Parameters Affecting Automation Engineering Efficiency

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Preface

This project concludes my education in engineering. The creation of this report has not been the straight forward, easy, walk in the park I expected. As the project evolved and more data were gathered the results just wasn't satisfying. So more data was gathered, slowly came the realisation that this data needed to be processed and analysed, this has not been an easy task.

When I started the project my belief was that this project was to give me insights in some theoretical frameworks and experience in writing a report. As the project is finished I realize that the personal benefits drawn from this experience is not only the theoretical knowledge gained, more importantly I have learned the benefits of a structural approach and that collecting even more data isn't always the way to go.

The topic of this thesis describes both the path I've chosen for my specialisation within the electrical engineering education and the numerous voluntary projects on which I have worked. It feels like a perfect end to a great time within Lund University, Faculty of engineering.

I would like to thank Bertil Nilsson for his guidance, advices and his attention for details, without him this project would not have reached the same quality. I would also like to thank the people at Global Projects for being understanding, supportive and providing insight essential for this thesis. Especially I would like to thank Wojciech and Magnus for their time and their feedback. And on a personal note I would like to thank Emma for listening to my concerns and thoughts, and my family for their support and guidance during my studies.

Lund 15 may 2012

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Executive summary

Title:	Parameters Affecting automation engineering efficiency
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Background & Problem:	The increased global competition has forced companies to perform project faster and better and minimising resource utilisation. This emphasis on efficiency is recognised by Tetra Pak Processing systems. Projects are complicated temporary endeavours, by exploring the efficiency decreasing parameters knowledge about how to increase efficiency can be gained.
Purpose:	The purpose of this thesis is to find the parameters affecting automation engineering efficiency. As the parameters are found suggestions on minimizing impact of the parameters are made. An evaluation model will be created from in which project affect can be analysed.
Method:	This project uses a modified action research approach with and abductive research strategy. In addition an internal benchmarking between projects are conducted. The data collection is done via interviews and studying archive material
Thesis Results and Conclusion:	Data gathered during the initial phase of the project provided a first set of parameters which were to be assessed in an evaluation model, these parameters included, Functional description, Template Plant Master and Customer Value. As the model was later used and the parameters evaluated and given scores the result was that the top 3 affecting parameters in automation projects was; Modules, Template Plant Master and Customer Value. Conclusions drawn from the study are that there are two different areas of affecting parameters, first the ones affecting the projects in a direct context, secondly parameters affecting in an organisational aspect. The most critical sub area is the tools and templates which prevent the re usage of code and also decreases efficiency and productivity within projects
Key words:	Automation projects, LEAN software development, CMMI-DEV, PMMM, Project management, Efficiency, TQM-projects

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1 Introduction

The aim for this chapter is to provide the reader with an orientation of Tetra Pak Processing Systems and also give a brief overview of the commercial tool used by the automation team. Moreover it will define objectives, deliverables and delimitations of this thesis.

1.1 Tetra Pak Processing Systems AB

1.1.1 Global projects

Tetra Pak Processing Systems AB (TPPS) is a company in the Tetra Pak group, one of the divisions within TPPS is called Global Projects (GP). The main responsibility for this division is coordination and implementation of those customer-order-projects which the market companies due to size or complexity lacks resources to complete. Automation is one of the services offered by GP, creating the control system for the plants designed and delivered by Tetra Pak.

Automation work is conducted in the form of a sub-project, based on the defined processes within TPPS. Because the scope of the orders both in time and in size is large it is a challenging task to maintain overview of the different activities within the sub-project, and relating them to the overall goal.

To be able to fulfil the goal of being more efficient the importance of efficacy in each project is a natural outcome. Efficacy can be achieved by knowing and being aware of what adds value to the customer, and finding a match between hours spent on activities and added customer value. Identifying the efficiency decreasing parameters will help GP gain the knowledge necessary to meet the present and future demands on effectiveness.

1.1.2 UCCD

The Process of TPPS is divided in to these following four steps, understand, create, convey, and deliver. Main focus during this thesis is on the Deliver phase.

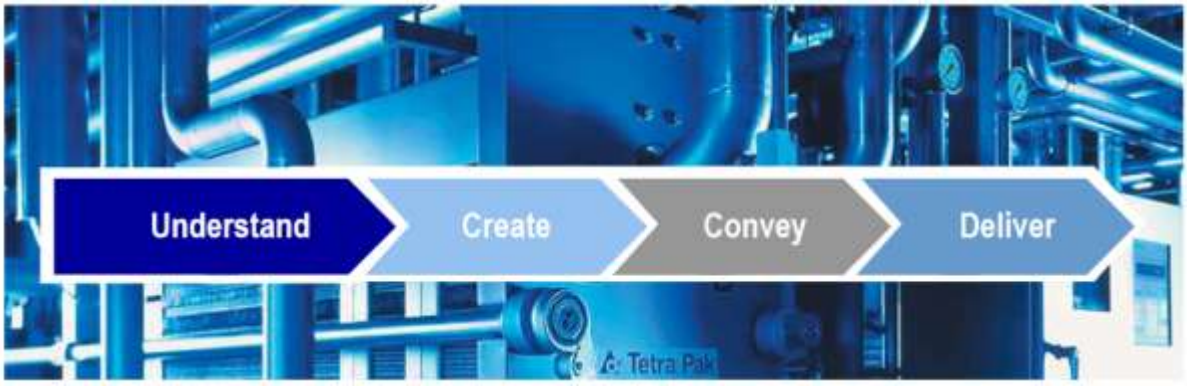

Figure 1 the Tetra Pak project business model (internal material, 2012)

Understand: Involves finding the main objectives and needs for the customer and also deciding if the project is in line with the business goals of TPPS. This phase also involves understanding the plant performance, how much energy is needed, what waste is inevitable and the environmental impact of the plant. The performance requirements for this type of process; such as quality, safety, environmental, operational and supply capabilities and parameters are also studied during this phase.

Create; This phase is where a solution is created based on production concepts to fulfil the identified performance requirements. In this phase the process criteria are identified and described, such as outputs, inputs and main process steps. Moreover a description of customer value is done. A plant solution is then designed and evaluated against requirements and customer value.

Convey: This is where the solution is presented to the customer with a guaranteed plant performance to best fulfil customer value. Secondly a contract is signed and the customer and TP agrees upon when, how, and what to deliver. Also a risk response plan is created.

Deliver: Can be divided in to the production solution design, installation and validation. First the production solution is engineered, then installed and finally verified. Production Solution Design can be divided in; scope confirmation, functional design and technical design. In this phase the plant is created installed and verified so that the customer can benefit from the new infrastructure.

1.1.3 Project organisation

Within GP the plant orders are carried out as a project. Below the project organisation for GP is described.

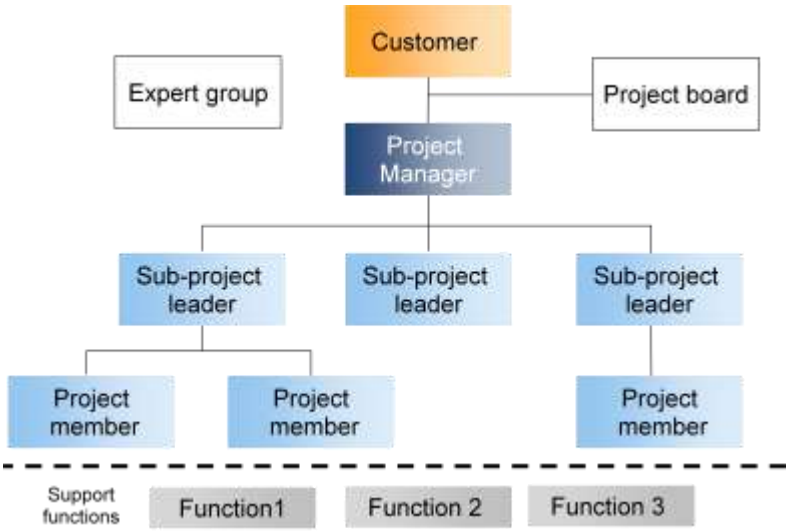

Figure 2 The Tetra Pak project organisation (internal material, 2012)

The project structure can be described as follows; the market company is the interface towards the customer, and has responsibility and accountability towards the customer. The project can be divided in three sub-projects, as described above. These three areas are, Automation-, electrical, and process-design. Each of these subprojects has a project leader, which is coordinated by the project manager that is responsible for the whole project.

