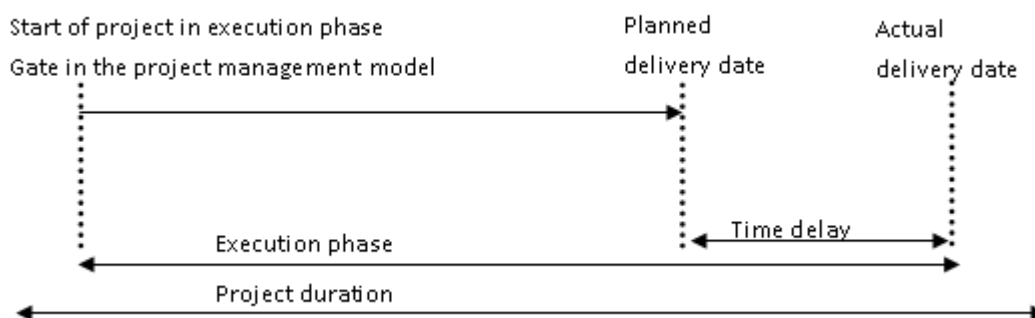
### 4.1 Foreword to presentation of empirical data

In the coming chapter the empirical data findings will be presented. What the authors think need to be said as foreword for this section is that since the study has focused on the factors behind time delay in the projects, only the issues that have been of negative nature in terms of time for the projects are presented in the empirical findings. In reality the lessons learned and final reports have usually contained an equal amount of negative and positive aspects from the projects. Therefore the findings from the projects in this report may seem more negative when taken out of its context compared with if the full context is viewed. No matter where on the continuous improvement ladder an organization is, there will always be things that can be improved. According to the writers it is more likely that an organization that has come further in its work of improvement also captures more issues with potential to improve compared to another organization.

### 4.2 Definition of project time delay

To define project time delay was not an obvious task at the beginning. It was realized that the projects were often re-planned at a later stage in the project. As one of the persons said when discussing this matter was: "Re-planning is often done in a later stage of the project for mainly two reasons. One is that due to the scope has been changed in a way that planning and budget needs to be updated. The other is that if a project has suffered from time delays, due to tightly set time plans, it is very hard for the project to catch up in time and then it is out of a human perspective better to re-plan the project so that it is not running on "red numbers" all the time". This might be similar to achievement as motivator in Herzberg's Motivation-Hygiene Needs Theory (Shani et. al., 2009).

The definition used in this study to decide whether the projects were delayed or not was stated as; the divergence between the planned project delivery dates at the start of the execution phase, in the project management model used in the project, compared to the actual project delivery date. If there was more than one delivery date in the project during the execution phase, the last planned and the last actual dates were used to set the time delay.



*Figure 9 shows the definition of time delay used in the study*

### 4.3 General description

When first starting to collect data of the projects, a list was acquired from the financial department. The list contained projects that had run during the last three years. The list was reviewed with help of the thesis supervisor in the organization to find all the projects that matched the research criteria of hardware development projects. Twelve projects were found in

Project	Timedelay [%]
A	17,1
B	80,2
C	89,4
D	27,9
E	235,7
F	36,2
G	24,1
H	16,9
I	33,5
J	72,2
K	25,9
Average	59,9
Median	33,5

total. Of these twelve projects, eleven hardware development projects had suffered from time delay based on the comparison of planned and actual delivery dates.

As seen in Figure 10, project E can be considered an outlier in the sample. The main reason for why this project generated more delay in time compared with the other project was due to the project had a short time frame from the beginning and products were scooped in to the projects due to transition from one site to another globally. The project was still included in the study though since it was seen as an opportunity to catch further useful information about time delay in projects. Project H had three deliveries, where the project managed to deliver the first one but not the two last ones before the project was terminated.

*Figure 10 shows the eleven hardware development project found and their time delays in percent*

### 4.4 Data capture

By help of lessons learned and final reports available from the eleven projects issues were captured. This resulted in a raw database with 162 rated issues that caused time delays in projects in the organization. The following sub-chapters describe the data capture and its findings.

#### 4.4.1 Lessons learned

By going through the all available lessons learned and final reports all issues were captured in three different ways of turning and viewing the data from different angles. First by reading through all the issues and trying to understand by looking up facts such as meaning of abbreviations used, what sites were involved, stakeholders and purpose of project, how was the project setup etc. The detail level of information varied. In one case the detail-level of issues in the lessons learned document could be structured in three stages: *Define*, *Analyze* and *Improve*. A clear picture of the issues mentioned was presented. An example from this is:

*Define:* – Handover from other projects (project x)

*Analyze:* – We had not decided handover criteria  
– No support from the delivering project (closed too early)

*Improve:* – Clear handover objectives  
– Shared planning  
– Competence handover (not only deliverable) to the receiving project

In another case the lesson learn document consisted of a few words under a headline in a spreadsheet such as “Mech-skills” under headline “Competence” which gives opportunities to guess but hard to know for sure what was meant. For example it might be perceived as competence missing in the area of mechanics. Did it mean that there were not any resource(s) available or was it that the resource(s) were available but lacking necessary knowledge for the project? At this stage the questions had to wait to be answered until the interviews and for the help from the project manager who wrote the issue description to get a clearer picture of the meaning of it. In general most of the lessons learned documents had a standard where the issues were mentioned as a headline of few words which was then followed by a brief description consisting of from one to four sentences.

#### **4.4.2 Interviews**

The second angle of data capture was attained through the view of a perspective based on interviews. Interview structures were created consisting of short questions in the shape of keywords that were formulated based upon the findings from lessons learned and final reports (described in the previous section). The questions were written down on post-it notes and sorted under possible main-areas. Examples of headlines could be: *Management, Planning, Scope changes, Resources changes, Competence* etc.

The interview work will be further described in following sub-sections:

*Interview procedure, Levels and weighting of levels, Visual conclusion of interview results and Data transfer into digital form.*

##### ***Interview procedure***

The interviews were performed with the project managers or, as in two of the projects; where the project manager was no longer available within the organization, by persons that worked closely to the project manager. Before the interview the interviewees were prepared by an introduction and were sent the material that would be gone through during the interview for them to refresh their minds and to be able to bring additional material if any. The keyword notes were introduced to the interviewee by following the structure in the lessons learned or final reports. The persons were then asked to elaborate on the issue and to place it on a whiteboard and under a headline that they found suiting. The answers while elaborating around the issue were written down on post-its that were placed under the key issues notes. If the person did not find a suiting headline, a new one was created. The most important thing was to understand the perspective the interviewee addressed the problem, not under what headline the issue was placed. After placing all issues on the whiteboard the persons were asked to rank them in order relative to each other.

The positioning of issues resulted in different levels of degree of negative issue-impact on the projects. An example of this is presented in Figure 11 below.



Original Level	Weighted Level
1	1
2	
3	
4	
5	2
6	
7	
8	
9	3
10	
11	
12	
13	4
14	
15	
16	

*Figure 13 shows weighting of levels for comparison*

To enable a comparison between the projects' levels even if the projects from the beginning contained different numbers of levels a form of weighting was found necessary. This was done by creating four "weighted levels". An example of this is shown in Figure 13 where project H that contained fifteen ranked levels was weighted into four new levels. Since most projects as mentioned above contained more than four levels this generally meant a reduction of levels and with that a loss in resolution of information. Meaning for example that issues that in project H used to be at level 13 now became equally ranked with the issues that used to be at level 15 when the levels both became part of the new level 4.

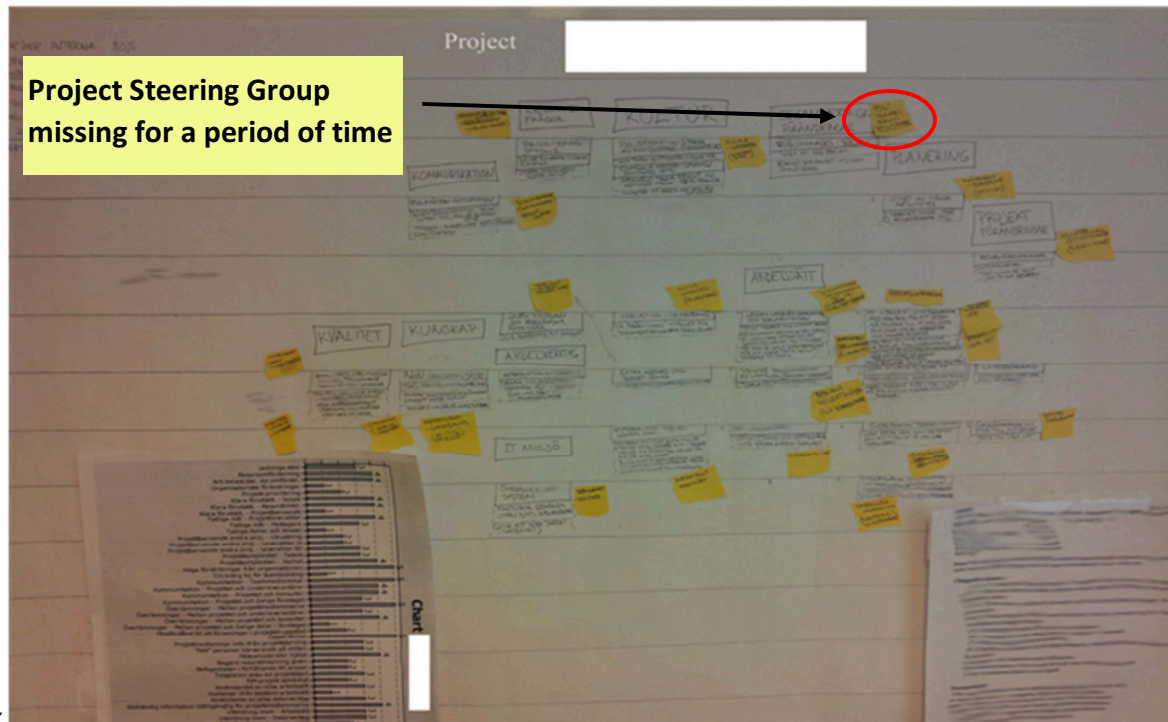
In the project (G), which was the only project containing less than four levels, there were only three issues in total which had been ranked at two different levels. To make the issues from these two levels fit into four new levels would have meant that an interpretation and estimation of their project impact would have to be done, which was thought to

subjectively have corrupted the data more than necessary. Instead the two levels were chosen to be kept at their original levels one and two.

The effect from this was considered marginal since the problem itself derived out of the fact that the issues were few, representing less than two percent of the total amount of issues. Other alternative solutions could have been either to reduce all the other projects' levels into two or to simply discard the project as whole. Both these options were considered to have meant to great a loss of valuable information.

### ***Visual conclusion of interview results***

The results from the whiteboards where then both photographed and written down on A1-sheets. All issues were then analyzed project by project and summarized into smaller notes, see examples (red markings) in Figure 14, with a key phrase or sentence describing the issue in a shorter format that both the authors agreed upon in consensus.



*Figure 14 shows yellow notes with key summary of the issues, reached in consensus*

### *Data transfer into digital form*

To make the concluded data from the interviews more easily accessible the data was transferred into a spreadsheet. The short descriptions from the notes were typed into a spreadsheet as issue-descriptions, together with project information such as level of negative project impact, project belonging and project delay etc. Each issue-description was sorted into identified main-areas of issues, which were divided in to sub-areas of issues. The area-groupings of issues were chosen with the aim to try and capture the core of the issues. The groupings were made by help of theory, lessons learned documents and understanding from the interviews. The main-areas of issues identified during work were; *Management, Technology Maturity, Way of working and Communication*. Filter-functions were applied to all columns of information to ease search, focus and comparison of the issues from different perspective, see Figure 15



							Main-areas =>	Management				1	
Type	Project delay [%]	Issues per project	Project	Original Level	Number of Levels	Weighted Level	Issue-description	Scope changes and resource redistribution	Overall planning	Project definition	Management Absence	3	
							Antal x	5	8	3	4	7	
							Rank =>	10	5	9	8		
							FILTI						2

The first column from the left told what project the issues concerned, the second column told at what level the issue was placed at by interviewee, the third column told how many level were presented in that project and the fourth column told what level the issue belonged to after weighting, the weighting procedure is described in detail in the next section.

The information in the fifth column contained a concluding issue description originating from the A1-sheets with project-conclusions as was shown in Figure 16. The issue-detail presented in the report had to be reduced, anonymously for publicity reasons and in accordance to signed non-disclosure agreements.

The example above showed that four different projects A, B, D and J were affected by issues concerning management absence. The issue was rated on the highest weighted level contributing to negative impact on projects in three cases A, B and D. Three of the issues appear to be of the same type of root-cause *Project Steering Group absence* this gave opportunity for further analysis. In the cases where more detail was found needed then the one presented in the spreadsheet, the authors went back to the A1-sheet project-conclusions and recorded interviews to complement.

#### **4.4.3 Questionnaire**

The third angle in the data capturing was performed by having the interviewees fill in a questionnaire at the end of the interview, with the project fresh in mind. The questionnaire was created after going through all the lessons learned, final reports, the initial literature study and by previous knowledge in the area. The different areas of problems, experienced in the projects, were put in one word on a post-it note until all material was covered and some extra notes with issues were added from literature study. The post-it notes were re-arranged in groups and on A1-sheet on the wall. An example of a board from the work procedure can be seen in Figure 17.

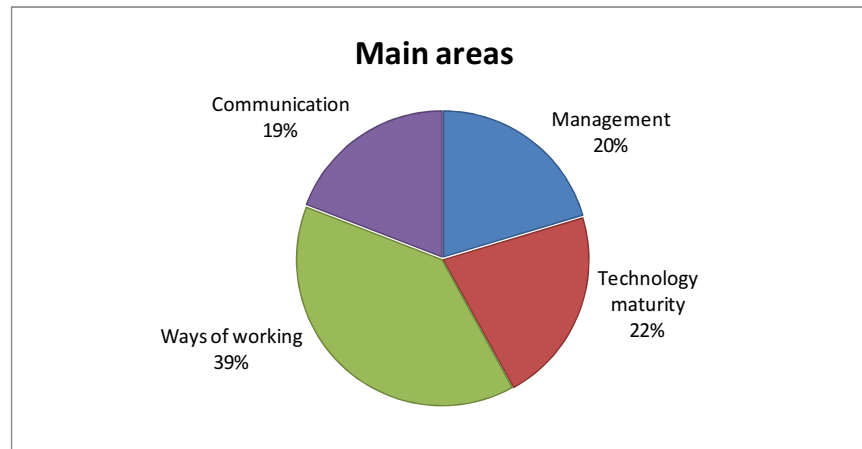


#### 4.5 Main-areas of findings

After reviewing the data, a total of 162 issues at four different levels of negative impact on projects were found. The issues were sorted into four main-areas of issue: *Management*, *Technology maturity*, *Ways of working* and *Communication*. Figure 18 shows a summary of the sorted issues, how the issues were presented over the four levels and also presented an average level value. The latter simply gave an indication about where the issues' center of mass lay in relation to the levels within each main-area. (Meaning that the closer the value was to 1, the more issues in the area were found at the top levels of impact on the projects)

	Management	Technology maturity	Ways of working	Communication
Issues per area	33	35	63	31
Total issues	162			
Number of issues in level 1	11	19	15	7
Number of issues in level 2	10	11	17	10
Number of issues in level 3	8	4	24	6
Number of issues in level 4	4	1	7	8
Average value level	2,15	1,63	2,37	2,48
Percentage of issues at level 1	33	54	24	23
Percentage of issues at level 2	30	31	27	32
Percentage of issues at level 3	24	11	38	19
Percentage of issues at level 4	13	4	11	26

**Figure 18 shows total issues experienced and the main-areas of issue including defined number of issues.**



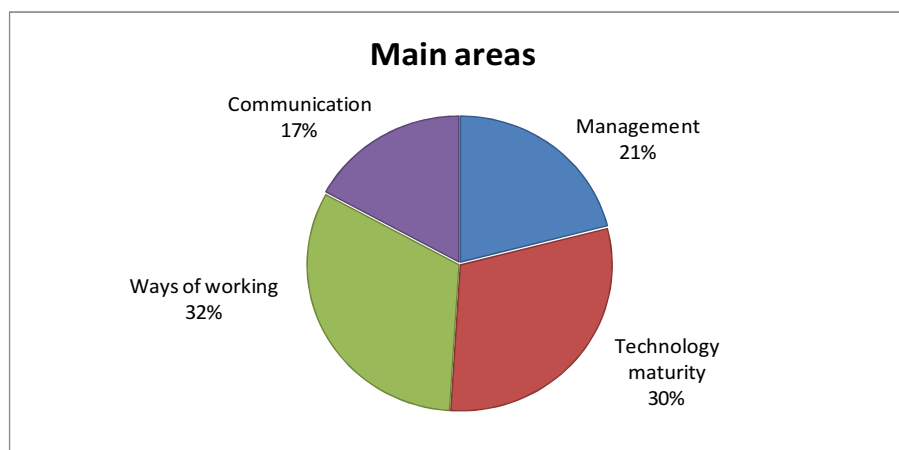
The issues found in the projects, presented in the defined four main-areas of issue; *Management*, *Technology maturity*, *Ways of working* and *Communication* before data reduction. The spread in percent is shown in Figure 19.

**Figure 19 shows how the distribution of the issues in the main-areas defined before data reduction**

To be able to manage the data and focus on the greatest contributors of time delay in the projects, the amount of issues were reduced to focus only on the upper two levels of the four levels in total. After the data reduction the amount of total issues was 100. The data spread is presented Figure 20 and Figure 21.

	Management	Technology maturity	Ways of working	Communication
Issues per area	21	30	32	17
Total issues	100			
Number of issues in level 1	11	19	15	7
Number of issues in level 2	10	11	17	10
Average value level	1,48	1,37	1,53	1,59
Percentage of issues at level 1	52	63	47	41
Percentage of issues at level 2	48	37	53	59

**Figure 20 shows total issues experienced and the main-areas of issue including defined number of issues after reduction**



The issues in the projects, presented in the defined four main-areas: *Management, Technology maturity, Ways of working and Communication*, after data reduction. The spread in percent is shown in Figure 21

**Figure 21 shows how the distribution of the issues in the main-areas defined after data reduction**

## 4.6 Technology maturity

In this section empirical findings are presented that are found related to *technology maturity*. This context is referring to a main-area in which the projects have gained further knowledge, development or preparations related to technology. Seen from a technology maturity perspective, all eleven projects managed to deliver what was decided upon at the start of the projects, except for one project (H) that managed a partial delivery before the project was terminated. Seven of eleven projects perceived technology complexity high or very high in the projects according to the questionnaire (Appendix 9). As one of the project managers stated “We are building the airplane at the same time as we are flying it”.

In ten of eleven projects, all but B (Appendix 10), have experienced issues related to the main-area of issue referred as technology maturity. The issues have been divided into the sub-areas of issues; *Supplier*, *Uncertainty in Planning, Quality & Risk-management* and *Resources*, see Figure 22.

	Technology maturity		
	Supplier	Resources	Uncertainty in Planning, Quality & Riskmanagement
Total issues	7	3	20
Number of issues in level 1	6		13
Number of issues in level 2	1	3	7
Average value level	1,14	2,00	1,35
Percentage of issues at level 1	86		65
Percentage of issues at level 2	14	100	35

Figure 22 shows how the main-area Technology Maturity is divided into three different sub-areas

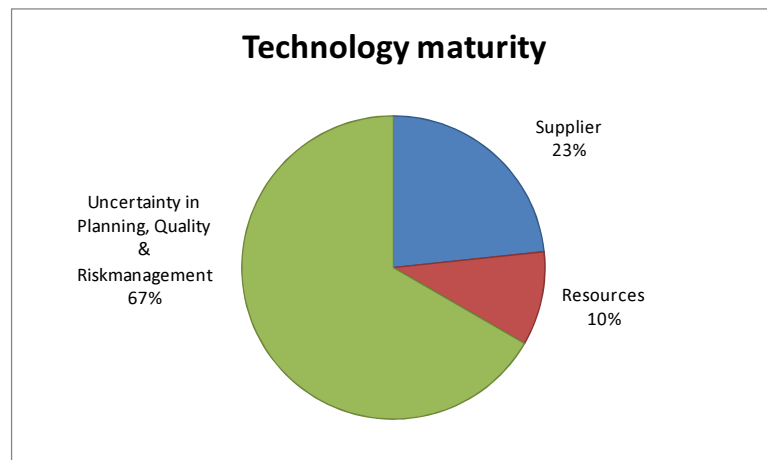


Figure 23 shows how the main-area Technology maturity's sub-areas and spread of the issues in percentage in each sub-area

Figure 23 shows how the issues are divided into sub-areas and the spread in percent in the main-area *Technology Maturity*. The sub-areas have then in the empirical findings been complemented with further information from the questionnaires and quotations from interviews in the cases where there have been matters of significance related to them.