The automation project is coordinated by the automation project leader (APL), in the project team lead by the APL there is a system leader (SL), and a number of automation engineers (AE).

The project board consists of a maximum of six people; the project board has full accountability of the project and is to provide leadership and support to the project responsible.

1.1.4 Template PlantMaster

A commercial product called the Template Plant Master (TPM) is an automation solution developed by Tetra Pak. The purpose is to integrate and connect modules and process equipment with business information and ERP (enterprise resource planning) systems. In Figure 3 one can observe a plant which can be automated with the help of TPM.

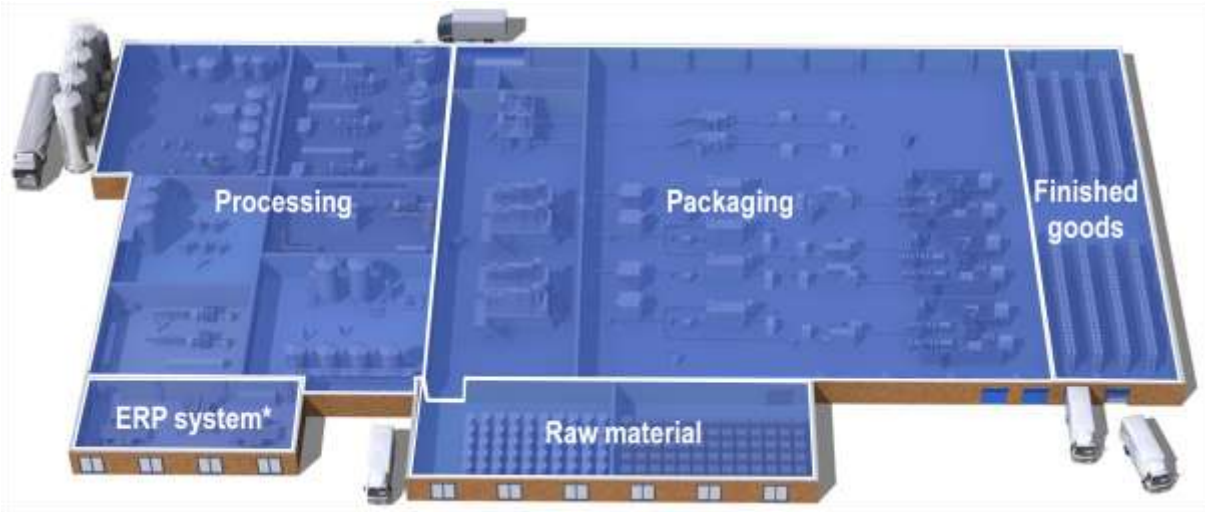

Figure 3 Plant wide overview, what TPM can control. (internal material, 2012)

The TPM integrates all these parts in a template based system. Templates are based on existing software from, Rockwell, Wonderware, Siemens and ABB. The templates are designed to make engineering faster, better and allow for reusability. This integrated system is designed by Automation Solutions which is a group within TPPS AB. During this thesis the usage of TPM in the projects are widely investigated. It is therefore important that the reader understands the main concept of TPM. To further guide the reader TPM could be thought of in two aspects, first as a tool where templates are used to improve productivity in projects, secondly as a concept which can be communicated to the customer.

1.2 Purpose/problem description

The global competition increases the need to produce more with less resources and at a higher quality. These increasing demands put on companies are also recognized by TPPS. As a global leader in the processing industry, TPPS recognizes the importance of continuous improvement and strengthening of their leadership position.

Striving after effectiveness and realising the importance of being more effective, TPPS wants to improve their efficiency in Automation projects. By focusing on the activities performed in the projects and the external and internal variables affecting efficiency, Conclusions on how to improve can be drawn,. Mapping these areas of improvements to better deliver value to the customer, will help TPPS extend their leadership position.

This thesis studies engineering efficiency within the automation area, to deliver conclusions and suggest areas of improvements on where and how TPPS can increase their efficiency, and better prepare for the global challenges of tomorrow.

1.3 Objectives & goals

The objective of this study is to suggest improvements about how TPPS can become even more efficacious. Furthermore, with the help of literature, conclude on areas in which TPPS can improve and find the parameters affecting the automation engineering efficiency. The main objective of the study is described and to assess the main objective the following questions needs to be explored.

- Parameters affecting efficiency in automation projects.
- Is there a difference in the perception of affecting parameters based on the role of the individual
- Implement LEAN, CMMI and TQM to minimize the effect of efficiency decreasing parameters
- Test if a definition of efficiency from literature can be transferred to the projects at GP
- Maturity of GP in the PMMM sense.
- Find conclusions on efficiency in automation projects at GP, drawn from a benchmarking study

These objectives are intended to be studied during this thesis. The main objective is to identify the parameters which affect automation engineering efficiency so that GP can improve its automation projects and increase productivity in their projects.

1.4 Delimitations

The focus of this thesis is on the parameters affecting automation engineering efficiency. Activities are studied in the context of their affect on the projects and their direct or indirect impact on the project. When studying the potential affect parameters have on the projects their impact on either time, cost or scope will be the measurement on which the judgement on including the parameter will be based,

The projects performed at GP are of different types, some projects are so called Greenfield projects where a plant is designed from scratch, in relation to Brownfield and Revamping projects which is upgrades and extensions of existing plants. This thesis will include all three. The automation part is a subproject within the creation of a plant; other areas such as process design and electrical design are examples of other subprojects. But as this thesis focuses on the parameters affecting automation engineering efficiency the study will be carried out from an automation perspective.

Three are different phases in the project, this study will focus on three areas within deliver; Functional description, Engineering, and FAT. Parameters affecting phases such as commissioning will not be studied within the scope of this thesis.

1.5 Deliverables

This thesis is written in cooperation with TPPS and therefore some well-defined deliverables are necessary. The deliverables is to form the basis for the result of the study but also to form checkpoint along the way where GP and the author can agree upon if the topic of choice is pursued in a satisfying manner:

1. A summary of lessons learned, Analysing the repetitiveness and usability. And how well they capture the parameters affecting efficiency.
2. A framework for evaluation of efficiency in projects.
3. Conclusions on what parameters which affects the efficiency.
4. Summary of the interviews stating the most common issues that decreases efficiency. Suggestions of improvements captured during interviews.
5. Suggestions on how to minimize the efficiency impact of the efficiency decreasing parameters
6. Ideas and suggestion on how GP can be more efficient not only based on the parameters but also ideas and practices found in literature that can be implemented.
7. The result will be delivered in the form of a report
8. The findings and conclusions will be presented on TPPS and at LTH.

When finished the intention is to deliver more knowledge about their projects to Tetra Pak, deliver a scientific contribution within the area of project efficiency, and also conclude the authors' education in electrical engineering.

1.6 Disposition

In this chapter a brief overview of the disposition of this thesis is given. The aim of the disposition is to provide the reader with guidance in the structure of the report and also a possibility to choose the chapters which one will read.

Introduction

This chapter gives the reader an introduction of the company and provides a context for this thesis. It describes the project organisation and the UCCD process used by Tetra Pak. Finally it gives a short introduction to the template tool used by Global Projects which is called Template Plant Master.

Methodology

Chapter 2 aims at defining some different scientific methodologies and approaches to this kind of study. As definitions are done the methodology for this thesis is described and also critically analyzed.