### 4.6.1 Supplier

According to the findings, seven of the eleven projects (B, D, E, G, H, J and K), have in a high or very high degree been dependent of the project suppliers' knowledge and processes (Appendix 11). In five cases (B, D, H, J and K) the projects state that they have, from a moderate to a very high degree, overestimated the suppliers' ability to deliver according to specification (Appendix 12). The issues addressed in the interviews have affected five projects (D, G, H, J and K) negatively (Appendix 13). The reasons for the issues were seen related to the technological maturity of the suppliers' processes components, processes or knowledge levels have not been up to the standards that the projects have requested from them at the start of the projects'

execution phase. The competence assurance is realized to be nothing of a straightforward task since the projects in some cases asked the suppliers to deliver something that had not been done before and where there sometimes were very few suppliers to choose from globally with the capacity to develop their processes to the requested levels. What may narrow down the options was that the suppliers had to be approved by the organization, which included fulfilment of criteria as for instance financial track records and ability to meet financial claims linked with breach of contract etc (Appendix 13). As one project manager who expressed the possibility to choose from suppliers with the following metaphor “We could choose any car model we liked in the world – As long as we chose a Volvo or a Saab”. What was also mentioned as a thought on what further complicated the finding of suppliers capable of meeting project requirements was as one interviewee expressed it “The suppliers are salesmen and as such they will rather say that -“Yes, we can deliver”, even if their components or processes at that moment were not fulfilling the project requirements, before risk losing the possibility to sign a contract of great importance for them”. Overestimation of supplier process capabilities has resulted in longer development times and more iterations than first expected in project D, G, H, J and K.

In all projects, except H, that had two project deliveries terminated in the end, the cooperation between project and suppliers led to an advance in supplier components, processes and knowledge to the extent that the projects managed to achieve their delivery targets in the end. But the difficulties are shown to be amongst the most important factors that in a great extent have had negative impact on five of the studied projects (B, D, H, J and K) (Appendix 12).

#### **4.6.2 Resources**

A problem that has appeared amongst the issues related with technology maturity is lack of resources and dependence on key-resources. The problem is not widespread but is experienced at the second highest level of negative impact in two projects F and H (Appendix 14). The lack of technical resources was shown in two aspects:

One was that the key-resources became bottlenecks in the organization where they were needed at in many activities at the same time in the organization and therefore were a limiting factor for the projects (project F). The second aspect was a perceived lack of a special resource expertise in the pre-study that would have helped to better define the project requirements needed for the project and to better estimate level of difficulty of some of the activities in the project planning (project H).

#### **4.6.3 Uncertainty in Planning, Quality & Risk management**

Regardless of level of technology maturity in the projects, eight (C, D, F, G, H, I, J and K) of the eleven projects in the study perceived the time plan to be tight or very tight at the start of the project execution phase (Appendix 15). This means that there is not much or any room for errors or miscalculations in the time plan. In nine of the projects it is stated that the projects are affected negatively due to uncertainties in planning that would have been improved with a more extensive pre-study (Appendix 16).

While planning it has shown that seven of the projects (A, C, D, F, H, I and J) experienced difficulties due to uncertainty in technical knowledge in the planning stage (Appendix 17). The findings are that it is perceived hard to define work packages and to know what to do on a detailed level. This has brought difficulties in estimation of how much time that was needed within each activity, how many and what type of resources that were needed to perform the

activity. In these projects the lack of needed knowledge in the planning has led to an underestimation in expenditure of time. Two cases, project H and I (Appendix 17), show where the expenditure of time were planned to be the same for the activities connected with new technology as with previous known activities, which have shown not to be the case and therefore caused project delays. “We had known cycle times that we based the planning upon but they showed not to be valid in the extent that we had expected”. Further, such negative impacts on projects deriving from uncertainty in technology has in three of the projects (A, C and F) led to affected evaluation or verification activities within the projects that led to increased workload later on (Appendix 18). One scenario experienced in project E where the planning and synchronization of phase-in and phase-out of products in that project had impact by postponing delivery, which led to a weakened business case in the end (Appendix 19).

The technology maturity level was also perceived to affect two projects I and K (Appendix 20) in the areas of quality that led to delays in time. One of the reasons is not verified ways of working that has given both direct and indirect quality issues. Whereas in the latter case means quality issues from variation and great quality spread (project K). In the former case, difficulties in planning have led to delays and less time spent on quality assuring tests before production. Another reason has been due to difficulties to present clear and detailed project specification requirements towards both internal and external suppliers. For project I the lack of well-defined requirements meant that input deliveries arrived outside the quality tolerance standards needed for the project to in its turn be able to deliver in terms of quality in the end. Another aspect mentioned during the interviews was “The lack of detail makes it harder to communicate formally” In the context this meant both towards suppliers, between organization sites globally as well as between functions within the organization.

Five projects D, F, H, I and J bring up issues related to risk management that have affected the projects in terms of time delays, which they say could have been reduced by more extensive pre-studies (Appendix 21). One of the cases (project D) states that the project would have gained to a high degree if further prototype tests had been performed in an early stage of the project to reduce uncertainty and risks linked to the technical design. It is not perceived easy to manage risks in terms of assessment, evaluation and to work proactively with risk mitigation. As one of the project states “We are good in assessing where the risks are but not as good to come up with detailed plans on how to mitigate these risks”. Another aspect of pre-study knowledge and risk assessment is that it also can be seen linked to the type of project setup chosen for the project. In one case (project H) the project setup is out of a technological competence perspective questioned since the project was set up including parts that are usually outsourced, which was stated to have a big impact on the project outcome in terms of both time delay and project results.



## 4.7 Management

In this chapter the issues are placed that are seen by the authors to be linked with management issues such as *Scope-changes and Resource re-distribution*, *Overall planning*, *Project definition* and *Management absence*. The number of issues under each sub-area is divided as shown in Figure 24. By management issues in this context it is here referred to management on a higher level and mainly external of the project.

	Management			
	Scopechanges and Resource re-distribution	Overall planning	Project definition	Management absence
Total issues	5	8	3	4
Number of issues in level 1	1	4	3	3
Number of issues in level 2	4	4		1
Average value level	1,80	1,50	1,00	1,25
Percentage of issues at level 1	20	50	100	75
Percentage of issues at level 2	80	50		25

Figure 24 shows how the main area Management is divided into four different sub-areas

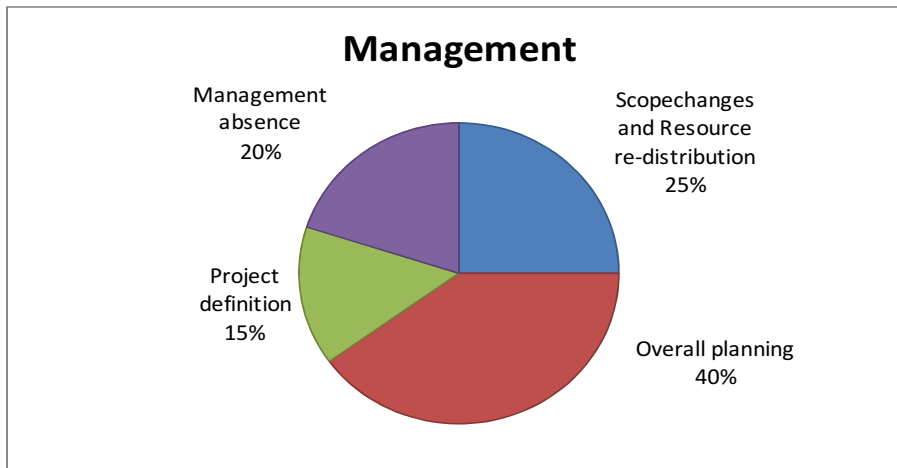


Figure 25 shows the main-area Management issue's sub-areas and spread of the issues in percentage in each sub-area

Figure 25 shows how the issues are divided in to sub-areas and their spread in percent. The sub-areas have then in the empirical findings been complemented with further information from the questionnaires and quotations from interviews in the cases where there have been

matters of significance related to them.

### 4.7.1 Scope changes and Resource re-distribution

Change in project scope is something that has been seen during the interviews in the study. The extent of project change size varies in degree and type and do not always cause negative impact on the projects. Issues linked with these changes are mentioned in two projects B and J (Appendix 1) where the changes are stated to have caused problems for the projects to keep up with the time plan. In project B work packages and activities were replaced with others at more than one moment, and sometimes changes could mean canceling or adding of new activities to the already planned ones. In project J the added activities were related to quality improvement work where quality issues related to products needed to be addressed by the organization. Since there were no resources free available that could handle these matters this led to place the work into ongoing projects. While it in project B was said that the scope changes were connected with the prioritization of simultaneously ongoing projects and the struggle for resources.

Nine of the eleven projects have stated that they were given the resources requested by the project in from a moderate to a high degree while two projects, B and J, were less satisfied with

the resource allocation (Appendix 2). Re-distribution and sharing of resources are issues that were stated to have had great negative impact on the project plan in three projects B, D and H (Appendix 3). It is stated to be connected with if the project has been setup correctly in the beginning, the prioritizing of simultaneously running projects, and the resources available in the near organization. Five projects B, E, F, H and J state that resource re-distribution has affected the project negatively in a high to a very high degree (Appendix 4). When it comes to sharing of resources one of the projects states that "Sharing of resources means loss of total efficiency" and can be graphically expressed by the formula:  $20\% + 30\% + 50\% < 100\%$  in terms of resource sharing versus resource efficiency.

#### **4.7.2 Overall planning**

By overall planning the authors refer to planning taken place outside the single project rather than within. This planning is often performed at a higher level in the organization hierarchy of management and includes synchronization of projects towards each other. The issues mentioned here derive mainly from such or similar activities that have showed to have negative impact on the individual projects. Eight issues are stated to have been present in six of the eleven projects A, C, D, F, G and H (Appendix 5). The main problem, five of the eight issues, has been due to the lack of synchronization between projects. This has resulted in difficulties due to dependency of other projects' receiving or deliveries in project, lack of or re-distribution of resources in project or lack of equipment in projects B, C, E and G. One thing mentioned during one of the interviews was that "There has been optimism when planning the start of many activities at the same time" which in the end resulted in lack of resources.

#### **4.7.3 Project definition**

How the project has been defined in the beginning is something that three projects E, H and I have said to have affected the outcome of the projects at the highest degree in terms of time delay (Appendix 6). What the projects refer to is that they would have gained from and experienced fewer issues if the chosen definition would have looked different from how they now were setup. In one of the cases (project E) the setup was questioned due to that the project was a transition project that was carried out in two steps instead of one, which led to an extra step of resources needing to catch-up with progress since there were new resources involved in each step. Another case (project H) states the project should have been divided to include a separate pre-study project preceding the main project since the project as it now was included activities in areas that the organization had not dealt with in-house since a long time. The third case (project I) talks about a mismatch in the definition where "The project would have gained from if the definition had been of system character". Which referred to a system definition and wider way of approaching the development work instead of the chosen sub-system definition that included one setup in the organization and another setup by the customer, with whom the organization worked closely together to deliver an end product.

#### **4.7.4 Management absence**

All the studied projects but three A, F and J that are slightly lower, perceive that they have had a moderate to a high degree of support by management during the project (Appendix 7). The issue that is stated to have affected four of the eleven projects A, B, D and J on the highest levels of impact on project is the absence of management (Appendix 8). In three of these cases this was due to the lack of a project steering group during a time in the projects. The absence of steering group was caused by a re-organization and the effects from not having this group in place were experienced by less clear decision making and unbalance in the decisions made which made

planning more difficult and changes harder to predict. It was stated that decisions were not efficiently made during this time which continued even after once a new steering group was formed and in position, since the roles of this group were new and the persons were perceived to be afraid to make the wrong decisions. As one of the project managers stated “It is important that people in the organization step up and are not afraid of taking responsibility when problems or potential problems occur”. The wish for faster response to warnings was supported by another project that stated to have suffered from quality problems leading to time delay in the project due to the absence of a quality responsible manager. In this case the position of a line manager, who is responsible of quality assurance within the line, was not filled.

#### 4.8 Ways of working

Ways of working is a wide range of main- area including connection to three different sub-areas. All the eleven projects in the study have expressed that their performance in terms of time has in some way been affected by factors connected to way of working. Thirty-three percent of the hundred issues collected are in some way linked to this main-area. In an attempt to achieve more clarity, the authors have divided it under following sub-areas, *Documentation*, *Work processes* and *Handovers*, see Figure 26 and Figure 27

	Ways of working		
	Documentation	Work processes	Handovers
Total issues	7	20	6
Number of issues in level 1	1	12	2
Number of issues in level 2	6	8	4
Average value level	1,86	1,40	1,67
Percentage of issues at level 1	14	60	33
Percentage of issues at level 2	86	40	67

Figure 26 shows how the main-area Ways of working is divided into three different sub-areas

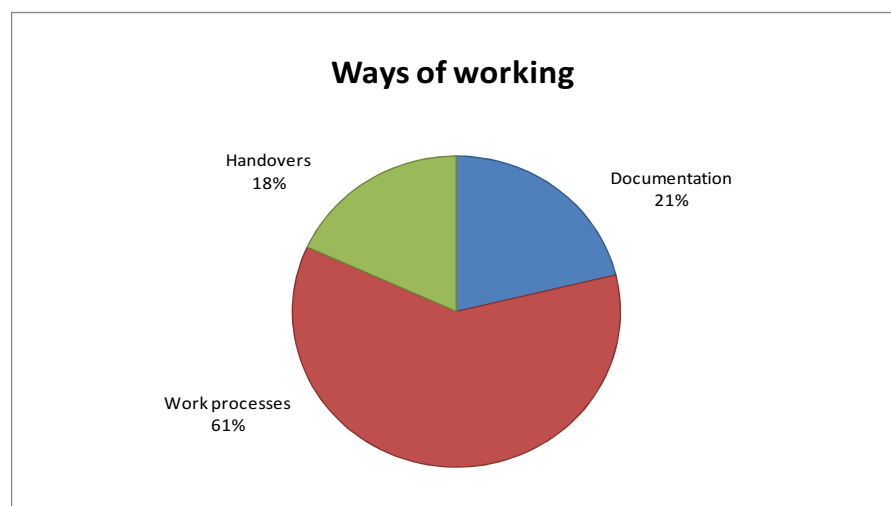


Figure 27 shows the main-area Ways of working's sub-areas and spread of the issues in percentage in each sub-area

#### **4.8.1 Documentation**

Documentation is defined in this study as data or information in a document or information system such as trouble reports and other project related data used to secure the product development. Five projects A, B, C, H and I (Appendix 22) stated that information or data in documents or in the information system needed in the project were sometime inconsistent or missing, which caused delays.

In project (C, I) the lack of some information or data in documents and information system required input information prior to the project and during ongoing (A, B, C, H) projects.

A variation is shown when writing trouble reports and different cultures are reflected in different departments. In some departments, trouble reports is looked upon as unnecessary and time consuming, which cause inconsistency between departments. Difficulties are caused when the information needs to be used in other sites or department in the organization. In project (C) the issue was related to the classification and coordination of the data in the system. This caused uncertainty around severity for the trouble reports or uncertainty about who is responsible for solving the trouble report in the project or organization. In project (I) specific information known in the organization was not stored in the information system and was not attached to the product as a trouble report. Project A stated the need of detailed data in trouble reports regarding other parts in the system that could be affected by changes. This would have made it possible to do suitable testing. All the above mentioned issues are stated as causes for time delay. Project C stated that documents used for input, prior to a project, needed to be more detailed. One of the interviewee stated "the ... department has the culture to think that administration is time-consuming and sometime unnecessary, but today when we work multi-site, it is even more important than before to formalize the information and data handling in the projects". Delays were caused in project H by documentation for a new component not known prior to the project. The documentation was in this case requested caused of a changed component in the project. Lack of documentation of certain decision taken during project B had a negative impact in time on the project. Project A stated that lack of documentation and control of configuration management had negative effect on the time schedule for the project. Variation of documentation in the handling of releases and the way of working with this matter were an issue for cause of delay in the project

#### **4.8.2 Work processes**

Seven of the projects (A, C, D, E, F, G, and H) in the study have experience of time delays related to work processes within the organization.

In project G and A it was related to work processes and documentation. The project manager in project G stated that the requirements on the component were dependent on the experience level of the designer, as one issue for time delay in this project. The project leader also stated that a requirement-specification for the supplier had been useful. The lack of a document with these requirements caused issues and made the work for the supplier more complicated according to the project leader. In project A the lack of documentation and coordination for the use of the prototype were causing delays. Routines lacked for knowing where the prototypes were held at times and a schedule for the use of the prototypes were not used. (Appendix 23)

Issues in project A, C, D, E and F related due to work processes. In project A the test results were affected by different brands on test equipment and software at the various sites. This resulted in difficulties to compare test results from different sites and caused frustration and time delay in the project according to the project leader. In this project (A) the quality of the test equipment

did also create an issue. It did not give correct results which caused time delay in the project. The project manager stated "After working a month we realized that it was not any problem with the product, the test equipment was the problem". In project C and D the review process of documents and drawings to avoid re-spins of the prototypes, had been a problem and not efficient enough. In project (C) it has been stated that people came unprepared to the meetings which led to time being underused. Hence unnecessary re-spins occurred. In one of the projects it was stated the importance of right attendance to make the meeting more efficient. Project H got technical problems due to the routine when evaluating new suppliers. The already approved suppliers did not meet the technical product requirement, and new supplier did not meet the company's supplier evaluation criteria. This matter caused delays in the project. (Appendix 24)

The re-spin problem, occurred in project D, was caused by low quality on components from a supplier. Information about poor quality was withheld and appeared late in the process. Project F was affected by a change in a standard, which resulted in rework of the product. This resulted in a time delay for the project. Lack of knowledge within the organization while developing a new product family from another company, resulted in a high risk time plan for a project (F). In project E the lack of documented trouble reports on a product inherited from another company, resulted in un expected work which delayed the project. Project A also stated that there was no time in the schedule for trouble report corrections.

Time-delays due to human-factors could be seen the study. In project C an issue occurred due to incorrect use of software tool which resulted in an error caused time delay. A second problem occurred in project C which was related to human mistake, which caused an unexpected re-spin of the product. (Appendix 25)

#### **4.8.3 Handovers**

The matter of handovers has had a negative impact on four projects; A, C, D, E. (Appendix 26) The handover issues, experienced in the study, have been linked to handovers of documentation and resources: from one project to another; from one site to another; and through introduction of new human resources within the project. In two projects (A and C) one of the contributors of negative impact has been the lack of handover support in the form of available resources. In these cases the projects have had deliveries from other projects already closed down or where the human resources with valuable knowledge have been assigned to new projects. No time was available to support the receiving project. Project D had experience of changes of people in the team but also changes of responsibility and roles were time consuming for the project.

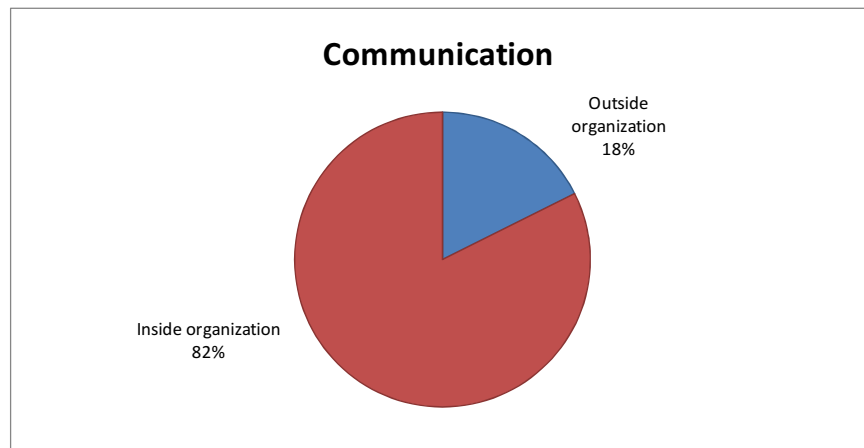
In project E the lack of handover support was related to the close down of a site. In one of the projects (C), it was also stated that they were affected by lack of handover documentation and by criteria on how the handover should be carried out. This matter caused time delay in the project.

## 4.9 Communication

The chapter presents findings related with communication issues in the sub-areas outside and inside organization. Figure 28 and Figure 29 shows how the issues at the two highest levels are divided in sub-areas and their spread in percentage relative to each other. Inside Organization includes issues related to culture in the organization.

	Communication	
	Outside Organization	Inside Organization
Total issues	3	14
Number of issues in level 1	1	5
Number of issues in level 2	2	9
Average value level	1,67	1,64
Percentage of issues at level 1	33	36
Percentage of issues at level 2	67	64

*Figure 28 shows how the main-area Communication is divided into two different sub-areas*



*Figure 29 shows the main-area Communication's sub-areas and spread of the issues in percentage in each sub-area*

### 4.9.1 Outside organization

Communication with supplier was stated in two projects (D and H) as one reason for the time delay. The communication outside the organization was described in these projects as more critical than the communication inside the organization because of lack of transparency in the communication and misunderstanding. One of the interviewee declared "Even if we had weekly meetings with the supplier, we realized late their status according to the requirements in the specification". Another project manager stated "We thought it was enough information within the specification with the tolerances required and that we had been clear enough in the verbal communication about the requirements, but when the prototypes arrived the quality was deficient". These two matters had big negative impact on the projects time schedule according to the interviewees. (Appendix 27)

#### **4.9.2 Inside Organization**

Six of the projects (A, B, C, H, I and K) brought up issues related to inside communication that had a negative impact on the projects and reason for time delay (Appendix 28). In three of the projects (A, C, K) the two-way communication and integration between the functions and departments in the project were stated as a problem. It is a need to improve this according to the interviewee. One of the project leaders (A) stated that the project would have gained if formal cross—functional meetings had been planned between the different functions in the project. In the other two cases (C, K) it was stated that if the communication between the functions and departments were improved, this could boost the result of delivering in time in the project. One interviewee stated that “Even if I thought I had been clear with the information during meetings and in documentation, the ones responsible for the issue concerned had not given any indications about delays in their job or misunderstandings.” It was also stated that one of the projects (B) were influenced by rumors inside the organization. Before the matter was sorted out it was experienced as a reason for uncertainty in the project, which in the end affected the project by unnecessary delay. Understanding each other’s profession between the departments was stated in project H as an issue related to communication; “people have sometimes no understanding of each other’s work and position and therefore is it hard to understand important issues for the other part.”

Two projects, C and H, perceived that misunderstandings in communication to a high degree caused negative impact on the projects according to time. (Appendix 29)

Three of the projects B, D and I mentioned issues that they have seen connected to culture within the organization. Mentioned issues were informal ways of communication in the organization, in documentation and in the way of working. In project B it was stated that decisions were taken outside the formal channels. These decisions affected the project essentially when rumors were spreading that the project would be shut down which caused delays according to the project manager. Project I stated the importance of working in structured ways to enable efficient communication between sites, which had been one issue in the project. It was also mentioned that the formality of documentation are sometimes perceived to be unnecessary inside the organization. In project D and B mentioned a culture of “Praising heroes” where problems were solved with immediate problem solving through “fire fighting”. These were issues in the projects according to the interviewees. (Appendix 30)

#### 4.10 Ranking of sub-areas

In an attempt to organize the data findings to present an overall view of how the sub-areas and their respective issues relate to each other, in terms of frequency of appearance and of project impact, a way of ranking was introduced. The ranking was therefore based on the amount of issues occurring in each sub-area together with the *average value* which, as previously mentioned in section 4.5, shows where the average-point of issues lies within the two levels. For example the closer the *average value* of a sub-area is to 1, the more issues rated at the highest level of negative project impact in terms of time where presented in that sub-area and vice versa. For the amount of issues within each sub-area to be taken into consideration in the ranking an *importance value* was calculated. This was done by dividing the total number of issues in each sub-area through its respective *average value*. For instance, by dividing the number of 3 issues in the sub-area *Outside organization*, see Figure 30, by its *average value* of 1.67 an *importance value* of 1.80 was given.

	Communication	
	Outside organization	Inside organization
Total issues	3	14
Average value level	1,67	1,64
Importance value	1,80	8,52
Ranking number	11	3

**Figure 30 shows the amount of issues, average value, importance value and rank of the two sub areas Outside- and Inside organization, under main-area Communication**

The *importance value* of each sub-area, ranging from 1.50 as lowest to 14.81 as highest, was put side by side to those of the other sub-areas to determine the overall ranking.

A presentation of the overall ranking can be seen in Figure 31 below. In the example above, *Outside organization* was ranked as number eleven of a total of twelve sub-areas.

The figure above also demonstrates how the amount of total issues in each sub-area affects the *importance value* and furthermore the sub-area ranking, in the case where only consideration of the *average value* would have given about the same importance and rank to both sub-areas.



	Technology maturity	Ways of working	Communication
	Uncertainty in Planning, Quality & Riskmanagement	Work processes	Inside Organization
Total issues	20	20	14
Number of issues in level 1	13	12	5
Number of issues in level 2	7	8	9
Average value level	1,35	1,40	1,64
Percentage of issues at level 1	65	60	36
Percentage of issues at level 2	35	40	64
<b>Ranking number</b>	<b>1</b>	<b>2</b>	<b>3</b>

	Technology maturity	Management	Ways of working
	Supplier	Overall planning	Documentation
Total issues	7	8	7
Number of issues in level 1	6	4	1
Number of issues in level 2	1	4	6
Average value level	1,14	1,50	1,86
Percentage of issues at level 1	86	50	14
Percentage of issues at level 2	14	50	86
<b>Ranking number</b>	<b>4</b>	<b>5</b>	<b>6</b>

	Ways of working	Management	Management
	Handovers	Management absence	Project definition
Total issues	6	4	3
Number of issues in level 1	2	3	3
Number of issues in level 2	4	1	
Average value level	1,67	1,25	1,00
Percentage of issues at level 1	33	75	100
Percentage of issues at level 2	67	25	
<b>Ranking number</b>	<b>7</b>	<b>8</b>	<b>9</b>

	Management	Communication	Technology maturity
	Scopechanges and Resource re-distribution	Outside Organization	Resources
Total issues	5	3	3
Number of issues in level 1	1	1	
Number of issues in level 2	4	2	3
Average value level	1,80	1,67	2
Percentage of issues at level 1	20	33	
Percentage of issues at level 2	80	67	100
<b>Ranking number</b>	<b>10</b>	<b>11</b>	<b>12</b>

Figure 31 shows ranking number of all sub-areas and issues spread within each sub-area

#### 4.11 Summary

This section is a brief summary of the empirical data presented in chapter 4.

The main-area *Technology maturity* was divided into three different sub-areas; *Supplier*, *Uncertainty in Planning, Quality & Risk management* and *Recourses*.

In the sub-area of *Supplier* eight of the eleven projects stated to have been dependent of supplier knowledge and processes to a high or very high degree. In five cases the projects stated to have overestimated the suppliers' ability to deliver according to specification, from a moderate to a very high degree. It showed that sub-area *Uncertainty in Planning, Quality & Risk-management* not only caused the greatest negative impact on the projects in the main-area *Technology maturity* but it was also ranked as the first of all sub-areas of issues defined in the study (see Figure 31, section 4.10). The sub-area has affected eight of eleven projects in total. Of twenty issues related to the sub-area thirteen are on the highest level of negative impact. The issues relates to difficulties in planning such as underestimation of time expenditure, synchronization

of activities across functions and synchronization of phase-in and phase-out of products. The issues in the sub-area *Recourses* have been related to lack of recourses or dependence of key-recourses. The area is lowest ranked of the total twelve sub-areas in the study with all of its issues at the second level.

*Management* was one of the four main-areas defined and includes the sub-areas; *Scope-changes and Resource re-distribution*, *Overall planning*, *Project definition* and *Management absence*. *Changes* in the project scope and re-distribution of recourses were seen as issues during the interviews. Five of eleven projects experienced re-distribution of recourses as one issue that caused delay in high or very high degree in the projects. Two projects mentioned scope changes as cause of delays but only one of these projects ranked the issue at the highest level of negative impact. In the sub-area *Overall planning* issues were found related to lack of synchronization of recourses, equipment or dependency of other projects deliveries into the projects. In the area the issues were divided equally over the two levels of impact. The sub-area *Project definition* was seen to affect three of the projects at the highest level. In two of the three cases the issues were related to the project structure where the projects claimed would have gained from if the structure had been of more pre-study- or system character. Issues related to the sub-area *Management absence* concerned four of eleven projects and in three projects at the highest level of impact.

The main-area *Ways of working* was divided into three different sub-areas; *Documentation*, *Work processes* and *Handovers*. The sub-area *Documentation* showed to effect five projects with issues closely related to ways of working with necessary documents or trouble reports. The most re-occurring issues refer to lack of detail, quality of the information or content in the documents needed by projects and were in a few cases claimed missing or not updated in the information system. The sub-area *Work processes* was ranked as the second most important sub-area as contributor of negative impact on time in the study (see Figure 31, section 4.10). The sub-area affected seven of eleven projects in total where twelve of a total of twenty issues were found at the highest level. The most common problems were seen were dependent on the inconsistency in the work process or work practices causing delays in the project. Problems in the area also derived from quality issues inherited from previous projects and issues concerning status of technical equipment. In the sub-area *Handovers* issues were experienced related to lack of handover support, from one project to another or from one site to another in the form of human resources or documentation.

The main-area *Communication* contained sub-areas; *Outside organization* and *Inside organization*. Both sub-areas included issues that were said to be related to culture in the organization that affected the projects in terms of communication, documentation and way of working. *Inside Organization* was ranked third of the sub-areas that caused negative impact on the projects in terms of time (see Figure 31, section 4.10). The sub-area issues affected seven of eleven projects in total with five of the fourteen issues at the highest level of. The most re-occurring issues referred to difficulties in cross-functional communication and expressed needs for greater interactional activities between functions and better understanding of each other's requirements, while the issues included in the sub-area *Outside Organization* were related to difficulties and misunderstandings in the communication with suppliers and was lower ranked at eleventh place.

## 5 Analysis

The chapter presents the analysis of empirical data connected to the sub-areas included in the main-area; *Technological maturity*, *Management*, *Ways of working* and *Communication* be analysed and compared with the support of theories covered in the theoretical framework in chapter 3. The main findings will be presented in a short summary of key-sentences in Section 5.5

### 5.1 Technology Maturity

The issues linked with the main-area *Technological Maturity* makes about one third of the total issues experienced at the highest two levels in the study. Further sixty-three percent of the issues in this main-area are by the interviewees positioned at the top level of impact on project in terms of time delay. The issues in sub-area *Uncertainty in Planning, Quality & Risk-management* have caused the greatest negative impact in terms of time on the projects not only in the main-area *Technology maturity* but among all sub-areas defined in the study.

An overview of the mentioned sub-areas is shown in Figure 32.

	Technology maturity		
	Supplier	Uncertainty in Planning, Quality & Riskmanagement	Resources
Total issues	7	20	3
Average value level	1,14	1,35	2,00
Importance value	6,13	14,81	1,50
Ranking number	4	1	12

Figure 32 shows a sub-area overview with the importance value and overall ranking of respective sub-area of issue in terms of time delay

As general information regarding supplier and technology it can be said that the organization today works with suppliers on so called preferred supplier-lists where the supplier has to fulfil certain criteria such as financial and track-records to become approved as suppliers. When it comes to technology it is understood that the organization does not perform any pure research, meaning that the product development in this sense can be seen as more of an incremental development, see Figure 4 in section 3.2.1. Most of the time there are ideas on for instance how to increase performance of an existing product which are being examined in the pre-study phase preceding the project execution phase. In some cases there has also been special research projects performed where uncertainty has been seen to great.

What is seen in the main area *Technology maturity* is that many of the issues would have had smaller impact on or even fully lost significance to the projects, if the level of technological maturity had been higher. Issues related this will be analyzed in the following sections.

Since *Resources* is a smaller sub-area that covers issues that are seen closely related to planning the area has been integrated into the sub- area *Uncertainty in Planning, Quality & Risk-management* in the analysis.

#### 5.1.1 Supplier overestimation and lack of process insight

One way that technology uncertainty shows in the study is the supplier communication and insight in their processes which has led to underestimations of their delivery capacity. This is seen in five projects (B, D, H, J and K) where the projects state that they have, from a moderate to a very high degree, overestimated the suppliers' ability to deliver according to specification.

The problems that follow from overestimation and of lack of insight into supplier processes are not unique for situations with technology uncertainty, but it may in these situations be of essence for the technology and processes development to proceed, as seven of the eleven projects stated to in a high or very high degree have been dependent of the project suppliers' knowledge and processes. By working closer in supplier-relations, processes can be developed together and joint investments in these can be made that otherwise would have seemed too great of financial risk to go through with and by this way reach new levels in the overall development work. Slack and Lewis (2008) mention partnership supply, a relation between customer and supplier where partners "cooperate to the extent of sharing skills and resources to achieve joint benefits beyond those they could achieve by acting alone".

In a supplier situation where there is little communication the work can be compared with somewhat of a black box with limited insight in what is going on inside. Information such as: Have the specification requirements been detailed enough? What is the present status of development at the supplier and will the product be delivered on time? What is needed to overcome difficulties with the supplier processes and how can the organization help in these matters (by for instance change in design)? How can the organization become better prepared to handle an outcome with potential weakness in quality or performance (i.e. risk management)? Does the organization need to take any actions to mitigate potential disturbances in the overall planning or synchronization of activities due to difficulties in the supplier processes etc.? In three of the projects (D, G and H) in the study, problems at the supplier were not seen until very late and came as a surprise with little possibilities to affect. This could relate to trust which Child and Faulkner (1998) in this context have defined "the willingness of one party to relate with another in the belief that the other's actions will be beneficial rather than detrimental to the first party, even though this cannot be guaranteed". Slack and Lewis (2008) state that the greater degree of trust the greater the willingness to make oneself vulnerable to actions of the other. This might be one of the reasons for why the insight in suppliers' processes in some cases has been limited. A thought around this can be reluctance to show vulnerability that may be linked with showing the extent of problems that a supplier may have had to deal with and how hard they had to struggle to meet the delivery requirements in the end, because of for example embarrassment or the worries of being seen as a uncertain choice when the organization consider suppliers for new contracts in the future. Information as such, that therefore could affect the supplier's commercial or strategic advantage.

### **5.1.2 Uncertainty in Planning, Quality & Risk-management**

It has shown in the study that there have been issues related to lack of detail in requirements, specifications and documentation. The lack of detail level in the project requirement specification was mentioned to have affected five projects negatively; an example of the effect of this was mentioned during one interview: "The lack of detail makes it harder to communicate formally". In the context this meant communication towards suppliers, between organization sites globally as well as between functions within the organization. The uncertainty level in requirement specifications show as problems experienced with external as well as internal suppliers where it has resulted in project input deliveries that have not met the requirements that would have needed for the project to progress, in for example terms of quality and performance. An example of this is project I where lack of well defined requirements was mentioned to have caused input deliveries to arrive with specifications outside the quality tolerance standards needed for the project which in turn affected the project's ability to deliver in terms of quality in the end. Slack and Lewis (2008) states that activities to outsource needs to

be clearly defined and with contracts that cover what will happen if parts of the deal are not kept such as penalties if delays of delivery and quality defects etc. The better the project understands what is required from the product that is being developed, the more detailed the requirement specifications towards suppliers can be and the clearer it will be for them of what is expected of their processes and of what possible capability development measures needs to be taken to meet these requirements. System engineering as a holistic approach looks at the development as a whole and contains procedures going from specified requirements to design and system validation. According to Oliver et al. (1997) the system engineering process can be divided in two parts: a *Systems Engineering Technical Process* and a *Systems Engineering Management Process*. Where the Technical process includes evaluating available information, defining measurements of effectiveness, trade-off analysis, creation of structure model, build and test plan. While the Management process focus on organization of efforts related to the technical process. The overall purpose of these models is focusing on capturing and analyzing customer needs and functionality requirements at an early stage in a development cycle. NASA (2007) stresses the importance of assessment of technology maturity in the early phases of system engineering, a newly invented technology (e.g. component, material etc.) is usually not ready to be incorporated directly into a system without first having been explored, tested and increasingly refined through iterations. This is also supported by (Dawson, 2007) that means that a certain level of maturity is wished for to gain a good understanding of technology status , transition possibilities, risk management and decisions related to technology funding.

Another aspect that has also derived from uncertainty in technology and lack of details and was difficulties in planning, that has shown to have had negative impact on seven of the projects in the study. It showed that it was perceived hard to define work packages and to know what to do on a detailed enough level, which in turn brought difficulties in estimation of how much time that was needed within each activity, how many and what type of resources that were needed to perform the activity. Melton and Iles-Smith (2009) states that some of common root causes to problems in generic planning in projects are lack of contingency plans, lack of contractual obligations, integration of cost, time and scope issues, lack of communication, lack of understanding of team member responsibilities, poor scope management and control, and lack of understanding of what the project needs to deliver to enable expected benefits from the outcome. The areas related to these root causes all need a certain level of detail to prevent them from becoming reality which can for example be seen to refer back to the mentioned uncertainty in requirements. It is seen in the study that even if the projects have had technical competent resources that have managed to solve the problems that have arisen during the projects, and also have had a great deal of experience in planning of activities, the projects still have suffered from delays deriving from a need of greater detail and knowledge connected to immature technology and processes. As one interviewee said “We had known cycle times that we based the planning upon but they showed not to be valid in the extent that we had expected”. This also showed in project H and I where the expenditure of time was planned to be the same for the activity connected with new technology as with previous known activities, which shows not to be the case and therefore caused project delays. The fact that the activities take longer time than expected and time plans burst is one of the reasons for why resources have become shared or re-distributed between projects as mentioned in project B, C, D and E. The issue is addressed by Wheelwright and Clark (1992) as a matter of capacity where they claim that the demand of resources in virtually all organizations far exceeds the capacity of resources available and that the consequence from overextension of resources lead to declined productivity, longer project

completion times and declining rate of completed projects. Planning has in the mentioned projects shown to be a difficult task to perform with accuracy. This due to the high complexity and uncertainty in technology and of what could be achieved with support of existing processes or on how these processes could be developed, what resources and competences are needed to perform related activities etc. This is one of the reasons for why system engineering and work with increasing technology maturity such as Mankin's Technology Readiness Levels (1995) has been developed, as it helps to provide structure to break down and specify the requirements in detail, which in the projects mentioned would have been needed in a greater extent to help them avoid issues and achieve higher planning accuracy.

Since the time schedule have usually already been perceived tight in most projects, see appendix 15, the results of miscalculations or underestimations in planning activities have often showed as delays of other activities within the projects, see further discussion in the section 5.2.1 in *Overall planning*. The delays have in some projects (E and H) led to compression of other activities, where time has been prioritized before quality, which has led to a greater risk taking by having less extensive quality testing performed before production. Other commonly mentioned issues in eight of the projects have shown in form of variation and quality spread. Even if they seem most often to have been solved before customer delivery, or judged small enough not to effect the product performance in field (project F), they have generated additional design iterations or through extra work in the production phase. Thomke and Fujimoto (2000) addresses this problem and claims that an organization can cut costs, reduce development time and free up resources by shifting the identification and solving of problems earlier in the product development process. A concept they define as front-loading. Front-loading that in the context of projects D, F, H, I and J would have meant needed to origin from the acquisition of further knowledge early in the projects to reduce risks and quality issues later on.

## 5.2 Management

The issues linked with the main-area *Management* equals twenty of the total issues experienced at the highest two levels in the study. Further, fifty-five percent of the issues in this main-area are positioned at the top level of impact on project in terms of time delay.

The empirical data to be analyzed in the main-area is sorted under the sub-areas *Scope-changes and recourse re-distribution*, *Overall planning*, *Project definition* and *Management absence*. An overview of the mentioned sub-areas is shown in Figure 33.

	Management			
	Scopechanges and resource re-distribution	Overall planning	Project definition	Management absence
Total issues	5	8	3	4
Average value level	1,80	1,50	1,00	1,25
Importance value	2,78	5,33	3,00	3,20
Ranking number	10	5	9	8

*Figure 33 shows a sub-area overview with the importance value and overall ranking of respective sub-area of issue in terms of time delay*

### 5.2.1 Overall planning, Scope-changes and resource re-distribution

By *overall planning* the authors of the study refer to issues shown to be mainly related to the synchronization of activities, resources, equipment, handovers and project deliveries between projects in the organization. Since the issues in the sub-area *overall planning* are perceived to be closely related to those of the sub-area *Scope-changes and resource re-distribution* the two sub-areas will be analyzed jointly in this section. An example of correlation of overall planning and resource re-distribution and scope-changes can be as stated by one of the interviewees: "The management was too optimistic when planning the start of many activities at the same time which resulted in lack of resources in the end". Where, issues in one area often directly results in issues in the other.

If assuming that the initial overall planning worked in theory with respect to resources and equipment and so on. That might not really be the case, but nine of the eleven projects have stated that they were given the resources requested by the project in from a moderate to a high degree while two projects, B and J, were less satisfied with the resource allocation. There are yet three reasons identified in the study for why the overall plan may have ruptured: *Burst of internal planning*, *Arise of quality issues* and *Start of new activities*.