Theoretical Framework

The intention of the theoretical framework is to provide the reader with necessary knowledge in relating fields, also providing a foundation of related research. One should keep in mind that this topic is not a focused area of research and this has lead to the extent of the theory chapter where a number of different theories have been explored. First in this chapter a definition of productivity and efficiency is provided. . Next projects and project management is defined, followed by a description of some maturity models for projects. Requirements are subsequently explored with an intention to specifically provide knowledge about software requirements. LEAN and a LEAN extension for software projects are explored, followed by a rationale for describing an automation project as a software project. Additionally some management theories are presented providing a framework in particular for the conclusions

Empirics 1

Semi-structured interviews have been conducted and in this empirics chapter the results from these interviews are presented. The first topics from parameters are identified and will form the basis for the rest of the thesis. The choice of respondents have been made based on their involvement in one of the eight assigned projects distributed by Tetra Pak.

Analysis 1

After the interviews are conducted an evaluation model is the next step. In this chapter analysis on the first empirics will be conducted, and form the basis for the questions to be asked in the model.

Evaluation model

The model is a set of questions which will both be asked to the documents and during interviews. In this chapter the questions are presented and divided into; question answered by studying documentation and questions to be answered during interviews.

Empirics 2

In this chapter the result from the evaluation model is presented, moreover a maturity assessment model by Kerzner is used and the result from this survey is presented. In this chapter the content of each of the parameters are described and explored further.

Analysis 2

The Analysis identifies the parameters affecting automation engineering efficiency based on the ranking of the parameters per project and also a summary of all projects. The scores from each of the parameters are then ranked to provide information about the affecting parameters.

Analysis summary

In the final analysis the results from the first set of interviews are analysed in the light of the second set of interviews. This last analysis summary is done to connect the two interviews and to find whether there are similarities between projects and issues that are returning.

Conclusions

The conclusions chapter provides four areas from where conclusions about parameters can be drawn. The four areas which have been found to affect efficiency, and are believed to be areas to assess to increase efficiency. These areas are a well performed Understand Phase, proper tools, internal cooperation and a coherent project process.

Suggestions on improvements and lessons learned

In this chapter the main focus is on three suggestions of philosophies which GP could pursue to increase efficiency. The main suggestions involve minimizing waste, stating and measuring quality and developing the organisational learning by addressing the process improvements steps in CMMI.

Discussion

In the discussions chapter the methodology is evaluated against the ends result. Further research is emphasized and some personal reflections are given.

Below the process of this thesis is described, the disposition of the thesis follows the process.

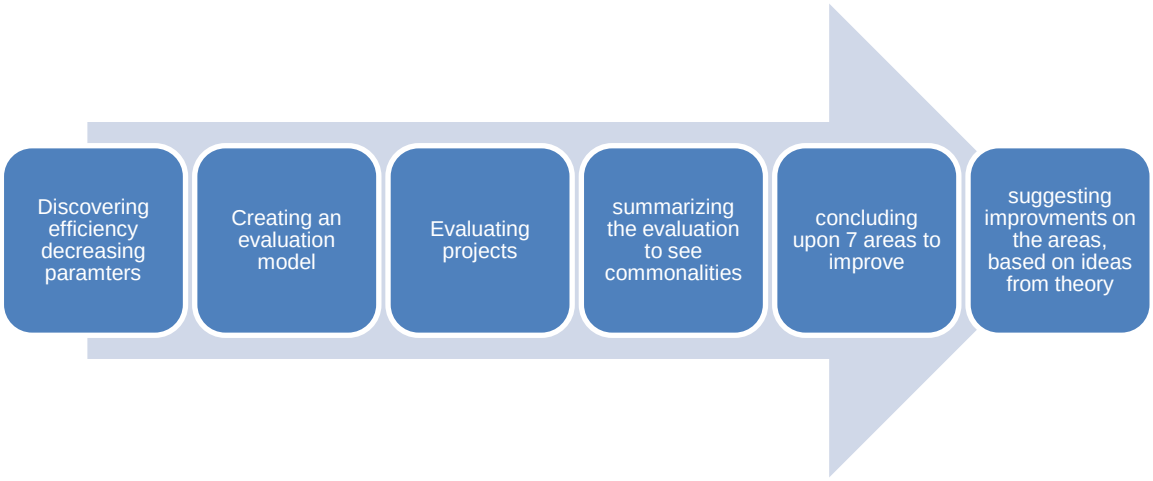

Figure 4 the main process of this thesis

1.7 Abbreviation list

This table provides the reader with a list of the common abbreviations used in this thesis with the intention to make reading easier.

Table 1: Abbreviation list for this thesis

Abbreviation	Explanation
KPI	Key performance indicators
BPM	Business process management
PMMM	Project management maturity model
CMMI	Capability mature model integration
CMMI-DEV	Capability mature model integration for development
TOC	Theory of constraints
TQM	Total quality management
TPS	Toyota production system, the basis for LEAN production
JIT	Just in time
PI	Performance indicators
TPPS	Tetra Pak Processing Systems
GP	Global projects
TP	Tetra Pak
D&B	Dairy and beverage another Tetra Pak internal company
FD	Functional description
PFS	Process functional specification
WBS	Work breakdown structure
APL	Automation project leader
PL	Project leader
TC	Technical coordinator
AE	Automation engineer
SL	System leader
PMI	Project management institute
SEI	Software engineering institute
SRS	Software requirements specification
FAT	Factory Acceptance Test
PM	Project Management
AS	Automation Solutions
MC	Market company

2 Methodology

This chapter will give a short introduction to the science of research-methodology, explaining different types of research-strategies and -design available, and deepening the study on the areas relevant for this thesis. The second part of the chapter will justify the methods of choice and give the author's motivation for those choices and their possible shortcomings. The third part will explain how the research will be conducted and what different types of activities that will be the foundation of this thesis.

2.1 Scientific methods -a brief overview

2.1.1 Research methodology, why and how?

Höst, Regnell and Runesson (2006) argues that methodology is the choice of *modus operandi* for the thesis, and that it does not in detail describe do's and don'ts but explains the way from overall objective to an increased knowledge in the subject. Denscombe (2009) states that choices on methodology are to be made, but no method is perfect, every choice has its drawbacks as well as its advantages. It is just a matter of choosing those that have the most advantages for the topic of choice. Bryman (2009) states that one should focus on three things; firstly knowing what not to do, secondly knowledge about your options, and finally the benefits of general knowledge. All these definitions gives different views on the scientific methodology; summarizing one can say that the choice of methodology defines the path to follow, what roads to avoid and also making the trip a bit smoother when writing your thesis.

2.1.2 Research design

The research design of choice is dependent on where and how data is available and also the overall objective of the study. Höst et al. (2006) defines it as the *"goal and objective of the study"* in addition to Denscombe (2009) who describes it as the method on how to gather and construct empirical data. Bryman (2009) defines it as the technique on how to gather data. The authors have the same view on what types of studies that exists.

Case study

A case study is a method in which the researcher tries to give a general description of a phenomenon by studying a specific case. Denscombe (2009) argues that this method is used to study a single unit. Höst et al (2006) widens the focus to an object as well as to a phenomenon. Bryman (2009) defines the term in a more geographical context to be limited to a certain place or an organisation. Denscombe (2009) also describes the importance and the considerations to be made choosing the case

" a case study is to be chosen carefully concerning the characteristics found in the case-characteristics that are especially significant for the problem or hypothesis the researcher wish to investigate." (Denscombe, 2009, p. 64)

In practice the gathering of empirical data is done via, interviews, observations and analysis of archive material. It is a common method of choice when analysing a phenomenon and especially when that phenomenon is hard to distinguish from its environment (Yin 1994 in Höst et al. 2006).