#### ***Burst of internal planning***

The first identified reason is that the projects *internal planning* bursts so that the projects fall out of synchronization towards each other. This showed in six of the eleven projects (A, C, D, F, G and H) where the issues that arose were delays from late project inputs, lack of resources in projects and busy equipment resulting in bottlenecks.

The planning of the projects have been tight from the start as stated by eight of the eleven projects in the study that perceived the time plan to be tight or very tight at the start of the project execution phase. If then only those activities that can be predicted a need for at the planning stage have been added into the schedule this leads to a planning without any buffers that can capture unexpected events. Events such as technical problems, resource loss, overlooked equipment capacity or under-estimations in the time required.

An advantage of setting tight time plans during the planning stage may be that any deficiencies and weaknesses in planning directly show. By identifying the weaknesses it makes it easier to fail-safe the work processes, take corrective actions and fact-based decisions on project and organization requirements as in for instance skills acquisition in form of employment or education and so on. As Howell and Ballard (1996) put it when they state that the classical approach to planning produces waste in the lack of achievement of what was done against what should have been done. They mean that it is better for a dynamic project to consider the concept of what can be performed to provide a yardstick and then the planning process involves adjusting between what should be done, to what can be done, to produce what will be done. This provides better knowledge on the process and by identifying and correcting one weakness in the process another weakness is likely to show, and another spin of Deming's PDCA-cycle in the work of continuous improvement can take place.

Issues following from under-estimation of time required of activities when planning has among other things been mentioned in the project H and I. In the projects it was mentioned that there were known cycle times available from previous work which had been judged to be similar to the new processes but where the new technology or ways of working required more time than

was expected. Dawson (2007) means that one of the reasons for why an organization gains from raising the technology maturity level are that it provides a better understanding of the technology status, which in turn also provides the possibility of more accurate risk management and decisions related to technology funding. This leads not only to greater accuracy in planning of the work activities themselves but it also provides good means for pro-active measures that can be taken as part of the risk management.

As for overbooked equipment capacity that became a bottleneck in project E it was not due to mistakes in the initial planning but due to that the initially planned utilization had been displaced because of project delays, which resulted in two projects (E and F) ending up in parallel, where project F had higher priority. Situation like in these arise due to the fact that an organization will need to make trade-offs since its resource capabilities will not be unlimited. As Skinner (1996) states there are limits for what can be done in an organization and that trying to be good in all areas comes with the risk and likeliness of not performing well in any of the areas. "For instance, no one today can design a 500-passenger plane that can land on a carrier and also break the sonic barrier".

Trade-offs between, performance objectives that in this context, of product development in an organization, are competitive factors that reflect dimensions of performance such as *Quality, Speed, Dependability, Flexibility* and *Cost*, and decision areas such as *Capacity, Supply network, Process technology* and *Development and organization* (Slack and Lewis, 2008).

In the cases as with projects B, C, D, E, G and H where issues related with resource redistribution, lack of resources or equipment have caused negative impact on the projects the organization might want to increase *Dependability*. Meaning the ability in keeping delivery promises in aspects of time towards internal or external customers, and in the decision area this performance objective may be achieved through decisions on *Capacity* that states the potential level of productive activity. Where having too much capacity, for example under-utilized resources, may give possibility in terms of flexibility to respond quickly to increased product demands, but requires investments that will drive cost-per-unit when they are not in full use. On the other hand having too little capacity may lead to limits the ability to meet customer requirements.

What type of development decisions the organization choose to make might be a matter of what is seen as of greatest importance for it in the presence, as well as in development of future capabilities and in alignment with the overall business strategy. To assist in business alignment decisions and understanding of in which strategic direction an organization is heading Kappel (2001) suggests that *Product-Technology* roadmapping can be of help. Where roadmapping is; "A common way to help planning and cross-functional communication. It supports people at all levels in the organization to achieve milestones and to become committed to the overall process. Roadmapping also helps the organization to recognize in advance which new products and technologies that should be available and when." Investments in terms of resources and equipment could off course be an option necessary for avoiding bottlenecks and to be able to reduce impact of the issues experienced in the projects (B, C, D, E, G and H) enabling delivery with higher dependability than what was seen. An alternative to this may be to spend more time on securing the internal planning process so that the time schedule does not break in the first place. This can be done by increasing the level of detail, knowledge and risk management around



the requirements of the technology and processes used to achieve the goals of individual projects. The latter option might out of a continuous improvement perspective be a better solution in the long run as it means development leading to higher planning accuracy and by that reduced delay-related costs due to synchronization issues.

Skinner (1996) states there are limits for what can be done in an organization and that trying to be good in all areas comes with the risk and likeliness of not performing well in any of the areas. Trade-offs may apply in a similar manner in many of the issues mentioned in the projects. One example could be seen in project A where there were various versions of hardware- and software equipment in the organization that was perceived to make it more difficult to compare values between different sites and tests. In this case, a trade-off between cost of equipment updates and quality assurance might be necessary to be taken with consideration to the area mentioned by Slack and Lewis (2008) as *Development and organization*. Where the decisions should reflect on business strategy and on how the organization wishes to develop in accordance to this. As they claim: "Even small advantages in product and service specifications can have a significant impact on competitiveness".

### ***Arise of quality issues***

Secondly, a reason for why the overall plan does not hold is because as mentioned in the projects that quality issues sometimes arise. An example is as in project J where activities related to quality improvement were added to the scope. The issues that arise must be addressed somewhere in the organization and when there have been no adequate resources free the quality work it has sometimes been added to the project scope of individual projects which in turn has led to delays in the planned work. With a lean time plan as mentioned by Howell and Ballard (1996) these changes appear directly as delays in the projects, which in turn may make it easier to assess the cost of these implemented changes to each other. This may well contribute to an overall understanding and be of assistance in decisions concerning trade-offs, where it might show the importance and profitability of enhancements in the quality assurance of products in a way that unanticipated quality problems are kept to a minimum, through for example increased audits and more extensive testing. In the current situation this has in some projects been seen prioritized down in relation to time constraints and cost.

### ***Start of new activities***

Thirdly, yet for why the overall plan does not hold is because of market opportunities that were discovered by the organization that led to decisions to start new activities. As one project manager stated "The management were optimistic planning the start of many activities at the same time which resulted in lack of resources in the end." One reason behind these decisions was that it was seen important with short *time to market*. *Time to market* can be defined as by Smith and Reinertsen (1991) the time from when first a market opportunity was discovered through to the time when a final product is available on the market. Vesey (1992) and House and Price (1991) defines it as the length of time it takes to develop a new product from the product definition in the early stage of the development process to the time the product is ready for manufacturing release. Positive effects of achieving fast time to market are as mentioned by Wheelwright and Clark(1992) chance to set market standards, possibilities to catch a greater market share, longer time for the product to return on investments, a steeper learning curve, better market information and target accuracy.

The positives are many and cost-reductions can be great. What is seen in the study when these opportunities arise is that the organization therefore sometimes chooses to start more activities than the initial estimate in the overall planning. This leads to additional resource-sharing and resource-redistribution between projects and is followed by perceived deficiencies in the projects. As for resource-redistribution, these always take some time in the form of handovers. When it comes to sharing of resources it is stated in project H that sharing of resources means loss of total efficiency and can be graphically expressed by the formula:  $20\% + 30\% + 50\% < 100\%$  in terms of resource sharing versus resource efficiency." Adler et al. (1995) call this the congestion effect where the efficiency of resources is adversely affected in relation to whether the resources would have been one hundred percent dedicated project as also mentioned by. It should however be added that there are also benefits of resource sharing which are mentioned by Nobeoka and Cusumano (1997). They argue that shared resources lead to better utilization of resources, reduction in required development hours, as well as better learning across projects.

A thought on the market opportunities is that the projects are likely to gain from more knowledge in the new technology and processes. Where for example tighter supplier relations such as *partnership supply* mentioned by Slack and Lewis (2008) or research in accordance with Mankins(1995) Technology Readiness Levels would provide good opportunities for earlier identification and assessment of opportunities for new market products. Thereby lead to a decrement of unexpected start of activities and of negative effects impacting on the projects following from this.

### 5.2.2 Project definition

Wheelwright and Clark (1992) defines project definition as what determines how the organization sets the project scope, establishes bounds of what is included and not, and defines the business purpose and objectives of the project. From the study three projects (E, H and I) state that the project could have been defined differently and in a way that they perceived would have gained the project. The study does not show whether communication of differentiating opinions on project definition has taken place in an early stage of the projects involved where changes were still possible to apply or if the issues have been pointed out in hindsight as project learning's and areas of improvement at the end of the project.

In project E the setup was questioned due to that the project was partly a transition project that was carried out in two steps instead of one, which led to an extra step of resources needing to catch-up with progress since there were new resources involved in each step"

Project H stated that the project would have gained if it had been divided to include a separate pre-study project preceding the main project, since the project was included activities that the organization had not dealt with in-house since a long time. This goes well in hand with the system engineering theory and use of Technology Readiness Levels (Mankins 1995) to increase technology maturity before project definition and start. Dawson (2007) states that a certain level of maturity is wished for to gain a good understanding of technology status and transition possibilities, risk management and decisions related to technology funding.

It might not be clear from a project perspective to have an overview and understanding of what the aggregate project plan in the organization looks like, what resources are available, how these are best utilized and distributed between projects etc. An important factor for project efficiency

is that communication works well in both directions so that the project as well as management can have a good understanding of the different project perspectives. So that balanced decisions can be made that has taken as many aspects of project perspectives as possible in consideration. Based on Slack and Lewis (2008) view on operations strategy, the situation can be seen as a strategy that to achieve well may need to combine a bottom-up perspective from the project of what can be done in theory, with a resource based view of what is possible to pursue with today's capabilities, followed by top-down decisions on what resources to acquire and on how to best define the project. Wheelwright and Clark (1992) state that for a product or development process "the organization must have an effective way of defining products, must understand an appropriately deploy the mechanisms and tools for problem solving, and must understand and effectively deal with the issues involved in senior management review and control".

With communication and further integration of activities the situation of sub-optimization character in project I might have been avoided. In the project it was mentioned that there was a mismatch in its definition and that "The project would have gained from if the definition had been of system character". Which referred to a system definition and wider way of approaching the development work instead of the now chosen sub-system definition that included one setup in the organization and another setup by the customer with who the organization worked closely together to deliver an end product. Furthermore communication is a factor that can help motivation in a group through greater understanding of choices made by management and lead to increased efficiency by allowing full focus on the task that lies ahead as a positive motivator (Wheelwright and Clark 1992), instead of a wondering and spending energy on worries around whether project definition is set up properly or not, as a negative motivator.

### **5.2.3 Management absence**

Management absence is an issue that is stated to have affected four of the eleven projects A, B, D and J on the highest levels of impact on project. In projects A, B and J this was due to that a project steering group was missing during a period of time. The consequences that were pointed out by the projects to have had time delaying consequences to the projects were that decision making went slower and there was a greater perceived uncertainty around the decisions made due to the fact that some of them were taken outside the formal channels. Even in a situation where the organization can be considered mature and should be able to take responsibility for its actions, visible signals are sent out by not having management in place. Bergman and Klefsjö (2010) state that committed leadership is one of the cornerstones in total quality management and that the leadership through credible, clear and good communication and through working as good examples and role models can create commitment and engagement from the members in the organization. This is further supported by Wheelwright and Clark (1992) who states that senior management in the way they manage reviews, evaluations and modifies the project over time, sends signals of the degree of responsibility delegated to those working on the project which creates powerful incentives and motivations, positive as negative, during the project time. They further state the importance of matters which may be seen as routine such as frequency, timing and format of reviews can have significant impact on the overall effectiveness of the project.

The absence of management in project A also led to an expressed wish for people to step up and take responsibility which the project did not see work enough efficient today, and further meant that this was a part of the organizational culture whereas the project would have gained from if

this had worked better. In project D it was states that it suffered from quality problems leading to time delay in the project due to the absence of a quality responsible manager. In this case the position of a line manager, who is responsible of quality assurance within the line, was not filled. If situations with management absence still cannot be avoided for some reasons in the future it might be of help to have a formal way of handling these situations related with fail-safeing such as Poka-yoke or Failure Mode and Effects Analysis.

By having clearly defined ways of working, less time can be spent on worrying about on how to proceed, wondering of what the roles and responsibilities are or of what decisions have been made so that the disturbance can have as little effect as possible and the negative incentives or motivation mentioned by Wheelwright and Clark (1992) are held low. An example that shows on potential for improvement in way of working related to management decisions is as in one project where decisions were taken that to some extent affected the project budget which was overlooked due to informal decision making and lack of documentation.

### 5.3 Ways of Working

The issues linked with the main-area *Ways of working* equals thirty-three of the total issues experienced at the highest two levels in the study. Further, forty-five percent of the issues in this main-area are positioned at the top level of impact on project in terms of time delay.

*Work Processes* is the sub-area in the main-area *Ways of Working* that has caused the greatest negative impact on the projects throughout their project duration. The sub-area is further ranked as the second largest contributor of negative impact on the projects in the study.

The empirical data analyzed in this main-area is sorted in the sub-areas *Documentation*, *Work processes* and *Handovers*. An overview of the mentioned sub-areas is shown in Figure 34.

	Ways of working		
	Documentation	Work processes	Handovers
Total issues	7	20	6
Average value level	1,86	1,40	1,67
Importance value	3,77	14,29	3,60
Ranking number	6	2	7

**Figure 34 shows a sub-area overview with the importance value and overall ranking of respective sub-area of issue in terms of time delay**

#### 5.3.1 Documentation

It has been shown in the study that there have been issues related to poorly executed documentation which caused time delay in five projects. Three factors that have affected the documentation negatively and been identified in the empirical data are; how to do the documentation, where it is stored and how the stored documentation is used.

According to Huber (1991) it is important that the organizational memory is stored in a way where it easily can be fetched when needed. It is also important that the information is reachable for the members of the organization in processes that gives the information meaning. Huber (1991) states that the construction of the organization memory is important for organizational learning, which could include norms, methods for storing information and methods to retrieve stored information. The information produced or needed as input in a project need to be

transferred between departments or between people during the project, but also after the project has been closed down. For this matter there are several different information systems in the organization. During the interviews it has become clear that there is a variation in how to handle the data in the information systems e.g. some information are not stored in the information system or the documents stored do not include all data needed. Another example is handling of data, such as trouble reports, where the information stored in the information system can differ from the information and knowledge within the organization. To sort these issues out has been stated as time consuming for the projects and can sometimes be the reason for the time delay. The documentation itself can be experienced as time-consuming and non-rewarding when the main purpose for the project is to be on time.

The feeling of documentation, as time-consuming instead of a helpful tool, could be caused by the mental attitude in the organisation and by the effect of experiencing a non-rewarding documentation. Argyris (1999) states that in double-loop learning the value system must change before corrective actions can be taken. If the system for documentation is held together and is made to create more value than today, it might lead to a change of mind.

One of the project managers stated "the...department has the culture to think that administration is time-consuming and sometime unnecessary, but today when we work multi-site, it is even more important than before to formalize the information and data handling in the projects". Therefore it is important for the organization to create an understanding in the projects that the documentation and data in the information systems are used to assure quality for future project and for organizational learning.

In organization learning it is important according to Huber (1991) that the information is distributed within the organization in a way where the information is shared and combined. When the information is shared and combined new information and understanding obtains and new knowledge is developed (Huber, 1991).

One reason for structuring and standardizing the way of working with information and data, are to ensure that the information in the system is easy shared and combined. It is also important to structure the information in a standardized way for having a simplified and easy process for searching and retrieving information.

The organization has good potential since they have information systems, processes and routines for handling information and data. Empirical facts show that some inconsistency in the way of working with documentation and in the documentation system leads to delays in projects.

### **5.3.2 Work processes**

Eight of the projects in the study had experience of issues related to work processes. It has been shown that mainly the causes of delays due to work processes were linked to the responsibilities of the line organization, but also within the documentation processes and due to the human factor.

One factor shown in the empirical data is the lack of routines or inconsistency in existing routines or work practices during the work processes. This is a general pattern that can be seen in several of the projects. According to Kerzner (2003) the line management and the project management have different roles and responsibilities during a product development project. The line management has responsibility for the accumulation of right competences, the resource

allocation, the employees, and the equipment used in the organization. The data shows that there is a pattern of lack or inconsistency in routines or handling of routines within the line organization. One example of these issues was that the test equipment in different sites did not correlate and therefore did not give satisfactory results which resulted in some time delay in one of the projects, another example were when the equipment did not work as assumed in the project (A). The project manager stated that "After working a month we realized that it was not any problem with the product, the test equipment was the problem". Another issue for time delays mentioned, which could be caused by inconsistency in the work practices and routines, was when handling different releases of prototypes in project (A) which stated as troublesome.

Routines when working with suppliers is one issue in this study that seems to require both improvements and an enhanced relationship with the suppliers to secure quality of the product. In project D it was experienced that information about poor quality was withheld and appeared late in the process. In project H better knowledge about the technical competence and capacity of different supplier, instead of just meeting the common company's supplier evaluation criteria, in the pre-study could have helped the project to gain the quality required in the project and the possibility to be on time.

A need for enhanced routines regarding preparations before project meetings and structure during project meetings can be seen in project A and C. In one of the projects (C) it was suggested that the meetings should be led by a moderator to insure that they followed a firm agenda. Secured quality in the review meetings was experienced in the projects as one possibility that could enhance to deliver in time. Mainly getting and taking part of the required information and documents about upcoming meetings prior to the meetings would make the meetings more efficient. The importance of the group constellation when meetings are held is of great consequence hence decisions might be withdrawn in cases when key-persons do not attend. In the organization a culture of participating during meetings, without preparations, has grown. Wheelwright and Clark (1992) describe overcommitment of available development resources as one reason for that deadline passes and that the cost of development increases. In this case could overcommitment of the team members between a number of projects be one of the reasons for insufficient time for preparation prior to the meetings.

In all cases related to work routines and work practices mentioned above, it is important finding root cause in order to understand the underlying reasons (Bergman and Klevsjö, 2008) for inconsistency in the work practices. According to Argyris (1999) it is also important for learning that before corrective action first examining and change the value system. Working continuously with techniques, such as flowcharts and fishbone diagram, to constant examination of work practices (Dean and Bowen, 1994), the organization could gain knowledge to secure quality in the practices and improve their work.

Routines for catching the tacit knowledge (Chennamaneni et al, 2011) in the organization is a required area mentioned in the study. In project G the project manager stated that the quality of a component was depended on the experience of the designer, but also that a document of requirements was needed for the work of the supplier. It is important for organizational learning to transfer knowledge to an organizational memory to be stored for future use (Huber, 1991). Hence a higher level of capturing tacit knowledge according to Chennamaneni et al (2011) could improve quality and organizational learning in the organization. Mechanisms for transferring tacit knowledge could be e.g. fishbone diagram or concept mapping. Transfer of tacit knowledge

can be made in two steps according to Nonaka and Konno (1998), first to use a technique to visualize, secondly translating the tacit knowledge into explicit knowledge. Then the organization can reuse the tacit knowledge of e.g. the designer.

Time delays due to the human factor have been seen in the study. Mistakes happen sometimes and often hard to prevent. One possibility could be to fail-safe the work, e.g. with one more review of the work before action to secure the quality, but it is always a trade-off between time and cost.

### 5.3.3 Handovers

The quality of the handover between projects was low in two (A, C) of the projects. The handover documents were unclear or some of the criteria needed were missing. The writers of the handover documents seem to have underestimated the knowledge of the receiving project in resource and competence. The data indicates that the writers of the documentations are not always aware of what information is needed or to what extent of information needed for the receivers of information. Chan and Ghaedian (2012) points out that when codified knowledge in documents it is essential for the sender of the document to get specific and full information from the receiver what knowledge is needed. The handover between persons when team members are changed is experienced as time-consuming. Chen and Ghaedian (2012) mean that personalization could be useful for capturing knowledge, when structured. Based on the assumption that dialogue is necessary they states that the personalization needs to be formalized, otherwise informal use of the personalized knowledge grow within the company. This shows that the process for handover needs to be improved or to be implemented in a better way in the organization

## 5.4 Communication

The issues linked with the main-area *Communication* equals fifteen of the total issues experienced at the highest two levels in the study. Further, forty-one percent of the issues in main-area are positioned at the top level of impact on project in terms of time delay.

*Inside Organization* is the sub-area in the main-area *Communication* that has caused the greatest negative impact on the projects throughout their project duration. The sub-area is further ranked as the third largest contributor of negative impact on the projects in the study.

The empirical data analyzed in this main-area is sorted in the sub-areas *Outside organization* and *Inside Organization*. An overview of the mentioned sub-areas is shown in Figure 35.