Action research

Action research has four characteristics: it is practically oriented, it takes place during a change, it's a cyclic process and the researcher is involved in the process. The researcher is involved and gathers

data during the process and observes the implications of the changes made. Höst et al (2006) concludes that the action research approach is a method of choice when implementing improvement, and observing the result of the change. Somekh (1995 see (Denscombe, 2009)) argues that action research is the integration of the research process and the action processes, meaning that the action is implemented and the research is conducted on effects of the changes made. Denscombe (2009) states that the most distinguishing detail of action research is the participation of the researcher in the process.

Survey

The survey methodology usually focuses on the width rather than the depth of a research field. Survey refers both to the methodology of gathering data and conducting a detailed and comprehensive study (Denscombe, 2009). Bryman (2009) on the other hand avoids the name survey and instead introduces the term "cross sectional study" arguing that survey to often is misinterpreted as the gathering of data via questionnaires. Bryman defines the cross sectional study as *" gathering data from more than one case (often many more than one) at a certain point in time with the intention to come up with a series of quantifiable and qualitative data with relation to two or more variables (often much more than two) that are examined to detect patterns regarding different kinds of connection"* (Bryman, 2009, p. 64)

Experiment

Experiment is the observation of a phenomenon and the understanding of that phenomenon via an empirical gathering of data. The experiment procedure isolates a number of variables and examines the causes of that isolation on the system (Bryman, 2009). The experiment method is normally used in applied science and something people relates to white coats and expensive equipment. According to Denscombe (2009) the experiment method is used to examine the cause-effect relationship by manipulation of single variables.

2.1.3 Data collection

Data forms the foundation for analysis and a number of gathering methods are available, a short introduction to the methods at hand is described below.

Surveys

Surveys are a data collection method often conducted on paper or in an electronic form where respondents are asked to answer a number of questions. To be characterized as *research-related* a survey must fulfil the following requirements: be designed to gather information that can be used as data, consist of a series of questions and gather information by asking people directly (Denscombe 2009). Bryman (2009) categorises the survey method as a quantitative data collecting method.

Observations

Observation is a data-collection method which relies on visual observation of a series of events (Denscombe 2009).

Different ways of participating in a group or activity is; observing-participant, complete-participation, participating, and completely observing (Höst et al 2006). Two dimensions can be identified: interaction and the knowledge of being observed. An observation can take place without the group

knowing and with the researcher having little interaction. Or the group being well aware of the observant and the researcher participates as yet another group member.

Archive material

Studying archive material in companies is a way of learning of past behaviour and analyzing the work with the end-result of for example a project at hand. When conducting an archive analysis and studying documents in general Denscombe (2009) uses Platt (1981) and Scotts (1990) criteria; authenticity, credibility, representatively, and contents. The document must be evaluated against and fulfil these four criteria to be able to fulfil the requirement of a valid research document.

Interviews

To gather information and data in qualitative research a common method is interviews. The interview can be conducted in different ways and depending on the aim with the interview there are different approaches to the technique. Denscombe (2009) describes a number of methods available. Below unstructured and semi-structured will be described. In these interviews the aim is to get the viewpoint of individuals about certain topics (Denscombe, 2009). The unstructured is often referred to as a conversation where the researcher listens and let the course of the interview be set by the interviewee. In a semi-structured interview some questions and topics to be discussed is set but the interviewee is given a freedom to pursue thought and develop arguments around the topics. Another interview form is the structured interview which focuses around a set of predefined questions and the respondent is asked to give short answers to the questions.

Denscombe (2009) describes some of the criteria for a successful interview which are derived from Kvale (2006). Some of these criteria are; the researchers need to be skilled in the topic, structured during the interview, and also to interpret the interviewee and clarify the answers about what the interviewee states.

Benchmarking

On the topic of benchmarking a variety of techniques and methods are available. The benchmarking models can be categorized in to three different categories (Anand & Kodali, Benchmarking the benchmarking models, 2008); Academic/research-based, Consultant/expert-based, Organization-based.

There is no consistent definition of the benchmarking term but as proposed by Maire et al (2006 in (Anand & Kodali, Benchmarking the benchmarking models, 2008)) the differences can be seen as a description of the evolution of benchmarking, as the methods are adopted and customized.

The background to term Benchmarking is often thought to be from the process of putting devices on a bench and comparing them. According to (Karlöf & Helin Lövingsson, 2007) the term derives from the land surveying term were a spot was marked in red on the bedrock which then was used as a reference point. The point was fixed in three dimensions and where used to measure heights for building and other construction work.

A definition is proposed by Kumar in Anand &Kodali (2008)

> *"It is the process of identifying, understanding and adapting outstanding practices from organizations anywhere in the world to help an organization improve its performance. It is an*

activity that looks outward to find best practice and high performance and then measures actual business operations against those goals" (Kumar et al, 2006 in (Anand & Kodali, Benchmarking the benchmarking models, 2008))

Benchmarking in industry is said to be invented by the Xerox Corporation which due to decreasing margins travelled to Japan and did a comparison study of their copy and printer industry (Karlöf & Helin Lövingsson, 2007) , (Larsson, 2007).

The result of Anand & Kodali (2008) study is a 12 phase 54 step model for benchmarking. Below in, Figure 5 the proposed 12 phase model is illustrated.

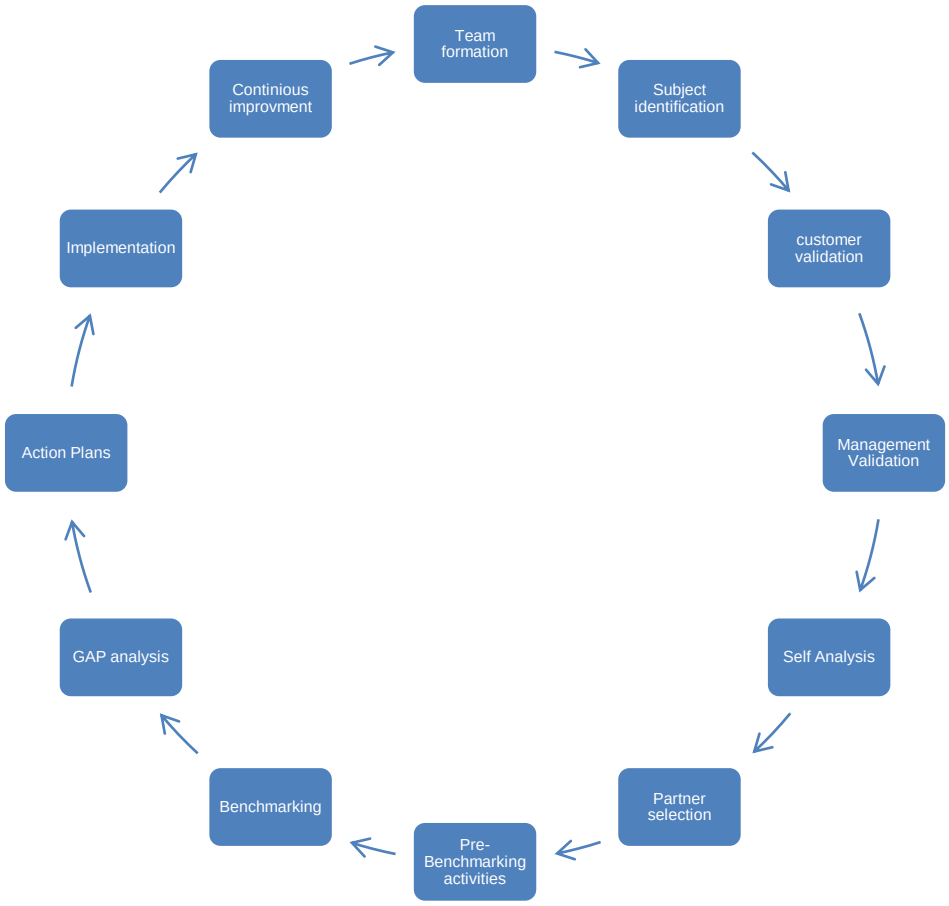

Figure 5 12 Phase Benchmarking process, Modified from (Anand & Kodali, 2008, p. 282)

As seen in this figure the preferred benchmarking model involves the implementation and continuous improvement phase as well as the collection of data along with the planning of the collection. Meaning that the process does not end with the collection of knowledge but also focuses on improvements as findings are derived.