	Communication	
	Outside organization	Inside organization
Total issues	3	14
Average value level	1,67	1,64
Importance value	1,80	8,52
Ranking number	11	3

Figure 35 shows a sub-area overview with the importance value and overall ranking of respective sub-area of issue in terms of time delay

#### **5.4.1 Outside organization**

Difficulties in communication between the project organization and the supplier have been stated as issues in two of the projects in the study. One factor identified, was how the inconsistency or lack of two-way communication affect the project in time and that the quality on the components delivered were not as expected.

Two of the projects (D and H) in the study stated that the communication between the project and the suppliers have been problematic and as one issue for time delay during the projects. In the first of the projects (D), where it was discovered that the supplier was not able to deliver as expected on time, the project manager stated " Even if we had weekly meetings with the supplier, we realized late their status according to the requirements in the specification". In the second project (H) it was mentioned that communication between the project and the supplier was an issue for time delay. The project manager stated " We thought it was enough information with the specification with the tolerances required and that we had been clear enough in the verbal communication about the requirements, but when the prototypes arrived the quality was deficient". According to Wheelwright and Clark (1992) communication is affected by the dimensions; richness, frequency, direction and timing. In these cases the dialogue or the two-way communication between the parties can be seen as weak because of the late information about the quality on the component. Another issue in these case could also be that the communication most likely had a low level of face-to-face interaction, and the frequency of the information sharing between the project and the supplier.

#### **5.4.2 Inside organization**

It has been shown in the study that there have been difficulties in communication inside the projects organization. Three factors shown in empirical data were related to communication inside the project organization. Two of these factors were identified as inconsistency in the two-way communication and understanding for each other's work between the functions in the project. Five of the projects had mentioned issues related communication between project members as reason for time delay. One factor related to interaction between departments or between different functions has been identified. In one of the projects (B) communication issues occurred in the organization which affected the project negatively. Most of the issues mentioned about communication, during the interviews have been related to communication between members in the project. During the interviews it has been clear that even if the information seems to be delivered correctly from the sender, the receiver of the message has misinterpreted the information and did not deliver as expected. Two-way communication is necessary to provide feedback, which is important for a dialogue between people according to Smith and Reinertsen (1991). Feedback gives an important possibility to confirm that the information is understood and received (Maltén, 1992). The lack of systematic use of feedback and confirmation can have been one of the reasons for the communication to become issues in the project.

Four dimension of communication is described by Wheelwright and Clark (1992). They present richness, frequency, direction and time as critical elements for communication. In one of the projects was communication between project members mentioned as "Even if I thought I had been clear with the information during meetings and in documentation about the delivery plan. The responsible for the issue concerned had not given any indications about delays in their job or misunderstandings." The level of richness, face-to-face interaction, and the timing of the



information shared, seems to be high in this specific case but the dialogue and the feedback between the both parties can be seen as weak. Presumably the frequency of the communication was low because misunderstandings in the communication occurred. It could indicate that the level of feedback between the project members were low in this case. According to Weelwright and Clark (1992) the level of the dimensions of communication influences the cross-functional integration in the project. Hence, even if it seems that project meetings are held and that communication is transferred between the project members in the project, still communication issues occur in the projects. Therefore could visual communication be a compliment in the communication to stimulate and to secure the dialogue during meetings. To visualize the information and visualize the planning on in an analogue way on boards during project meetings, can be a tool to facilitate the verbal communication and the face-to-face interaction between the team members during the meetings. It can also be a tool to get a shared understanding and a shared point of view of the project (Sebestyén, 2006).

Informal communication in the organization were one issue that through rumors caused time-delay, which shows the importance of keeping the communication formal in the organization (Vouuren and Elving, 2008) to hinder rumors spreading and speculations.

The statement of one of the project managers “people have sometimes no understanding of each other’s work and position and therefore is it hard to understand important issues for the other part” indicates that there are barriers caused by different language, education or culture (Trygg 1992) between departments. It also indicates that a low level of understanding and knowledge for each other’s work can generate friction and could be one of the reasons for difficulty in communication between the departments.

The iceberg analogy according to Schein (1992) shows that the underlying values in a company has greater effect on how the work is done than the expressed organizational values and strategies. The way people behave in an organization is steered by what is taken for granted and unconsciously deep-rooted values and beliefs. In the empirical data, two of the projects mentioned issues related to that formal channels were not used for specific information and that the documentation is time to time perceived as unnecessary and time-consuming. Together with the praising heroes mentality, mention in two of the interviews, could be a sign of underlying values in the organization that has a greater influence than the formal expressed values and strategies (Schine, 1992).

A culture of “praising heroes” mentality seems to be spread in the organization, which was mention as one reason for delay in two of the projects. Black et al (2001) states that “fire-fighting” is an organizational pathology which left unhandled can be degrading for the organizations productivity. The responsibility of discouraging the “fire-fighting” mentality is strictly a management responsibility since “praising heroes” is contra-productive and drains the company of competence. Kim (1993) claims that organization learns via individual learning, but it is important for the organization that the learning is transferred into the organization for organization learning. There is a risk in an organization that “praises heroes”, that the knowledge will not be transferred into the organization. There is also a risk that the organization will be depending on specific employees and vulnerable when specific employees leaving the organization for one reason or another.

## 5.5 Summary

In this section the factors identified within the main-area *Technology Maturity, Management, Ways of working and Communication* are summarized. They are briefly described in terms of key-sentences to give an overview of the findings from the analysis chapter. The factors in the top ranked sub-areas, *Uncertainty in Planning, Quality & Risk-management*, *Work processes* and *Communication – Inside organization* will be further discussed in chapter 6: Conclusion and discussion.

### Technology Maturity:

- The uncertainty level in project requirement specifications has resulted in project input deliveries that have not met the requirements that would have been needed for the project in terms of for example quality or performance. Situations resulting in time delays and in which projects have perceived to have overestimated the suppliers' capacities.
- Uncertainty in Planning, Quality & Risk-management. Where uncertainty has made it harder to define work packages, which has led to delays and in some cases have resulted in compression less extensive quality testing and greater risk taking.

### Management:

- Overall planning Scope-changes and resource re-distribution. Where tight individual project plans have burst and have caused projects to fall out of synchronization with each other leading to capacity problems concerning resources and equipment.
- Delays from project scope-changes as result of arising quality issues in the organization. Where the issues in some cases have been added to the scopes of individual projects due to lack of available resources and were these changes due to lean time plans have appeared directly as project delays.
- Discovery of new market opportunities have sometimes led to decisions of start many and new activities at the same time that has resulted in additional resource-sharing and lack of resources in the end.
- Management absence has led to time delaying consequences for projects. Where decision makings have gone slower and have been associated with greater perceived uncertainty around the decisions made.

Ways of working:

- A variation in the way of working with documentation influence the projects. For the organizational learning it is of importance to secure the information so it can be easily shared and combined in the organization.
- Inconsistency in existing routines and work practices can be seen as a reason for time delay. It is of importance to assure the quality in the work practices.
- The need of securing routines for catching tacit knowledge for the organization learning.
- The work to securing documentation and knowledge transfer during handovers needs to be improved.

Communication:

- The inconsistency in two-way communication and use of feedback influence the communication between team members and suppliers involved in the project.
- Barriers between functions or departments can be one reason difficulties in communication, but also of one low level of understanding and knowledge for each other's work.
- Consistency in the formal communication to e.g. hinder rumors spreading and speculations are seen as an improvement area.
- The culture in the organization influence the way of working and how to manage documentation and communication.

## 6 Conclusion and discussion

The chapter contains conclusions and discussions that origin out of the highest ranked sub-areas identified during the study. These sub-areas are addressed in the report as “Uncertainty in Planning, Quality and Risk-management”, “Work processes” and “Communication – Inside organization”.

The purpose of the study is to identify underlying factors that cause time delays in hardware product development projects in a product development unit at Ericsson AB. One conclusion is that projects suffer from time delay not just of one factor; it is a combination of factors which cause time delays. During the study it has been clear that the projects affects by issues related to the pre-work to the execution phase, to management issues during the project, inconsistency in ways of working and that communication between members in the projects cause time delay. The idea to focus on the top sub-areas in this section of the report is to focus on the sub-areas which according to the ranking in the study caused most time delays. It is further believed by the authors that the organization by addressing the underlying factors identified from these sub-areas will be able to reach the most efficient and effective result in its improvement work. In the highest ranked sub-areas the underlying factors causing time delay are identified and presented as: *Immature technology*, *Inconsistency in work processes* and *Verbal communication*. Figure 36 shows the relationship between the main-areas and the underlying factors found in each top ranked sub-area.

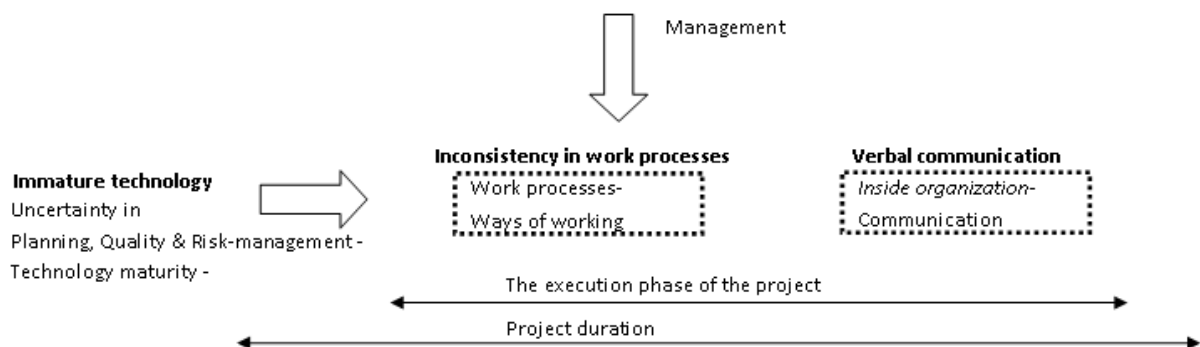


Figure 36 shows relationship between main-area and underlying factors from sub-areas.

### 6.1 Uncertainty in Planning, Quality & Risk management

The factor immature technology, in the sub-area Uncertainty in Planning, Quality and Risk management is seen in the study as the largest contributor to delays in projects. The factor affects the projects negatively in many ways, described in the empirical and analytical sections 4.6 and 5.1. The main problems arising from this factor is difficulty in knowing the complexity of the selected product design in terms of quality and time frames. Without having further explored and tested new technology central for product development before projects start it has many times been assumed that the new technology being developed is similar to one by company previously developed technology. Often it has been seen in the organization to be more about raising the performance of existing technology than actually developing new. Where the organization actually is on the technology maturity scale, see section 3.2.2, with the technology in their projects can be discussed, but the study shows that the projects might be closer to technology development than the organization itself thinks.

The consequences from not having a baseline with more proven technology and better knowledge of complexity in the selected designs result in difficulties in planning work schedules that holds. The complexity has led to questions about areas such as: resource requirements, skill requirements, duration of individual work packages etc. With time schedules that bursts it becomes more difficult to synchronize activities within the project, which also has impact on activities of other projects and parts of the organization. For example, the sharing of test equipment or integration activities of the organization that is necessary for the projects. This means that delays in one project in some cases also cause delays in other projects. Because of the broken timetables hyperextension and redistribution of resources between projects in progress take place based on the project's priority towards each other. This is done to concentrate the efforts where they are thought to serve best, but results in loss of resource efficiency in a long term run.

Moreover, broken schedules are seen to trigger higher risk in terms of quality. In a business situation where it is of great importance to keep time to market short to take full advantage of opportunities this will also reflect upon the projects in the organization. The projects in the study show that it usually is of high priority to deliver the products as quickly as possible to customers. When schedules are tight set from the beginning there is no room to make up for lost time. Due to this delays do in several cases has mean that the projects try to compress planned activities related to testing and verification which leads to increased risk taking whether the selected design can indeed achieve the requirements for manufacturability and quality. This result in products with more unfinished quality status reaching the pre-production phase, with the consequence that additional design iterations are required before the product is considered good enough to be able to put into production.

Another difficulty that currently comes with working with less proven technology is that it from a project view is harder to know what requirements must be imposed on the components of the product to achieve the right level of quality and performance in the final product as a whole. In situations where the requirements of the components are not sufficiently determined or detailed it makes it more difficult for the subcontractors to know what is required from their processes and how those processes should best be developed in order to be able to deliver components that will work well for projects in the end. With the cases where design iterations mean that suppliers need to re-do existing or even develop new components follows often also long lead times with large delays in the projects as result.

Overall, immature technology is a main contributor to the time-delays experienced. A discussion can be held around the technology maturity status within the projects in the organization where two different perspectives might be possible reasons for why this is. One perspective may be that the organization is not fully aware of how demanding the technology being developed in fact is and therefore underestimate the difficulties that follow from this. Another perspective may be that the organization is well(?) aware of the risks and difficulties that follows from not having explored the technology further before initiating the projects, but where the organization still out of time- and cost point of view thinks of it as more effective and efficient to resolve the problems that arise from immature technology within the projects rather than through increasing its efforts before project startups. In the latter perspective it might be a combination of trade-off decisions around where the cost, i.e. to meet customer satisfaction, market opportunities, for the organization is considered lower together with alignment of business

strategy and philosophy. Out of a short-term perspective it might be less costly to deal with the arising problems within the projects but the difficulties lie in the estimation of how this will affect the organization in a long-term run. For example how will decisions leading to a quality heritage in a product from one project affect the results of future development projects and with that also the development of the organization as a whole? How do time-delays affect the business case or even the brand image in the end? The questions and aspects that need to be taken into consideration are many.

Aside from greater planning abilities, better resource utilization, higher quality and easier supplier communication an increased level of technology exploration also provides opportunities to sooner identify and act upon market opportunities. This includes opportunities that derive from alternative technology solutions that otherwise might never have been discovered. What is the cost of missing out of these?

## **6.2 Work processes**

Inconsistency in work processes is seen in the study as the second largest contributor to delays in the projects. Within the structure of the sub-area *work processes*, the factors are identified where inconsistency in routines or work practices causes difficulties and time delay in the projects.

One effect seen in the study caused by inconsistency in work practices is quality issues within the way of working. It should be of great importance for the organization to assure the quality of the work practices and a way of working to secure internal and external customers satisfaction. Another reason for time delay seen related to inconsistency in work processes is the need to assure quality and efficiency in the review meetings and team meetings during the projects. Routines for catching tacit knowledge, from specific personnel, in the organization have been shown to be one of the challenges for the organization. One issue that has been seen is when the knowledge is kept within the head of specific employees and not easily reachable to the rest of the organization.

One question to ask when discussing the inconsistency in the work practices is if it has been a deviation in the existing routines or if it exist any routines. This could be it a symptom of that the employees do not see the value of follow existing routines, or that the work practices of the way of working could be hard to follow when the preconditions and prerequisites change during the project. Or is the reason that the management in the organization or in the project does not take enough responsibility to secure the way of working? Another issue could be that the ownership and how responsible for the routines are not clear enough. Are the team members involved when routines and work practices for the project are created? If not, this could be one cause for less engagement and motivation for commitment of the improvement work. When project members are engaged in the process as a whole the result might be responsibility, continuous improvements to assure the quality in routines and work practices.

Attending at meetings without preparations and having to cancel decisions taken, because members of the project are missing can be seen as costly in the long run for the organization. Employees that arrive at the meeting, if not the required members are attending, waste their time. The waste is time in the organization, the employees get paid and the organization loses money. Preparations before meetings by everyone attending seem to be essential for creating a

quality culture of meetings in the organization. One thing to consider when discussing meeting is why some of the participants come unprepared. Is it because lack of time because of engagement in other projects or just a culture grown in the organization? Furthermore, it seems also important in this case that the person, who calls the meeting, must be clear about what the time will be used for. One reflection in this case is that everything could be about to change the approach and attitude how meetings should be dealt with and fulfilled, to create a culture there time is valued and respect for each other's time is in focus.

When talking about knowledge and specific information needed it seems that, if it is not obvious where to find information, difficulties can occur each time the information is needed. Knowledge can be lost for the organization when only a few people know where to find it. As an example, if knowledge or information needed in project is not accessible in an easy way it takes efforts and time for the employee to obtain the knowledge or information. In worst case the information is not found or found in a late state of the project, which could be devastating for the time frame. This area seems to be a challenge for organizations when individual rewards seem to lie within to keep the knowledge. Knowledge can be seen as power. A culture of sharing knowledge will hopefully be of gain for the whole organization in time, but until the employees sees it is rewarding, the implementation should be enforced by the management. Creating a culture of sharing might be created through a system that pays off for the employees that shares their knowledge. There are ways to transferred knowledge in documents with different technique and methods before storing in a computer system which makes the information easy to reach for everyone working in new projects or the organization. Arenas, beside digital format, where experiences are shared between employees could be of importance for the transfer of the information and knowledge in the organization.

### **6.3 Communication –Inside organization**

Verbal communication is seen in the study as the third largest contributor to delays in projects. Within the structure of the sub-area *communication -inside organization*, factors are identified where the verbal communication causes difficulties and time delay in the projects.

The analysis shows that misunderstandings in the verbal communication between team members is a matter related to why time delays occur in the projects. Inconsistency in the dialogue and two-way communication between the sender and receiver of information seems to be a reason why information do not flow as expected in the projects. Therefore can feedback or other systematic methods for securing the accuracy in communication, be of use to reduce the issues for misunderstandings and misinterpretation in the projects. It gives a possibility to confirm if the information is understood and processed from both the sender and receiver of the information. It also indicates that a need for increased formal cross-functional interaction between functions included in the project. The analysis also shows that different barriers between functions or departments causing low levels of understanding and knowledge of each other's work and can be a reason for difficulty in communication in projects. It can also be seen that an increased way of working with formal communication channels could minimize the risk of rumors spreading and speculations in the organization and the project organization.

One reflection is, even if the projects have recurrent planned cross-functional team-meetings for sharing information and interaction between team members, still issues related misunderstandings and misinterpretation seems to be one reason for delay in the projects. Why is it like this? One reason for time delay could be misunderstandings and misinterpretation between the sender and receiver of the information in the two-way communication. It could also be depending on that the project members have to prioritize between different tasks in different projects and not clear communicate what other issues could affect the work and influence the time frame.

When discussing how the understanding for each other's work influences the communication, it could be of importance for the management to create cross-functional arenas or communication channels where knowledge about the important issues for the other part can be exchange and transferred between members in the organization. In the end, it could be of importance to gain an understanding for what information is required and why, for the other part to realize the need to be clear in communication, and to get an acceptable and satisfactory result. This matter could be of importance both for documentation and in verbal communication to know who will receive and for what the information will be needed in the end.

To minimize and prevent the risk of spreading rumors and speculations in an organization, it could be of importance to create agreed ways of communication. The better these ways of communication are working and used, less interesting the use of informal discussions should be. Hence building up communication channels for everyone and making informed could be a way to stop rumors spreading and speculation. Informal cultures caused by lack, or inconsistency of use of formal communication channels, always seems working against formal ways of communication.

Understanding, respect, valuing each other's roles and time, can be seen as cultural issue and it is only the management how can decide how to work and set good example of how it should be.

#### **6.4 Discussion about the results in the study**

In this section a discussion around the reliability and validity of the results along with possible weak points in the method used and of how it was carried out.

One question to discuss is how the facts are influenced by the project leader. The lessons learned documents or final report, which the study is built on, are written by the project leader and the project leaders are interviewed. Therefore, is the outcome influenced by the project leader's view of the project, even if the result presented in the lessons learned document should represent a unified point of view of all project members. In one aspect the project leader has the responsibility for the result in the end which can influence the documents.

Worth mentioning about the content in the lessons learned is that it may vary from one project to another depending on how mature the technology in the projects has been. Meaning, for instance that the lessons learned from a project that experienced great technological problems has usually focused mainly on these matters rather than on for example perceived difficulties in documentation work. Whilst a project that has experienced less difficulty with technology and that can be seen positioned higher up on the continuous improvement ladder thereby often tend to focus more on for example work processes. The somewhat unbalanced contents between lessons learned in the study is not by the authors seen to have had any negative effects on the study but rather to have offered a wider range of issues to be captured.



An aspect mentioned that could influence the study is the time factor. Meaning that the time elapsed between when the project was completed and now can influence the mind, but even the fact that the lessons learned documents are completed in the end of the project. This last matter could affect the issues mentioned in the document, which could be the ones remembered most important in the end of the project.

This leads to another area of uncertainty in the method, how the issues were ranked by the interviewees. During the interviews in the study it was not all a straightforward task and easy to have the interviewees to rate and place the different issues at different levels on the whiteboard. Two reasons are found to add difficulty to this moment: One, the time that had passed since the project closed as mentioned above. And two, the sometimes perceived difficulties of “quantifying” issues where the issues would be directly compared to other issues in the project studied. Meaning that it in some cases was perceived easy to tell how much time-delay an issue had caused the project. While the interviewees in other cases did not perceive it as direct a task to estimate how much an issue contributed to project time-delay which therefore also made it harder for them to rank the issues in the project.

Another issue that may have influenced the result of the study is how the authors have interpreted and decoded the data from the boards and questionnaires from the interviews. This is likely to have effect on the repeatability of the study. Furthermore, the interaction between the interviewees and the interviewers during the mapping and ranking of issues in the interview sessions might also have influenced the answers and results from the interviews even though a neutral role as interviewers was tried to be kept.

Yet an area that can be discussed is the way that the issues were narrowed down from 162 to 100 by cutting away issues ranked at level three and four. Here it is still believed by the authors that the no issues of importance were discarded since these issues would have been rated at projects’ higher levels together with the fact that most projects contained more than four levels of negative project impact (the average number of levels in the study was eight point five). Hypothetically though, if many projects had contained a few number of levels and the issues at level three and four still would have been cut away this would have led to a loss of significant data. A way of addressing this matter in the future could be to put a weight on each issue individually based upon how much time-delay the specific issue caused the project it appeared in.

There is also the way in how the issues were categorized and sorted into different sub-areas that can be discussed. This was by the authors seen necessary to be able to handle the issues in terms of practicality as well as for analysis purpose. A hypothetical scenario from this could be that an issue of great importance for one project that gets sorted into a sub-area with a large group of lower levelled issues and that therefore will be part of a low ranked sub-area in the overall ranking. In the study no such scenarios have been observed and the consequences of such would have been limited. Partly since all sub-areas have been included in the analysis and partly since the issue would have been likely to appear in more than one project. But again, the above mentioned way of putting weights to individual issues could help to avoid such hypothetical scenario.

To evaluate the reliability of the ranking of the sub-areas, an alternative ranking was created. The alternative ranking took in consideration of how much the projects were delayed. Each

individual issue was weighted from the project time-delay that was experienced in the project that the issue appeared in. For example, project H experienced a delay of 16.9% each issue level value (1 or 2, depending on what level the issue was positioned) was divided by 1.169 to achieve a new weighted “level” value. This meant that the greater the time-delay in percentage the lower the new weighted “level” value was. The calculations then followed the same steps as the non-weighted ranking previously described in detail in section 4.10.

	Uncertainty in Planning, Quality & Riskmanagement	Work processes	Communication Inside Organization	Supplier	Overall planning	Documentation
Rank	1	2	3	4	5	6
Alternative Rank	2	1	3	5	4	8

	Handovers	Management Absence	Project definition	Scopechanges and resource re- distribution	Communication Outside Organization	Resources
Rank	7	8	9	10	11	12
Alternative Rank	6	7	9	10	12	11

*Figure 37 shows Sub-area ranking and comparison with an alternative time delay based ranking*

The result from weighting the issues is presented in Figure 37 and shows a few shifts in rank positions between some sub-areas but can overall be said to correlate well with the ranking method previously used in the report.

#### 6.4.1 Generalization

Factors such as the organizational structure, the organization culture and the type of technology used in the organization can affect the result. Therefore, to generalise the findings and apply them to other companies are not possible.

### 6.5 Further investigation

The authors believe that it can be of interest to continue the research by an investigation of how values and organizational culture affect the way of working in the organization. Furthermore to look more into detail in how the project management model used today fits the work in the organization and in what extent work process models are used as assumed.

## 7 Recommendations

*This chapter presents the recommendations for the factors; Immature technology, Inconsistency in work processes and Verbal communication. The chapter also includes a recommendation regarding lessons learned.*

### 7.1 Immature technology

In response to the above mentioned issues that originate from immature technology, the recommendation will be to increase the technology maturity levels before entering the execution phase of the projects. There are several approaches and models to help provide structure to break down and specify technological requirements in detail which have been seen needed in the projects of this study.

One approach is Mankin's Technology Readiness Levels, TRL (1995). It is a model developed for technology maturity assessment is the Technology Readiness Level by NASA. The model is widely used in organizations and agencies beside NASA such as U.S. Department of Defense, European Space Agency, U. S. Department of Energy and Federal Aviation Administration etc. There have been individual adaptations to the model and there are some differences in the definitions used by different agencies but the model is somewhat overall similar. The purpose of this model is as NASA (2007) stresses the importance of assessment of technology maturity in the early phases of system engineering, a newly invented technology such as components or materials is usually not ready to be incorporated directly into a system without first having been explored, tested and increasingly refined through iterations.

The levels in TRL are defined from TRL 1 - *Basic principles observed and reported* to TRL 9 - *Actual system "flight proven" through successful mission operations*. A detailed description of the levels is presented in theory section 3.2.2.

By assessing technologies against the criteria for each level as an organization can with this gradually evaluate and address what is needed to reach the next level, thus gradually raising the level of maturity step by step before it is implemented in the projects.

A challenge with the model may be to adapt it so that it corresponds well with the technology that the organization wants to develop. Another thing to keep in mind is that a product that is judged mature with high readiness level in one setting does not necessarily mean that it is mature in another setting, as for example in different product systems or environments.

### 7.2 Inconsistency in work processes

Work with continuous improvements to improve the quality of routines and work practices used in the projects in search of better methods. Use techniques as flowcharts and fishbone diagram for constant examination of the way of working and to gain understanding and knowledge about the work practices used in the projects, see section 3.4.1.

Work continuously to secure the tacit knowledge in the project and in the organization. Transfer the tacit knowledge with mechanism such e.g. fishbone diagram and concept mapping to visualize it before translation and managing of the knowledge in the organization, see section 3.4.7. Improve the work securing norms and methods for storing the information, but also for locating and retrieving stored information for the organizational learning, see section 3.4.5.

### **7.3 Verbal communication**

Work to secure the dialogue and two-way communication between sender and receiver to reduce misunderstandings and misconception, the use of feed-back in the communication is of importance when information is transferred between team members. Working with feed-back in a structured way that creates a higher level of the accuracy in the understanding if information is transferred correctly, is of importance. Introduce visual communication or visual planning, described in section 3.5.3, to improve the interaction between team members during the meetings. The method can improve, according to literature, the mutual problem discovery and a shared cross-functional understanding. This method can be used as a complement to the work with feedback and be beneficial to improve the verbal communication and the understanding for each other's work between the members in the project.

To prevent the risk for spreading rumors and speculations create agreed ways of communication and secure that these ways are used in the organization, see section 3.5. In this area the organization management has a possibility to create formal communication channels between sender and receiver of the information.

### **7.4 An additional recommendation regarding lessons learned**

A recommendation for the future creations of lessons learned from the projects could be to not only include the problems that have arisen during the projects, but also to include the project group's estimation of how much delay in time each issue has contributed to in the project specified in for example days or weeks. By this, meaning a form of numeric weighting of the issues that could make it easier to learn the extent of project impact of issues within a specific project, as well as to contribute to a less difficult comparison of issues between all projects in the organization and thereby making it easier find out what issues to focus on in the work of continuous improvement.

## 8 References

- Aalto, T., M. Martinsuo, et al. (2003). "Project portfolio management in telecommunications R&D: Aligning projects with business objectives". *Handbook of product and service development in communication and information technology*, ed. T. O. Korhonen and A. Ainamo. Boston: Kluwer Academic Publishers: p.p. 99–147.
- Adler, P., Mandelbaum, A., Nguyen, V. and Schwerer E. (1995) "*Managerial and Methodological Challenges in Engineering Process Management: Lessons from a Case Study*," in Design Management, S. Dasu and C. Eastman (Eds.), Kluwer, Amsterdam
- Alänge, S., (1994) "The New Paradigm for Industrial Practices, Total Quality Management". CIM Working Papers, No. WP 1994-01, ISSN 0280-9753.
- Antoni M., Nilsson-Witell L., Dahlgaard J.J (2005) "Inter-project improvement in product development" *International Journal of quality & Reliability Management*, Vol.22, No.9, p.p.876-893.
- Argyris C. (1999) "*On organizational learning*" Blackwell Publishers Ltd: Oxford
- Bellika, T.-A., Arleth, J., Varnes, C.J. (2004). "*Profitable innovation management practices – Benchmarking tools reveal large profit potential in innovation*". Available at [http://www.telenor.com/en/resources/images/Page\\_102-108\\_tcm28-45382.pdf](http://www.telenor.com/en/resources/images/Page_102-108_tcm28-45382.pdf) [Accessed: January 30, 2012 ]
- Black et al (2001) "Past the tipping point: the persistence of firefighting in product development" *California Management Review*, Vol24, No4, p.p.44-63.
- Bergman B. and Klefsjö B., (2008) "*Quality for customer needs to customer satisfaction*" Studentlitteratur AB: Lund.
- Boyer, K.K. and Lewis, M.W. (2002) "Competitive priorities: investigating the need for trade-offs in operations strategy", *Production and Operations Management*, Vol.11, No.1, p.p.9–20.
- Bryman and Bell. (2011). *Business Research Methods*, 3rd edition, Oxford University Press
- Chen, B. and Ghaedian, S. (2012) *How to support and facilitate knowledge flow in PD at Volvo Group Trucks Technology*, Thesis Paper, Chalmers University of Technology
- Chennamaneni, A. and Teng J.T.C (2011)"An integrated Framework for Effective Tacit knowledge Transfer" *Proceeding of the Seventeenth Americas Conference on Information System*, Michigan August 4<sup>th</sup>-7<sup>th</sup> 2011.
- Cooper, R.G., Edgett, S.J., Kleinschmidt, E.J., (2004)" Benchmarking best NPD practices – II, *Research Technology Management*; May/Jun; Vol. 47, No. 3; p.p.50-59.

Dawson B. (2007) "*The Impact of Technology Insertion on Organizations*" Human Factors Integration Design Technology Centre. Available at:  
<http://www.hfidtc.com/research/process/reports/phase-2/HFIDTC-2-12-2-1-1-tech-organisation.pdf>. [Accessed: 20 May 2012]

Deen J. and Bowen E. (1994) "Management theory and total quality: Improving research and practice through theory development", *The Academy of Management Review*, Vol. 13, No .3, pp.392-418.

de Weerd-Nederhof, P.C Bernice, P.C, da Silva Gomes, J.F and Pearson A.W (2002) Tools for the improvement of organizational learning process in innovation" *Journal of Workplace Learning*, Vol. 14, No.8, pp. 320-331.

De Long, D.W. and Fahey, L. (2000) "Diagnosing cultural barriers to knowledge management", *The Academy of Management Executive*, Vol. 14, No. 4, pp. 113-127.

Eklund J. (2000) "Development work for quality and ergonomics" *Applied Ergonomics* Vol.31. pp. 641-648.

Ernst, D. and Kim, L., (2002)"Global production networks, knowledge diffusion and local capability formation" *Research Policy*, Vol. 31, No.8-9, pp.1417-1429.

Fiol M. and Lyles M., (1985) "Organizational Learning" *Academy of Management Review*, Vol.10, No.4, p. p. 803-813.

Ferdows, K. and De meyer, A. (1990) "Lasting Improvements in Manufacturing Performance: In Search of a New Theory," *Journal of Operations Management*, Vol. 9, No.2, p.p.168–184.

Friedman J.V. and Berthion Antal A., (2005) "Negotiating Reality A Theory of Action Approach to Intercultural Competence", *Management Learning* Vol. 36, No.1, p.p. 69–86.

Goffin, K., Koners, U., Baxter, D. and Hoven, C, (2010) "Managing lessons learned and tacit knowledge in new product development", *Industrial Research Institute*, July-August, pp.39-51.

Government Accountability Office (2008) Available at:  
<http://www.gao.gov/new.items/d08467sp.pdf> [Accessed: 20 May 2012]

Groenveld (2007)" Roadmapping integrates business and technology" *Research Technology Management* (Nov-Dec):p.p. 3-19.

Guba, Egon G. & Lincoln, Yvonna S. (1985). *Naturalistic Inquiry*. Newbury Park: Sage Publications.

Hallikas, J., Karvonen, I., Pulkkinen, U., Virolainen, V.-M., Tuominen, M, (2004) "Risk management processes in supplier networks", *International Journal of Production Economics*, Vol. 90, No.1, p.p. 47–58.

- Hansen M.T., Nohria N., Tierney T. (1999) "What's your strategy for managing knowledge?" *Harvard Business Review*, March-April, p.p.106-116.
- Huber G. (1991) "Organizational Learning: The contributing processes and the literature" *Organization Science*, Vol.2, No.1, p.p.88-115.
- House C.H., Price R.L. (1991) "The Return Map: Tracking Product Teams" *Harvard Business Review*, January-February, p.p.92-100.
- Howell, G., and Ballard, G. (1996) "*Managing uncertainty in the piping process*" RR47-13, Constr. Industry Inst., University of Texas, Austin, Texas.
- Högman U. (2011) "*Processes and Platforms Aligned with Technology Development - The Perspective of a Supplier in the Aerospace Industry*". PhD Dissertation at Department of Product and Production Development, Gothenburg, Sweden, Chalmers University of Technology.
- Institute, Project Management (2008) "*A guide to the project management body of knowledge*" (pmbok guide), fourth edition. [Books24x7 version] Available at: <http://common.books24x7.com.proxy.lib.chalmers.se/toc.aspx?bookid=29854>. [ Accessed: 20 May 2012 ]
- Jenkins, M; Ambrosini, V and Collier, N. (2007), "*Advanced Strategic Management; A Multi-perspective Approach*", Palgrave MacMillan.
- Johnson, G. and Scholes, K. and Whittington, R. (2011) "*Exploring Strategy*", Ninth Edition. Financial Times Prentice Hall. ISBN 0273737007
- Kappel, T.A (2001) "Perspective on roadmaps: how organizations talk about the future" *The Journal of Product Innovation Management*, Vol.18, p.p.39-50.
- Kim D. (1993) "The link between individual and organizational Learning" *Sloan Management Review*, Vol. 35, No.1, p.p. 37-50.
- Kotnour, T. (1999) "A learning Framework for Project Management" *Project Management Journal*, Vol.30, No.2, p.p.32-38.
- Kerzner H. (2003) "*Project Management: A system approach to planning, scheduling and controlling*" 7<sup>th</sup> edition, John Wiley & Sons; US
- Lindlöf L. , Söderberg B., (2011) "Pros and cons of lean visual planning: experiences from four product development organizations", *International Journal of Technology Intelligence and Planning*, Vol. 7, No. 3, p.p. 269-279.
- Magnusson, M. (2004) "*Managing the knowledge landscape of an MNC: Knowledge networking at Ericsson*", *Knowledge and Process Management*, Vol. 11, No. 4, p.p.261-272.
- Maltén, A., (1992) "*Grupputveckling*" Studentlitteratur, Studentlitteratur AB: Lund.

- Mankins, J. (1995) *"Technology Readiness Levels: A White Paper"*, Advanced Concepts Office, Office Space Access and Technology, NASA.
- Melton, T. and Iles-Smith, P. (2009) *"Managing Project Delivery: Maintaining Control and Achieving Success"*, Elsevier Science, ISBN:9780750685153
- Meredith J.R. and Mantel S.J., (2012) *"Project Management: A managerial approach"* 8th edition, John Wiley & Sons; US
- NASA (2007) *"Systems Engineering Handbook"*, Washington D.C., National Aeronautics and Space Administration: 340.
- Nobeoka, K. and Cusumano, M.A. (1997) "Multiproject strategy and sales growth: The benefits of rapid design transfer in new product development" *Strategic Management Journal*, Vol.18 (March) p.p.169–186.
- Nonaka, I., (2007) "The knowledge-creating company" *Harvard Business Review*, Vol. 85, Issue 7/8, p.p.162-171
- Nonaka, I. and Konno, N., (1998)"The concept of "Ba": Building foundation for knowledge creation" *California Management Review*, Vol. 40, No.3, p.p.40-45
- Olausson D., Berggren C. (2010) "Managing uncertain, complex product development in high-tech firms: in search of controlled flexibility" *R&D Management*, Vol.40, Nr. 4 p.p 383-398.
- Oliver, David W.; Timothy P. Kelliher, James G. Keegan, Jr. (1997). *"Engineering Complex Systems with Models and Objects"*. McGraw-Hill, p.p. 85–94., ISBN 0-07-048188-1
- Parry G.C, Turner C.E (2006) "Application of lean visual process management tools" *Production Planning and Control*, Vol.17, Nr 1, p.p. 77-86.
- Patel, Runa & Davidson, Bo. (2003). *Forskningsmetodikens grunder*. Lund: Studentlitteratur.
- Pawar, S.P., Menon U, Riedel J.C.K.H, (1994)"Getting goods to market fast – and first. Time to Market" *Integrated Manufacturing Systems*, Vol. 5 No. 1, 1994, p.p. 14-22.
- Priest, J.W. and Sánchez, J.M. (2001). *Product Development and Design for Manufacturing: A Collaborative Approach to Producibility and Reliability*, Marcel Dekker, 2001, New York, NY., ISBN: 0824799356
- Schein, E. (2010) *"Organizational Culture and Leadership"* (4nd Ed.), San Francisco, CA, Jossey-Bass.
- Shani, A.B. et al, (2009). *Behavior in organizations - an experimental approach*. New York: McGraw Hill/Irwin.
- Sebestyén U. (2006) *"Multiprojectledning-skapar puls i produktutveckling med lean tänkande"* Parmatur; Rönninge; Sweden



Skinner, W. (1996) "Manufacturing: Missing Link in Corporate Strategy," *Harvard Business Review* (May-June), p.p.136-145.

Slack, N. and Lewis, M. (2008) *Operations Strategy* 2nd ed. Financial Times Prentice Hall

Smith, P and Reinertsen, D. (1991) "*Developing Products in Half the Time*" Van Nostrand Reinhold Publishers, New York.

Swink M. and Way M.H. (1995) "Manufacturing strategy: proportions, current research, renewed directions", *International Journal of Operations and Production Management*, Vol.15, No.7, p.p. 4-26.

Tan, K.H and Matthews R.L (2009) "*Operations strategy in action: a guide to the theory and practice of implementation*", Edward Elgar Publishing Ltd

Thomke S and Fujimoto T. (2000) "The effect of "front-loading" problem solving on product development performance", *Journal Product Innovation Management*, Vol. 17, (March), p.p. 128-142.

Trygg, L. (1991), "*Engineering Design — Some Aspects of Product Development Efficiency*", PhD Dissertation at Department of Industrial Management and Economics. Gothenburg, Sweden, Chalmers University of Technology.

Vesey, J.T., (1992) "Time-to-Market: Put Speed in Product Development" *Industrial Marketing Management*, Vol 21, p.p.151-158.

Van Vuuren M. and Elving W.J.L (2008) "Communication, sensemaking and change as a chord of three strands", *Corporate Communications: An International Journal*, Vol. 13 No. 3, p.p. 349-359.

von Zedtwitz, M., (2002) "Organizational learning through post-project reviews in R&D" *R&D Management*, Vol. 32, No.3, p.p.255-267.