Some comments on the implementation on benchmarking and the weaknesses that comes with misinterpretation are made by (Karlöf & Helin Lövingsson, 2007) where comparisons can be made with either non regulated key figures, or regulated key figures, correct benchmarking involving correct key figures, process descriptions and effect cause correlations. The weaknesses of the two first methods are apparent and needs to be avoided if the benchmarking process is to gain knowledge to build on and examples to implement.

2.1.4 Quantitative versus qualitative

One can categorize data in two categories; the quantitative which is often seen as numbers, and the qualitative which is often seen as subjective opinions. According to Höst et al (2006) quantitative data is: "such *data that can be counted and classified, and qualitative as words and descriptions"*. Bryman (2009) gives a deeper dimension to the different data collection strategies; claiming, that the quantitative research takes the approach of a deductive viewpoint, where as the qualitative approach is more of an inductive approach.
There are ways to convert qualitative data to quantitative data with the help of for example content analysis (Bryman, 2009)

2.1.5 Two different types of research-conclusions

The choice of research-strategy is the first decision to be made by the researcher depending on the aim of the study; if it's to produce theories by gathering empirical data or whether it is to verify theories by gathering empirical data. The strategy forms the basis for the hypothesis and therefore the foundation for the study. According to Bryman (2009) inductive and deductive methods are the relationship between theory and results, and Denscombe (2009) widens the perspective to it forming the underlying philosophy of the study

Inductive

Inductive theory is when the theory is the result of the research (Bryman, 2009). Basically the start of the project is gathering data via observation and producing theories to give a general explanation of the phenomena studied.

Deductive

Deductive methodology is a mapping of theories towards data, and via empirical tests verifying the results (Denscombe, 2009). This is the most common approach in the research field of social sciences.

Combining inductive and deductive

There is the possibility to alternate between the approaches and Björklund and Paulsson (2003) argue that this is to be called an abductive approach. Denscombe (2009) states that the two methods contain some degree of the other and do not give a distinct name on the mix.

Grounded theory

In 1967 Glasser & Strauss published a book called, *The discovery of grounded theory: Strategies for quantitative Research.* The idea behind their method is that during the empirical gathering of data the analysis is taking place simultaneously whereas the end result is a theory. The latest definition of grounded theory is *"Theory which has been derived from data collected and analyzed in a systematically way during the research process. " (Strauss & Corbin 1998 p12 see* (Bryman, 2009)*).* Denscombe (2009) means that this approach is preferable in small-scale-project research and research that focuses on human interaction. Grounded theory offers a method suitable in four different categories of research: qualitative, exploratory, studies of human interaction, and small-scale-projects

Triangulation and methodology combination

At a first glance triangulation and methodology combination can seem identical, but there are differences between them. Triangulation is the viewing of the problem from different perspectives while methodology-combination is the usage of different methods to reach a conclusion. Denscombe (2009) gives some examples on different kind of methods in triangulation all with the common goal on verifying the result. The combination of methods gives the researcher a possibility to overcome the weaknesses of a chosen method by combining it with another one

2.2 Methodology of choice and tradeoffs

This thesis is written at Tetra Pak Processing Systems AB (TPPS) and their department for Global Projects (GP). The study will take place during four months and are to be presented in May 2012. It consists of the following parts:

- A study of finished projects with the intention to identify the activities that affects automation engineering efficiency
- Interviewing employees at TPPS.
- Evaluation of the parameters affecting automation engineering efficiency

This is characterized as an abductive study which alternates between theory and result. Being mainly based on a cross sectional study at TPPS, the weaknesses with the cross sectional study is to be avoided by combining aspects of other methods such as the case and action research method. The study takes place at TPPS and investigates whether conclusions from old and ongoing project about engineering efficiency can be drawn. The data gathering is done via observations, interviews and studying archive material. This will give a view of the automation projects from a participants view. Combined together with the other data a systematic viewpoint can be constructed and analyzed to suggest areas of improvement.

The first set of interviews will be performed via a semi-structured interview model where some general questions about the situation and possible areas of improvement will be discussed. This will form the basis of the immersed literature study and also the evaluation model. The theories will be combined and condensed to fit the purpose of the thesis and give the foundation for further interviews.

The second round of interviews will be a structured interview based on both theory and the study of the archive material. The findings in these interviews are to form the foundation for the conclusions

By using some ideas from grounded theory the conclusions from interview and data gathering will be analysed and used during the thesis work.

In conclusion; the research is an abductive method which uses a combination of methodology and data gathering methods described above. That in this project is described as a modified action research

Furthermore the selection for the internal interviews will be based on availability and experience.

2.2.1 Choices made

The choices will be made based on how well they suited the information available, the expected results, and the characteristics of this study. In order to give conclusions and not stating the obvious a number of different data must be collected and analyzed. This is done with different techniques and creates a broad analysis. The choice of a modified action-research approach guarantees the result to be relevant and also implementable.

2.2.2 Critique of the research method of choice.

The modified Action research approach is not found in the literature studied and therefore the limitations and weaknesses of these methods are to be taken into consideration in the analysis. Asking for the implications based on a theoretical reasoning can be an approach that is time consuming and

does not provide a satisfying result by itself, therefore the result must be validated against other results and lessons learned.

Since the thesis cannot be defined as a focused area of research the connections to theory must be evaluated against a number of different theories in other fields. Nevertheless the theory available is perhaps not appropriate for this project and wrongful conclusions can therefore be made.

Finally the documentation about old projects and time spent is dependent on the form in which they are reported this can led to inadequacies in the archive analysis which means that a stronger focus is to be put on interviews and observations.

During the interviews the ethical aspects must be considered so that the employees feel comfortable sharing information about current weaknesses in automation projects.

2.2.3 Evaluation of results

Evaluation of the conclusions and the data will be done against theories and be assigned if the result is credible. To be implementable for TPPS the recommendations is to be done in such a way that they fit the organization of Global Projects and be based on the processes at TPPS. By evaluating the results against processes and added workload during the project the recommendations provides TPPS with a usable result for implementation in future projects.

Since the projects are complex and spans over long time it is not possible within the time limit of this thesis to conduct the study and observe the implementation of changes and evaluate the effects. Therefore this method is chosen to prevent the suggestions made from being of a non implementable character.

2.3 Conducting the study, an explanation of the phases.

By dividing the work in to a number of phases, the delivery of a phase can be mapped towards end delivery for a better overview of the project. This thesis will consist of four phases.

Phase 1: Preparation phase
Phase2: Initial Data collection
Phase 3: Data collection and analysis
Phase 4: Conclusions, recommendations and evaluation.

Phase 1

Phase 1 is the preface of the project, this is where methodology is chosen and theories are explored. This is also where the basic understanding of TPPS is done and the problematization of the subject is done.

Phase 2

Initial data collection is done to determine the projects to study and the questions for the interviews. In this phase initial interviews are done to decide upon parameters

Phase 3

Phase 3 is the general Data collection and analysis which will be conducted simultaneously.

Phase 4

Finally the conclusions will be drawn based on analysis and data, recommendations and lessons learned will be derived from the conclusions and the project will be evaluated.

3 Theoretical framework

The intention of the theoretical framework is to provide the reader with necessary knowledge in relating fields, also providing a foundation of research relevant for this thesis. One should keep in mind that this topic is not a focused area of research and this has lead to the extent of the theory chapter where a number of different theories are explored to provide the reader with useful terminology and theories in project and project efficiency.

3.1 Productivity and efficiency

The purpose of this thesis is to identify parameters affecting the efficiency in automation projects. As Tangen (2004) concludes: does neither productivity nor efficiency have one definition. Neither is there a consensus between academia and industry on the definition. However this thesis will not try to solve this dispute.