Wheelwright, S. and Clark, K. (1992). *Revolutionizing Product Development*. New York, NY: The Free Press

Yin, R.K. (2003): *Case Study Research, design and methods*, 5th edition, Sage Publications Inc., Thousand Oaks (CA, USA)

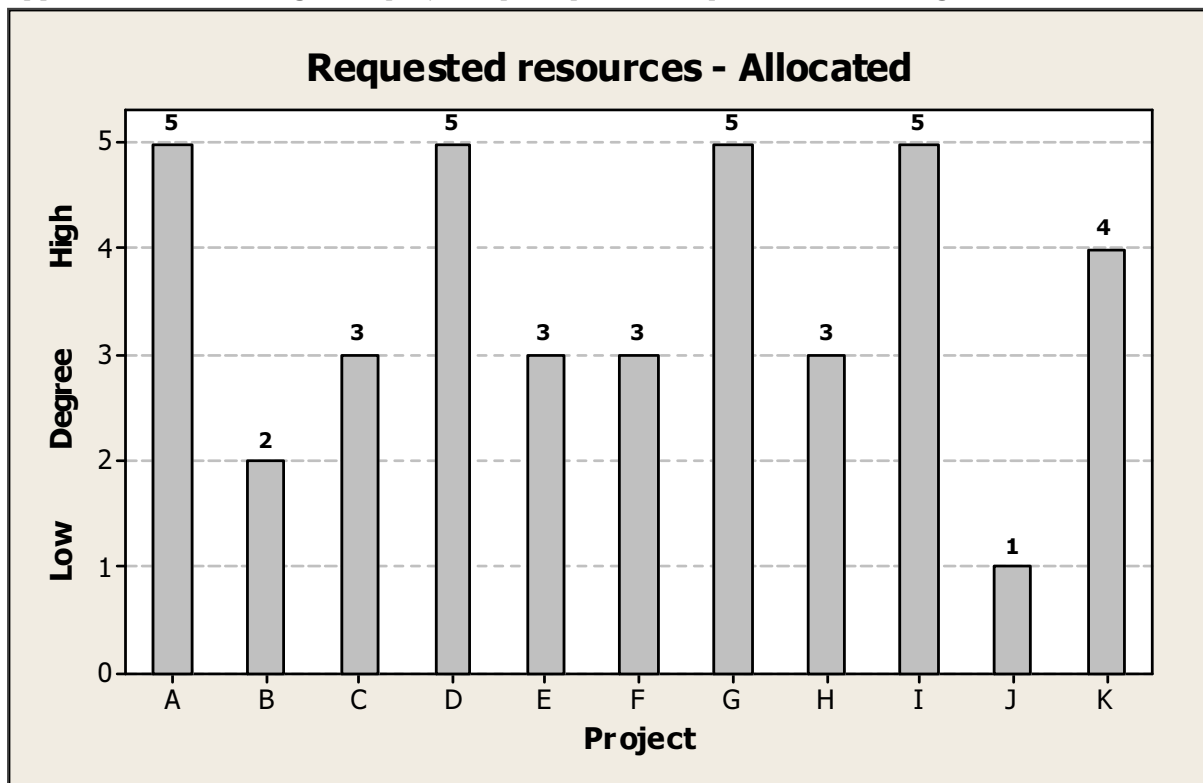
## 9 Appendix

Appendix 1 – shows projects affected by scope-changes

Filter: *Management, Scope-changes and resource re-distribution*

Project	Original Level	Number of Levels	Weighted Level	Issue
B	1	7	1	Project time consuming contributor Scope in - Scope out
J	2	6	2	New work-packages added to scope

Appendix 2 – shows degree of projects' perception of requested resources granted

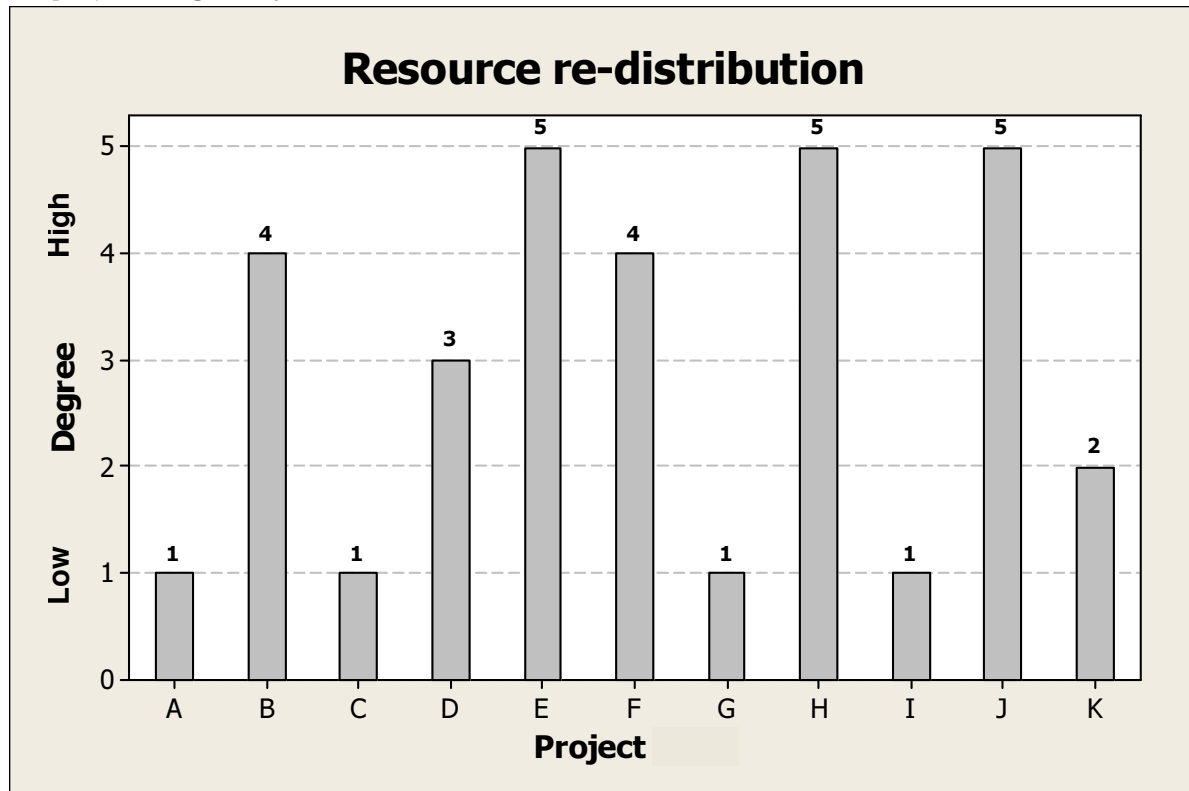


Appendix 3 – shows projects affected by resource re-distribution.

Filter: *Management, Scope-changes and resource re-distribution*

Project	Original Level	Number of Levels	Weighted Level	Issue
B	3	7	2	Resource re-distribution
D	3	9	2	Prioritizing => Resource re-distribution
H	6	15	2	Resource re-distribution 20+30+50<100%

Appendix 4 – shows degree of projects' perception of how resource re-distribution has affected the projects negatively



Appendix 5 – shows overall planning issues in projects

Filter: *Management, Overall planning*

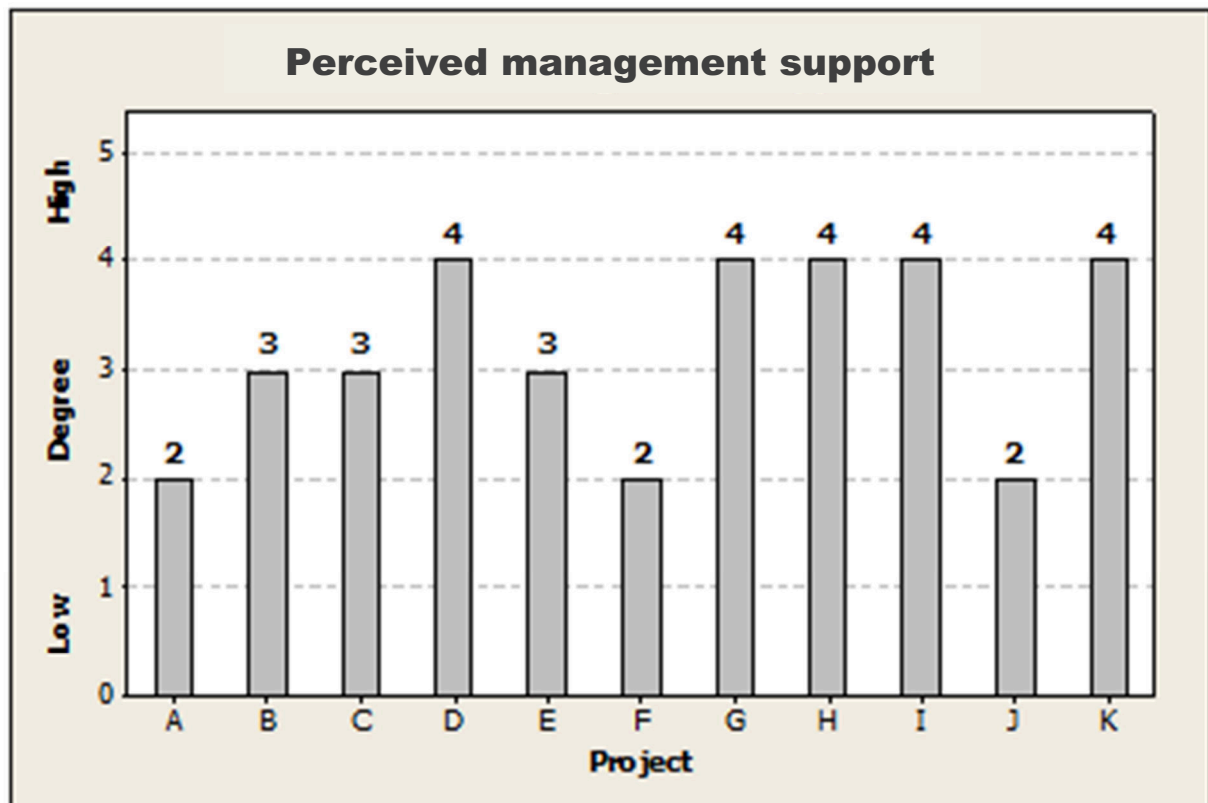
Project	Original Level	Number of Levels	Weighted Level	Issue
B	2	7	2	Many activities started at the same time in the organization
C	1	9	1	Dependent projects not synchronized with each other
C	1	9	1	Resources needed in other projects - moved
C	3	9	2	Integration activities between sites not scheduled
D	1	9	1	Better project available within the organization?
E	2	7	2	Equipment synchronization burst - bottleneck
F	4	13	2	Decision on total cost evaluation on feature to be added to project
G	1	2	1	Project delivery to other project missed delivery slot

Appendix 6 – shows issues concerning project definition

Filter: *Management, Project definition*

Project	Original Level	Number of Levels	Weighted Level	Issue
E	1	7	1	Project definition - Transfer of elements included projects done in two steps insted of one direct
H	1	15	1	Project definition - Included in-house activities that prviously had been outsourced. A reasearch project would have helped
I	1	9	1	A system setup approach would have gained the project

Appendix 7 – shows perceived management support during project time

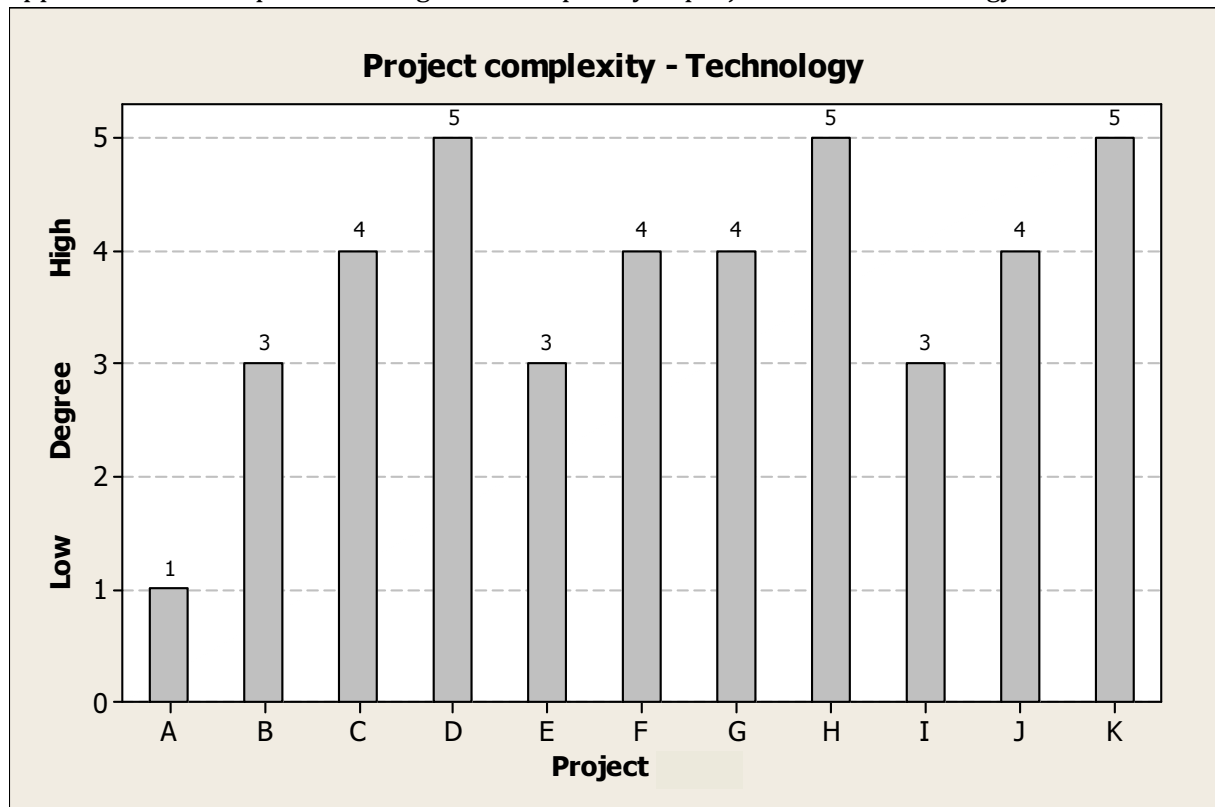


Appendix 8– shows issues of management absence

Filter: *Management, Management absence*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	1	12	1	Project Steering Group missing for a period of time
B	1	7	1	Project Steering Group missing for a period of time
D	1	9	1	Line manager missing for a period of time
J	3	6	2	Project Steering Group missing for a period of time

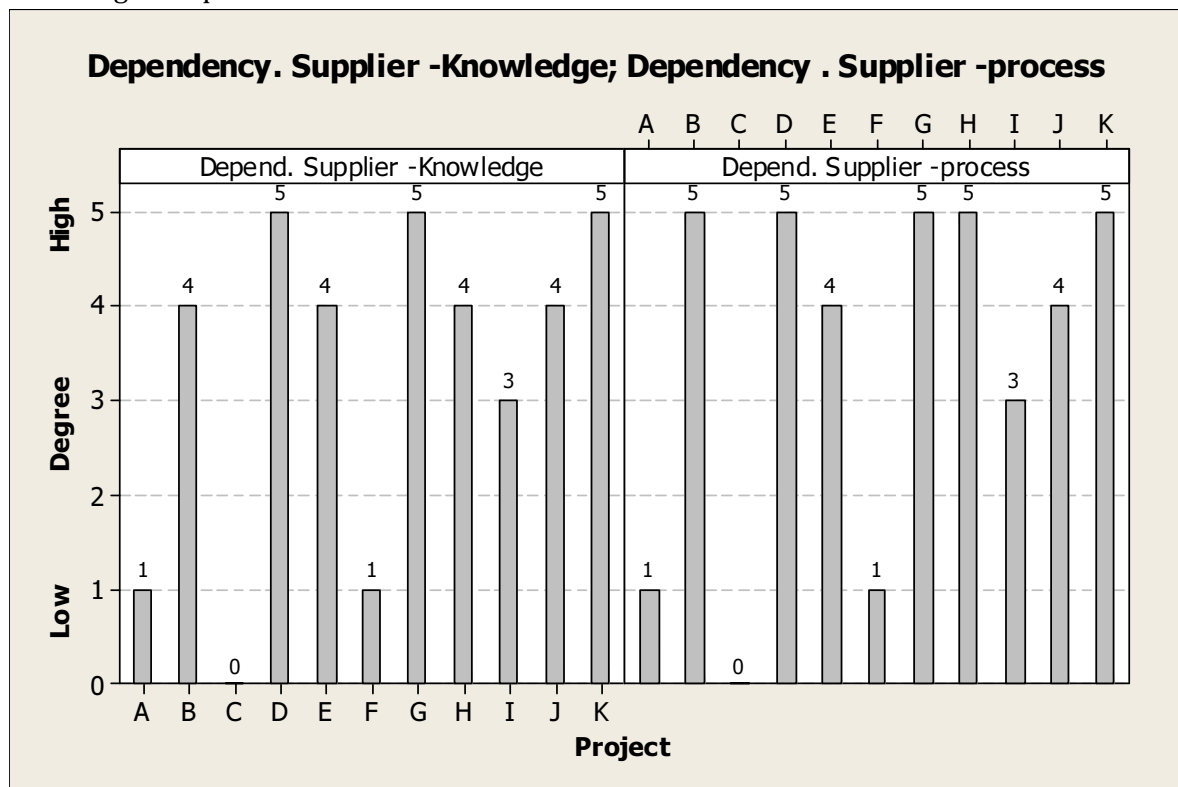
Appendix 9– shows perceived degree of complexity in projects due to technology



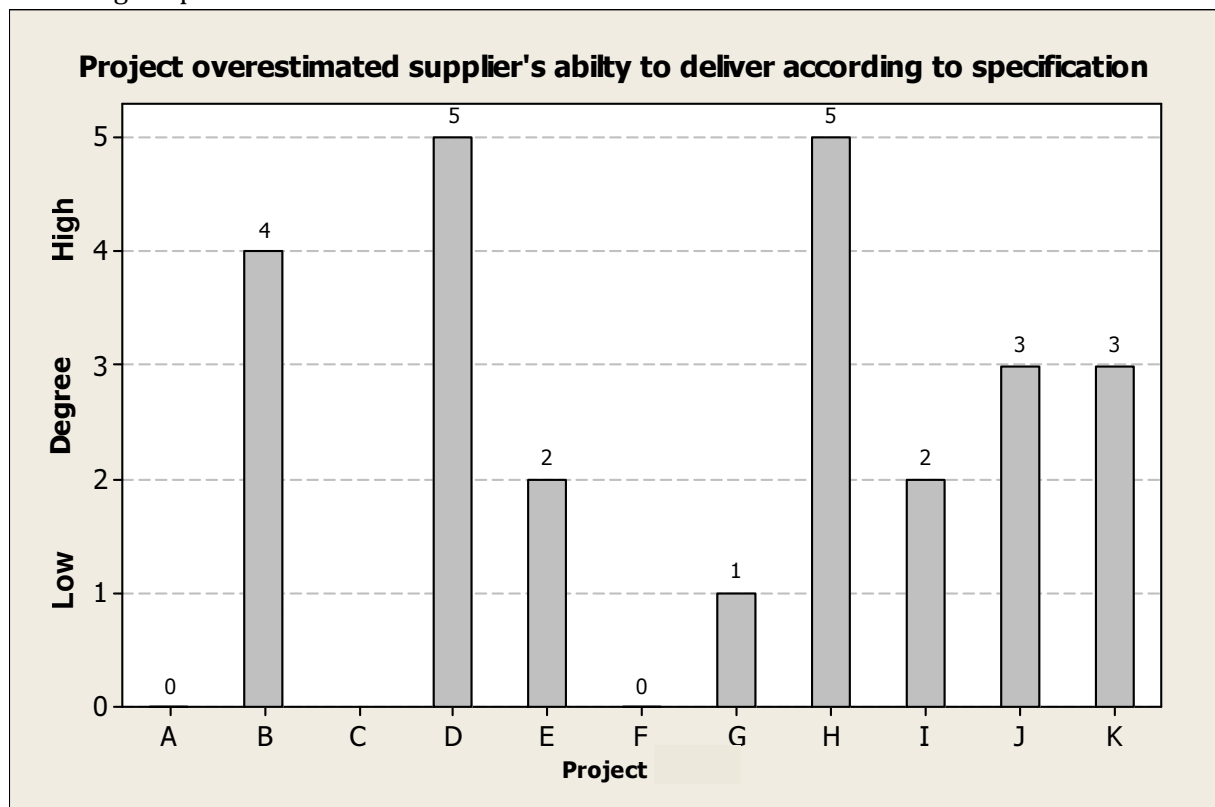
Appendix 10 – shows projects that experienced issues related to technology maturity  
Filter: *Technology maturity*

Project	Original Level	Number of Levels	Weighted Level	Issue	Technology Maturity Number of issues: 30
A	2	12	1		1
A	5	12	2		2
C	3	9	2		2
D	1	9	1		1
D	1	9	1		1
D	1	9	1		1
D	2	9	1		1
D	2	9	1		1
E	1	7	1		1
F	1	13	1		1
F	3	13	1		1
F	4	13	2		2
F	4	13	2		2
F	4	13	2		2
F	4	13	2		2
G	2	2	2		2
H	2	15	1		1
H	3	15	1		1
H	3	15	1		1
H	5	15	2		2
H	5	15	2		2
H	5	15	2		2
H	6	15	2		2
I	1	9	1		1
I	2	9	1		1
J	1	6	1		1
J	1	6	1		1
J	1	6	1		1
K	1	4	1		1
K	1	4	1		1

Appendix 11– shows projects perceived degree of dependence of the project suppliers' knowledge and processes



Appendix 12– shows projects perceived degree of overestimation of suppliers' ability to deliver according to specification



Appendix 13– shows issues related to suppliers and technology maturity

Filter: *Technology Maturity, Supplier*

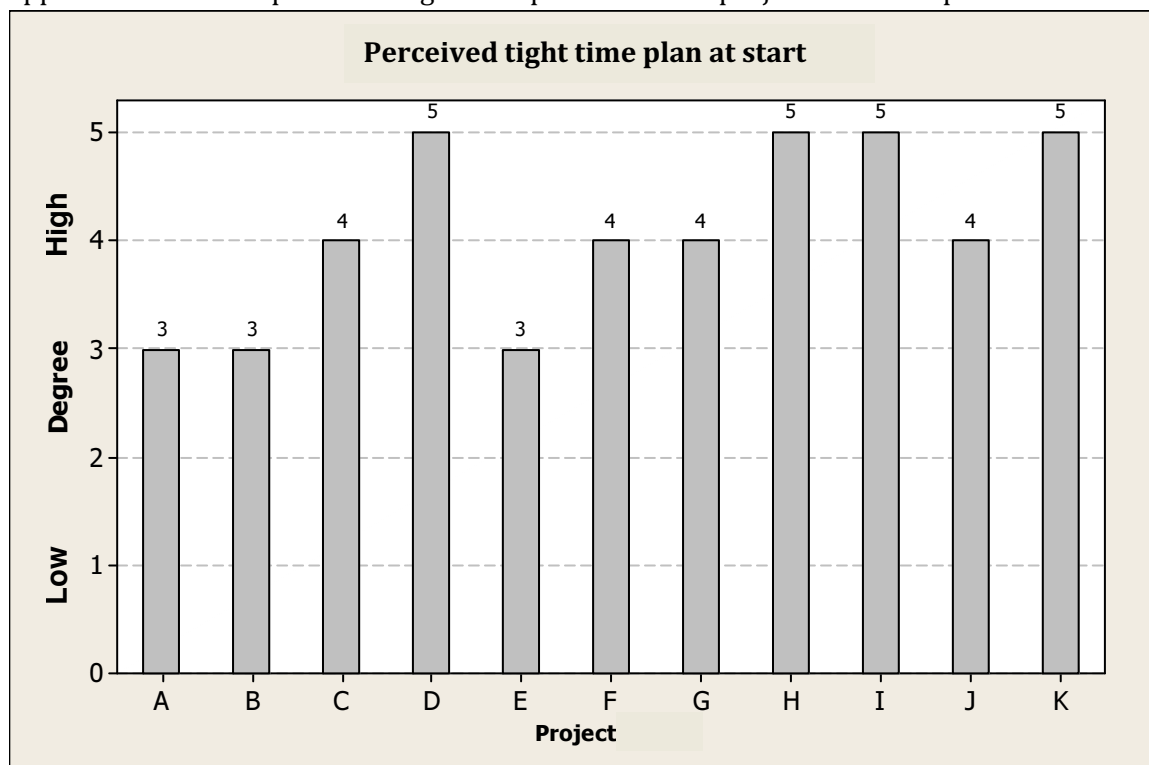
Project	Original Level	Number of Levels	Weighted Level	Issue
D	1	9	1	Few capable suppliers in the world to chose from
D	1	9	1	Supplier promised more than could be held
G	2	2	2	Supplier promised more than could be held
H	2	15	1	Lack of quality assurance in supplier process - New technology
J	1	6	1	Overestimated supplier capability to develop their processes
J	1	6	1	Few capable suppliers in the world to chose from. Intended supplier not approved initially
K	1	4	1	Supplier processes neede to be develop due to new technology

Appendix 14– shows issues of lack of resources related to technology maturity

Filter: *Technology Maturity, Resources*

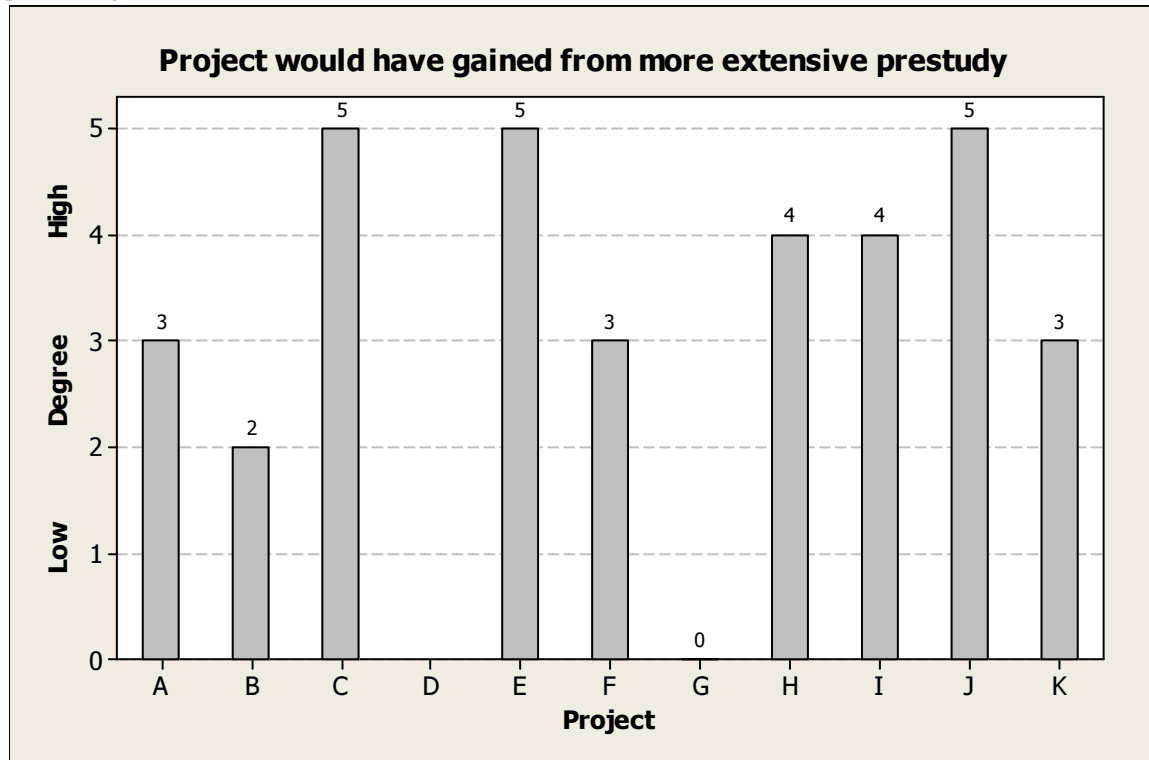
Project	Original Level	Number of Levels	Weighted Level	Issue
F	4	13	2	Lack of resources with needed competence
F	4	13	2	Key-resources became bottlenecks when needed in many activities within the organization
H	6	15	2	Lack of resources with needed competence. Expertise in pre-study phase

Appendix 15– shows perceived tight time plan at start of project execution phase





Appendix 16 – shows projects perceiving that they would have gained from a more extensive pre-study



Appendix 17– shows projects experiencing issues in the planning stage of the project due to uncertainty in technology

Filter: *Technology Maturity; Uncertainty in Planning, Quality & Risk-management*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	2	12	1	Planning - Further competence needed for balance
C	3	9	2	Planning - Higher level of detail needed for accurancey in planning
D	1	9	1	Knowledge neded to decrease risks
F	3	13	1	More difficult and time-consuming than expected
H	3	15	1	Lacked of experience made planning difficult
G	5	15	2	Planning - Earlier known cycled times diffent to new
I	1	9	1	Planning - Earlier known cycled times diffent to new
J	1	6	1	Uncertainty led to burst of planned time schedule

Appendix 18 – shows issues from technology uncertainty that affected tests and verification in projects. Filter: *Technology Maturity; Uncertainty in Planning, Quality & Risk-management*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	2	12	1	Further cross-functional evaluation over was needed
C	1	9	1	Uncertainty and lack of details led to misunderstandings in verification
F	4	13	2	Uncertainty and risk management in test resulted in further work later on

Appendix 19– shows project business case affected by planning of phase-in / phase-out synchronization

Project	Original Level	Number of Levels	Weighted Level	Issue
E	1	7	1	Planning - Synchronization phase-in phase out weakned business case

Appendix 20– shows technology uncertainty impact on quality and workload  
Filter: *Technology Maturity; Uncertainty in Planning, Quality & Risk-management*

Project	Original Level	Number of Levels	Weighted Level	Issue
I	2	9	1	Technology uncertainty led to wrong requirement specification
K	1	4	1	Technology uncertainty led to great variation spread in quality

Appendix 21– shows technology uncertainty effects on risk-management in projects  
Filter: *Technology Maturity; Uncertainty in Planning, Quality & Risk-management*

Project	Original Level	Number of Levels	Weighted Level	Issue
D	1	9	1	Minimization of uncertainty needed
F	4	13	2	Risk management would have gained from further knowledge
H	5	15	2	High complexity - would have gained from further knowledge from pre-study
I	2	9	1	Gain if requirements further investigated
J	1	6	1	Pre-study had helped knowledge on possibilities

Appendix 22– shows issues concerning way of working

Filter: *Way of working, documentation*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	2	12	1	Documentation - missing information, more detailed needed to understand consequences
A	4	12	2	Documentation - lack of information to keep control on equipment
B	2	7	2	Documentation - information forgotten
C	3	9	2	Documentation - information missing
H	7	15	2	Documentation - knowledge had to be updated about component
I	3	9	2	Documentation - data known in the organization was not stored in the information system
I	3	9	2	Documentation - need of formalised documentation due to different sites.

Appendix 23– shows issues concerning way of working

Filter: *Way of working, work processes*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	5	12	2	Work processes - documentation - coordination of prototypes
G	1	2	1	Work processes - documentation to support sub-contractors

Appendix 24– shows issues concerning way of working

Filter: *Way of working, work processes*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	4	12	2	Work processes - test equipment - differences between test results
A	3	12	1	Work processes - test equipment - quality of test equipment
C	3	9	2	Work processes - review process
D	4	9	2	Work processes - review process
H	2	15	1	Work processes - evaluation process of suppliers

Appendix 25– shows issues concerning way of working

Filter: *Way of working, work processes*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	3	12	1	Work processes - time for trouble report corrections
C	1	9	1	Work processes - tool
D	2	9	1	Work processes - iterations caused by low quality from supplier
E	1	7	1	Work processes - inheritance from former project
F	1	13	1	Work processes - new product optimistic plan
F	3	13	1	Work processes - changed standard resulted in rework

Appendix 26– shows issues concerning way of working

Filter: *Way of working, work processes*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	4	12	2	Handover between project - documents and recourse
C	1	9	1	Handover between project - project closed
C	3	9	2	Handover between project - documents and recourses
D	3	9	2	Handover between people-people
D	4	9	2	Handover within project
E	1	7	1	Handover - close down of site

Appendix 27– shows issues concerning communication

Filter: *Communication, outside organization*

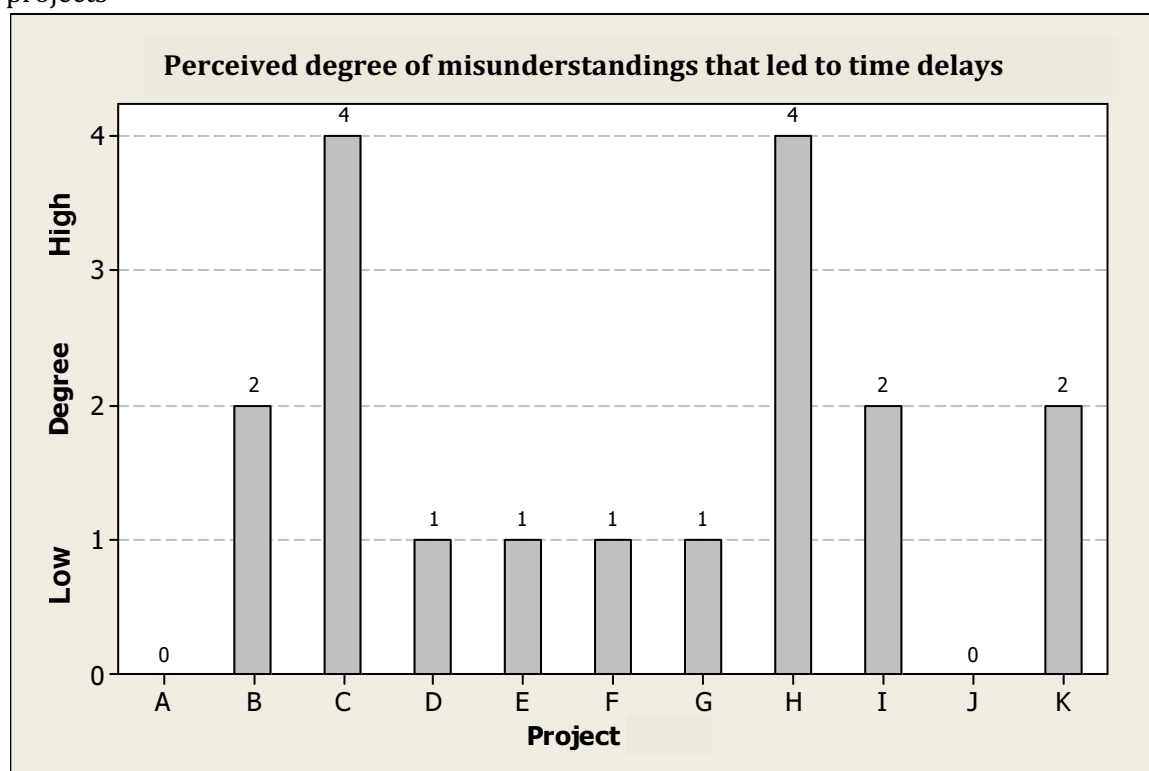
Project	Original Level	Number of Levels	Weighted Level	Issue
D	1	9	1	Communication with supplier -interaction
H	5	15	2	Communication with supplier - lead time with little feedback

Appendix 28– shows issues concerning communication

Filter: *Communication, inside organization*

Project	Original Level	Number of Levels	Weighted Level	Issue
A	4	12	2	Communication between functions - formal meeting needed
B	1	7	1	Communication between functions - rumour
C	1	9	1	Communication between functions - misunderstanding
C	1	9	1	Communication between functions - different sites
H	4	15	2	Communication between functions - unidentified roles from beginning
C	2	9	1	Interaction between functions - different sites
K	2	4	2	Interaction between functions - different sites
H	6	15	2	Interaction between functions - understanding

Appendix 29– shows perceived degree of misunderstandings causing negative impact on the projects



Appendix 30– shows issues concerning communication

Filter: *Communication, inside organization*

Project	Original Level	Number of Levels	Weighted Level	Issue
B	1	7	1	Culture - Informal way of working - decision making rumers
D	4	9	2	Culture - Informal problem-solving
I	2	9	1	Culture - Informal way of working - administration

## Appendix 31- Questionnaire

*Please make a circle around the option that best matches your view on the project*

In what extent did the project perceive managements support during the project time?

(Little support) **1 2 3 4 5** (Great support), **Do not know, Others:**

---

In what extent was the project time affected out of resource redistribution during the project time? (E.g. Project team member moved to another project)

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what extent increased workload at these reallocations?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

Was the project affected by changes in the organization during the project time?  
(E.g. closure of a site, managerial changes, from silos to programs or similar ..)

**If so, what affected? :**

And in what extent did it affect the project time?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

How big a number of the project (number of members) consisted of **internal** versus external resources?  
(E.g. internal resources versus consultants) (%)

**0 10 20 30 40 50 60 70 80 90 100** , **Do not know, Others:**

---

How big a number of the project consisted out of what external suppliers delivered to the project? (E.g. outsourcing) (E.g. budget could be used to assess the ratio?) (%)

**0 10 20 30 40 50 60 70 80 90 100** , **Do not know, Others:**

---

To what extent was the project given high priority compared to other projects running at the same time?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

How clear were the project conditions at the project start?

-Regarding the project scope?

(Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

-Regarding the resources allocated?

(Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

-Regarding the project's interdependency to other projects?

(Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

To what extent was the project goals perceived clear at the project start?

-Regarding to what was to be delivered?

(Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

-Regarding to whom to deliver? (E.g. to what project, external customer, etc.)

(Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

How clear were the roles and who is responsible for what? (During the project)

(Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

To what extent was the project dependent on other projects?

-Regarding equipment? (Eg, test equipment, etc.)

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

-Regarding other project deliverables into the project?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

-Regarding the project deliverables into other projects?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

To what degree was the complexity high in the project?

-With respect to technology?

(Not at all) **0**, (Low complexity) **1 2 3 4 5** (High complexity), **Do not know, Others:**

-Regarding the project as a whole? (Including e.g. engineering, planning, internal vs. external resources, outsourcing, etc.)

(Not at all) **0**, (Low complexity) **1 2 3 4 5** (High complexity), **Do not know,**

**Others:**

**And what was the main contributor of complexity in the project? :**



---

In what extent did you perceive that the organization had high expectations on the project outcome?

(Not at all) **0**, (Low complexity) **1 2 3 4 5** (High complexity), **Do not know, Others:**

---

Was the project given enough time in the project for team building?

(Not at all) **0**, (Low complexity) **1 2 3 4 5** (High complexity), **Do not know, Others:**

---

In what degree did the communication work well?

-Between the team members?

(Not at all) **0**, (Less well) **1 2 3 4 5** (Very well), **Do not know, Others:**

-Between the project and sub-contractors?

(Not at all) **0**, (Less well) **1 2 3 4 5** (Very well), **Do not know, Others:**

-Between the project and consultants?

(Not at all) **0**, (Less well) **1 2 3 4 5** (Very well), **Do not know, Others:**

-Between project and other parts of the company? (E.g. line etc.)

(Not at all) **0**, (Less well) **1 2 3 4 5** (Very well), **Do not know, Others:**

---

To what extent did handovers work well in the project? (E.g. documentation, support etc.)

-Between the team members?

(Not at all) **0**, (Less well) **1 2 3 4 5** (Very well), **Do not know, Others:**

- Between the project and sub-contractors?

(Not at all) **0**, (Less well) **1 2 3 4 5** (Very well), **Do not know, Others:**

- Between the project and consultants?

(Not at all) **0**, (Less well) **1 2 3 4 5** (Very well), **Do not know, Others:**

- Between the project and other parts of the company? (E.g. line, etc.)

(Not at all) **0**, (Less well) **1 2 3 4 5** (Very well), **Do not know, Others:**

---

In what degree did misunderstandings lead to delays in project time?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

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In what degree was there an open climate within the project team? (E.g. prestige)

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what degree was the team members reached by information from project steer group meetings?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

To what extent was the "right" people attending the meetings during the project? (E.g. t review meetings, PSG meetings etc.)

(Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

To what extent would a moderator have helped the project at the meetings?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what extent was the project given the resources requested by the project?

(Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what degree did the project have sufficient authority in relation to responsibility?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what degree was the timetable perceived tight for the project at the project start?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

How many projects did you work with at the same time? : \_\_\_\_

---

How big a part (estimated in percent) of the project members were full-time associated with the project?

**0 10 20 30 40 50 60 70 80 90 100**

---

To what extent did different ways of working in different parts of the project cause problems to the project?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what degree did work within the project deviate from defined ways of working?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what extent did the use of different computer work tools in different parts of the project cause problems to the project?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what extent was the necessary information easily accessible to project members?  
(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

To what degree would education have helped the project (in terms of time)?

-Regarding the ways of working  
(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

-Computer work tools  
(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

-Configuration Management (CM)  
(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

-TR Specification  
(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

To what degree was documentation within the project written during the project time? Where  
1 = Insufficient, 3 = OK, 5 = Overdoing it

**1 2 3 4 5 , Do not know, Others:**

---

In what extent was lessons learned gone through before the project start?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

---

In what extent was there a part of the project where the project would have gained from (in  
terms of time) if this part would have been more carefully included in the planning stage?  
(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others:**

If so, what sorts of things:

---

To what extent were there critical points identified in the project while planning the project?  
(E.g. bottlenecks etc.)

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

In what extent was it about these critical points that problems later arose?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

Were there any parts in the project that were "compressed" more than others to reduce the  
project's delay, and **if so which one / ones?** (E.g. testing, etc.)

: \_\_\_\_\_

Was the system responsible involved early enough in the project?

**Yes, No, Do not know**

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Did the testing plan work as intended? : \_\_\_\_\_

If no: What did not work?:

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How many people worked on the feasibility study? :

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To what degree were the right skills available at the feasibility study?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

In what degree was enough resources spend early in the project to minimize uncertainties in the project?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

To what extent were preventive measures taken from the project's risk assessment?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

**What was done?:**

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In what degree was the risk assessments updated during the project time? :

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

In what degree were there detailed action plans formed to deal with problems that could emerge as from the risk assessment?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

What was mainly the technical problems that arose?

(For example: Materials, Design, Effects of previous projects, TR, equipment, interface, etc.)  
:

---

In what degree did demands on technical features backward compatibility affect the time duration of the project?

(E.g. ensuring that new products work well with products already delivered / installed at customers)

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

To what extent was the project dependent on suppliers:

-Knowledge?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

-Processes?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

Were their ability to deliver according to requirements spec. overestimated?

-If so, to what extent?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

In what extent did staff turnover affect the project (in terms of time)?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

To what extent did for example sick leave or parental leave affect the project (in terms of time)?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

To what extent did lack of components affect the project (in terms of time)? (eg due to disaster or similar)

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**

---

In what degree did lack changes in legislation / regulation affect the project (in terms of time)?

(Not at all) **0**, (Low degree) **1 2 3 4 5** (High degree), **Do not know, Others**





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