As stated above is the definition for productivity neither consistent nor is there a coherent view of the term. It is believed that the term derives from the French physiocrats in the 18:th century, when it was defined as 'production capability' (SOU 1991:82, 1991). Depending on whether the definition is verbal or mathematical it has different meanings and depths (Tangen, 2004). Below are some definitions of both mathematical and verbal nature described.

Definition	Reference
Productivity=units of output/units of input	Chew 1988
Productivity=actual output/expected resources used	Sink and Tuttle 1989
Productivity=total income/(cost+goal profit)	Fisher 1990
Productivity=value added/input of production factors	Aspén 1991
Productivity is defined as the ratio of what is produced to what is required to produce it. Productivity measures the relationship between output such as goods and services produced and inputs that include labour, capital, material and other resources	Hill, 1993
Productivity is the ability to satisfy the market's needs for goods and services with a minimum of total resource consumption	Moseng and Rolstadås 2001
Productivity refers to the ratio between the actual result of the transformation process and the actual resources used	Jan van Ree 2002

Table 2 Definitions of productivity from different sources from (Tangen, 2004)

As concluded by Hayes "productivity, a concept that is almost as hard to explain as it is to measure, typically it is calculated by dividing a country's (or an industry) 'output', adjusted for inflation , by the numbers of labour hours required to create it" (Hayes & Wheelwright, 1984, p. 2)

3.1.1 Efficiency

The core of the term efficiency is the relationship between delivering a value that is greater than the cost of producing the same value (Karlöf & Helin Lövingsson, 2007). Tangen (2004) discusses the differences between the term *efficiency* and *effectiveness*. While no coherent definition exists in the case of productivity. Tangen (2004) concludes that efficiency can be seen as "doing things right" and effectiveness is "doing the right things" (Sink and Tuttle 1989 in (Tangen, 2004)). Another definition of efficiency is "the *gap between the production line and the best applied version of the same technique*" (SOU 1991:82, p. 76) which is a definition that is production oriented. Karlöf et al (2007) also describes these two terms and concludes that efficiency is the balance between usage of resources

and input and effectiveness is defined as the fulfilment of an organizational goal. This definition does not involve the customer or adding value if that is not stated in the goals of the organization.

Efficiency	effectiveness	Reference
"Efficiency is an input and transformation process question, defined as the ratio between resources expected to be consumed and actually consumed"	*"Effectiveness which involves doing the right things, at the right time, with the right quality etc, can be defined as the ratio between actual output and expected output"*	(Sink and Tuttle, 1989)
"Efficiency is the ratio of actual output attained to standard output expected, and reflects how well the resources are utilised to accomplish the result"	*"Effectiveness is the degree of accomplishment of objectives, and show how well a set of results is accomplished"*	(Sumantha 1994)
Efficiency is a measure of how economically the firm's resources are utilised when providing the given level of customer satisfaction	*Effectiveness refers to the extent to which the customer requirement are met*	(Neely et al. 1995)
Efficiency means how much cost is spent compared to the minimum cost level that is theoretical required to run the desired operations in a given system.	*Effectiveness in manufacturing can be viewed as to what extent the cost is used to create revenues.*	(Jackson 2000)
Efficiency=ideal system dependent time/total time	*Effectiveness=value added time/ideal system dependent time*	(Jackson, 2000)
Efficiency refers to the ratio between aimed resource use and the actual resources used in order to transform an input to an output.	*Effectiveness refers to what extent the actual result(output in quality and quantity) corresponds to the aimed result*	(Jan van Ree, 2002)

Table 3 Examples of definitions of efficiency and effectiveness, collected and presented by (Tangen, 2004)

As the Swedish language contains only one term regarding efficiency in the sense of the definitions above, some other terms are explained below to provide the reader with some definitions of words used later.

Efficiency	*"Economic efficiency*, the efficiency with which scarce resources are used and organised to achieve stipulated economic ends. In competitive conditions, the lower the cost per unit of output, without sacrifice of quality, in relation to the value or price of the finished article, the greater the economic efficiency of the productive organisation."(A. Gilpin *Dict. Econ. Terms*

	57 ,1966) "The relation between the prospective yield of a capital-asset and its supply price or replacement cost, *i.e.* the relation between the prospective yield of one more unit of that type of capital and the cost of producing that unit, furnishes us with the *marginal efficiency of capital* of that type."(J. M. Keynes *Gen. Theory Employment* iv. Ii. 135 ,1936) "Productivity is the efficiency · of production"(G. Hutton *We too can Prosper* i. 13,1953)
Efficacious	"That produces, or is certain to produce, the intended or appropriate effect; effective. (Said of instruments, methods, or actions; not, in prose, of personal agents.)" *(Oxford English dictionary)*
Effectiveness	*"The quality of being effective (in various senses)". (Oxford Enligsh Dictionary)*
Efficacy	*"Power or capacity to produce effects; power to effect the object intended" (Oxford English Dictionary)*

Table 4 Definitions of efficiency, efficacious, effectiveness, and efficacy

For the reason of this thesis the following context of the above mentioned words will be used.

- Efficiency- Will be used to describe how well a project is performed compared to the ideal state.
- Efficacious- is used in this thesis to describe actions and entities that has the intention to produce an efficient result.
- Effectiveness- if a work is produced with little gap in relations to the best result achievable. Then it has a high effectiveness.
- Efficacy- what does the tool produce, when a tool or measurement has the capacity to produce the intended effect

All these words describe in some sense the end result or the capacity to produce that end result. The definition chosen in this thesis are:

"Efficiency refers to the ratio between aimed resources use and the actual resources use in order to transform an input to an output."(van Ree 2002)

3.1.2 Relationship between Efficiency and Productivity

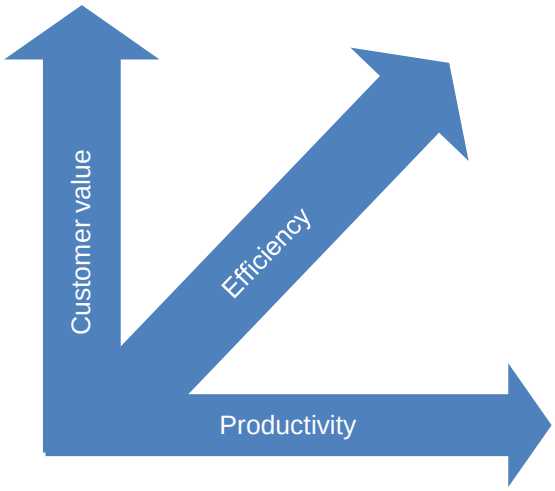

Figure 6 the two dimensions that forms the foundation of the term efficiency reproduced from (Karlöf & Helin Lövingsson, 2007, p. 86)

As seen above the productivity is basically measuring the transformation of resources and efficiency describes how well this is done compared to an ideal state.

One aspect is the customer value, which is often defined as the percieved customer value. Customer value is the sacrifice which the customer is willing to do to get the intended quality. If the customer pays a price at which the delivered quality is percieved to match the sacrifice, then customer value has been added. (Karlöf & Helin Lövingsson, 2007)

Productivity is according to the definitions above a relationship between input and the output, also measuring how well the inputs are used to produce the intended output.

3.2 Projects

During some years it has been a lot of focus on projects. (Mantel, Meredith, Shafer, & Sutton, 2008) argues that the reason for this is simple; projects align responsibility and organizational goals to individual and small group work tasks when their job is not part of the routine work at the company. Some definitions of projects are provided below

" A project is an organized endeavour aimed at accomplishing a specific non routine or low-volume task" (Shtub, Bard, & Globerson, 1994, p. 1)

The basics of a project is that it is limited in time, is unique in some sense and have a specific and denoted deliverable (Mantel, Meredith, Shafer, & Sutton, 2008) other definitions of projects such as:" *a temporary endeavour undertaken to create a unique product or service (project management institute, 2004)"* Or

" The entire process required to produce a new product, new plant, new system or other specified result"(Arcibald 1976 in (Shtub, Bard, & Globerson, 1994, p. 5))

"A narrowly defined activity which is planned for a finite duration with a specific goal to be achieved" (General electric 2007 in (Shtub, Bard, & Globerson, 1994, p. 5))

Projects are often carried out in programs, where a number of projects are carried out to achieve a certain program goal. At TPPS a programme can be the construction of a plant facility and the projects are subparts of the construction of this facility, for example the automation part or the mechanical engineering part.

There are different types of projects, ranging from types that are set up to achieve strategic goals, to projects that are designed to improve project effectiveness (Mantel, Meredith, Shafer, & Sutton, 2008)No matter what the project is designed to do one must be able to measure the success of a project. Three interrelated and sometimes conflicting variables are used to define the parts to be managed in a project. These are:

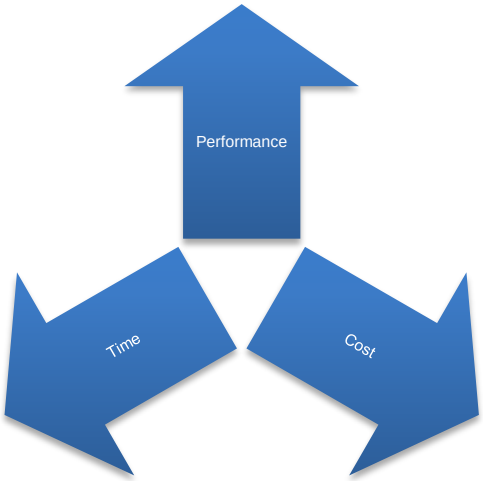

Figure 7 the three variables to be managed in a project (Mantel, Meredith, Shafer, & Sutton, 2008)

According to (Mantel, Meredith, Shafer, & Sutton, 2008) some argue that quality is one goal, Mantel et al. on the other hand argues that the quality is an inherent part of the project specification. The project goals are all approved by the client.

Projects are as mentioned before temporary endeavours created to provide value to the customer. But does the project make this task easy. The answer would be yes if the future was predictable and deterministic. But as the world and future is not fully predictable and not deterministic the project is characterized by uncertainty (Mantel, Meredith, Shafer, & Sutton, 2008)

Managing the uncertainty while fulfilling the performance, cost and time requirements is a matter of trade offs and planning. The management of projects is in literature extensively described and as in fashion there exist as many different methods as there are project managers, in the following part some comments about project management is made. But the question is whether projects can be a routine work, with solid scheduling in the beginning. The answer to this is no quoting Mantel et al.:

" projects must have some flexibility. Again this is because we do not live in a deterministic world. Occasionally a senior manager (who does not have to manage the projects) presents the Project manager with a document precisely listing a set of deliverables, a fixed budget and a firm schedule. This is failure in the making for PM. Unless the budget is overly generous, the schedule overlong and the specifications easily accomplished, the system is, as mathematicians says, "over determined." If mother nature so much as burps, the project will fail to meet its rigid parameters (Mantel, Meredith, Shafer, & Sutton, 2008, p. 7)

Concluding the project chapter, "*A pm manager cannot be successful without flexibility* (Mantel, Meredith, Shafer, & Sutton, 2008, p. 7)

When planning for a project one can use either of the curves in the figures below to map resource usage during the project life cycle. The derivative of the curve indicates the expected workload put on the project team. Whereas the left one indicates that 80 % of the work is performed during 20% of the time, and the right one indicates a slow start where the workload increases exponentially until project termination.

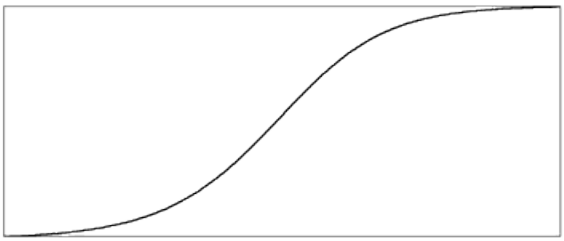

Figure 8 S-curve of a project life cycle, (Mantel, Meredith, Shafer, & Sutton, 2008, p. 8)

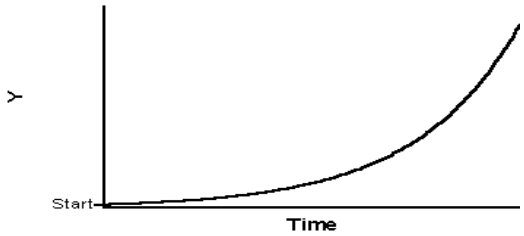

Figure 9 J-curve life cycle, (Mantel, Meredith, Shafer, & Sutton, 2008, p. 8)

These curves provide information about the accumulated usage of resources and are to indicate where a majority of the workload is put on the project.

3.2.1 Evaluating the project

Evaluation of a project is undertaken as a task to appraise against the initial plan of the project (Mantel, Meredith, Shafer, & Sutton, 2008). The task is not to be done only when the project is finished, but rather as a continuous review to create information that can be used for decision and control purposes.

A number of different techniques for evaluation exist and the description in this chapter aims at providing a generic insight on evaluation of projects. To measure project one must define what is seen as a successful project (Kerzner, 2001). In a study by Shenhar Levy and Dvir (1997) success was categorized as succeeding in four dimensions; how efficiently did the project meet its budget, customer satisfaction and impact, business success i.e. how successful was this project in business terms, and did the project create future potentials. Mantel et al. (2008) suggests that evaluation should be done with the selection process in mind, why was this project funded and selected. In conclusion: *"a project evaluation is an appraisal for use by top management. Its criteria should include the needs of management; the organization's stated and unstated goals; the original selection basis for the project; and its success to date in terms of its efficiency, customer impact/satisfaction, business success and future potential. Measuring the project's success on budget, schedule, and performance is easier than measuring revenues or qualitative, subjective factors. Establishing the measures at*

project formation is helpful, as well as using carefully standardized measurement techniques for the subjective factors" ((Mantel, Meredith, Shafer, & Sutton, 2008, p. 274)

3.3 Project management

Above the characteristics of a project are described. Since a project is a temporary endeavour undertaken by a cross sectional team, a manager with the responsibility of the project variables are needed. The task of the manager is to manage the project resources to meet the budget, schedule and performance requirements. Other tasks for the project manager involves conflict solving, negotiation with general management and motivational efforts (Mantel, Meredith, Shafer, & Sutton, 2008).

Mantel et al. (2008) explains the PM in the context of its difference from a functional manager. The functional manager has the responsibility of a well defined function within the company i.e. marketing, operations, human resources and so on, that has experience and knowledge about the technology being managed. The role of a functional manager can therefore be described as supervising the function. The project manager on the other hand has a responsibility for a cross sectional team with no functional placement in the organisation. Often managing a difference of technological competencies in which the PM has competence in only a fraction of them. The PM therefore can be seen to be a facilitator.

The responsibilities of the PM is described by Mantel et al (2008) as; Acquiring resources, fighting fires and obstacles, leadership and making trade-offs, and Negotiation, conflict resolution and persuasion.

3.4 Project evaluation models

3.4.1 Project management maturity model (PMMMM)

To understand the usage of a Project management maturity model one must realise the strategical benefits of a consistent project management methodology.

" Although projects are not repetitive they may take significant amounts of time and, for our purpose, are sufficiently large or complex to be recognized and managed as separate undertakings" (Shtub, Bard, & Globerson, 1994, p. 1)

Kerzner (2001) explains the need of a standard project management methodology to be developed for the strategic planning of project management. The repetitive nature of a consistent standard methodology will help reach the project objectives. This is a fairly straight forward method which provides an example of the activities defining a project management methodology. The methodology includes the technical aspects and the organizational as well as the financial.

Kerzner (2001) outlines the opportunities of integrating project management trends with the current methodology. The trends listed includes; Total Quality Management (TQM) and concurrent engineering process among others. The benefits of the integration of this model include a tighter cost control, corporate resource models and efficiency/effectiveness (Kerzner 2001).

If an organization is to achieve success in strategic planning for PM, it must be aware of its critical success factors (CSF). There are a number of different CSFs but they can be divided in to three categories: qualitative, organisational and quantitative (Kerzner, 2001)

To be able to measure if a project is successful one must define success. Success has historically been described as meeting the budget on time with the desired performance (Kerzner, 2001) ,but Kerzner

argues that organisations experienced in project management have extended the parameters to include minimal amount of scope changes, not disturbing corporate cultures or values and not disturbing the organisations usual work flow. In conclusion, *"for companies to reach excellence in project management executives must learn to define project success in terms of both what is good for the project and what is good for the organization (Kerzner 2001, s 30)"*.

The organizational factors include balancing the responsibility between project managers, line managers, and project sponsors. Kerzner proposes that in successful project management the following equation holds true.

Accountability= responsibility + authority

Kerzner concludes that *"executive project sponsorship must exist and be visible so that the project-line manager interface is balanced" (Kerzner 2001, p 32)*

To support the implementation of methodology one must have adequate tools to support the quantitative factors. There are a number of tools and although defining them all is not possible, to be able to reach maturity one must fulfil the following*: "project management education must precede software education. Also, executives must provide the same encouragement and support for the use of the software as they do for project management" (Kerzner 2001, p 33)*

To build on the strengths of the organization, an awareness of the project resources is crucial. Identifying the strategic resources to build upon requires knowledge and a *can do* attitude from management rather than a *must do* (Kerzner 2001). In Figure 10 the categories of resources are described

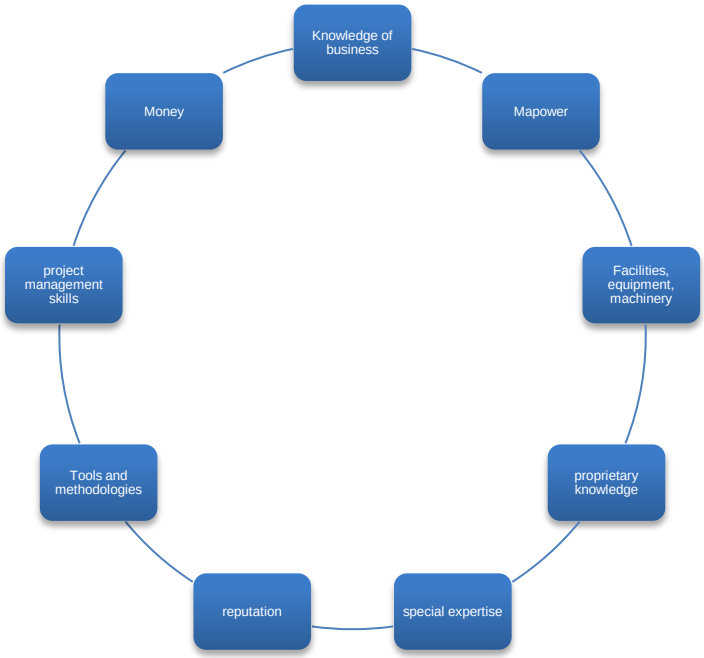

Figure 10 Project resources (Kerzner 2001 s 36)

Above the reasons for strategic planning in project management are described, also a number of tools to develop a methodology are provided and justified. The introduction of a project management maturity model can help organisations to faster achieve excellence in project management (Kerzner 2001)

The project management maturity model was developed by the Project management institute in 1998, and the five levels in the maturity model are described below.

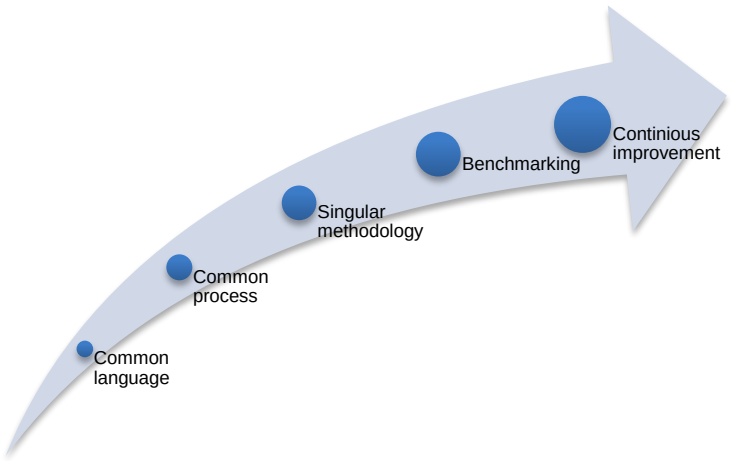

Figure 11 The five levels of project management maturity (Kerzner 2001, p 42)

In the PMMM model an organisation can compare its performance in project management to assess on where to put their efforts of improvements. A summary of the levels are provided below with the characteristics and the barriers for succeeding in the different levels

Level	Characteristics	Barriers and roadblocks
Common language	• Sporadic use of project management • Little support from executives • Isolated interest in a small part of the firm in project management • Managers are focused around preserving their own power • No education or training in project management	• Resistance to change • Not invented here attitude • An opinion that there it is not applicable to us • Rejecting project management because "we don't need it."
Common processes	• Recognizing the benefits of project management • Organizational support from all levels • Process and methodology needs are recognized • Realizing the need of cost control	• Why change a working methodology • Believing that methodology needs rigid policies and procedures • Resistance to " horizontal accounting
Singular methodology	• Integrating processes and the streamlining of processes • Creating a cooperative culture • Understanding and support d from the management structure at all levels • Minimizing paperwork, instead basing the control on guidelines and checklists	• Unwillingness to change because of a already working process • Fear of changing the balance of power • Line managers are resisting shared responsibility

	• Behavioural training is developed to enhance project management	• Over focusing on documentation
Benchmarking	• Establishing an organizational function for excellence or projects. • Dedicating the organization to benchmarking • Understanding the importance and benefits of looking at similar and non similar industries	• Not invented here • Not applicable to us • Not understanding the benefits of benchmarking against other industries • Fear of the results • Unwillingness to change
Continuous improvement	• Using lessons learned and case methodology to learn from mistakes • Transferring knowledge of mistakes and failures to other projects and teams • Understanding that enough is never enough, continuous improvement is an ongoing process	

Table 5 Summary of the characteristics and barriers for the five levels in PMMM adapted from (Kerzner 2001)

The model above is proposed by Kerzner and Called PMMM There are other maturity models available such as PMI OP3M or CMMI among others (Khoshgoftar & Osman, 2009). A comparison of the different models is made by Khoshgofar & Osman and their result reveals that the superior model is the OP3M. But their Result is not significant enough to question the choice of Kerzners model in this thesis. The Main difference found in the article is that the scale of OP3M is continuous as opposed to Kerzners which is discrete. And Kerzners model does not assess the portfolio management but for the purposes of this thesis the discrete model is found convenient and easier to use and the portfolio management is not covered in the scope of this project. Therefore Kerzners model will be used although some comparisons against other models will be made.

3.4.1.1 Level 1 Common Language

The first level describes organizations that have lack of project management organisation. The fear of changes in the power of authority as well as a resistance toward change is among the common signs of a level one organization (Kerzner, 2001). There could be knowledge about that project management exists but there is little acceptance towards the implementation of the method.

The advancement criteria involve training for project management, hiring project management professionals, communication in project management language. The time spent in level one ones deciding to apply the PMMM, can be measured in months or years. This is not something that is done by a trip where management decides to advance to level two on a teambuilding exercise. This takes commitment and the time spent depends on previous experiences, economic situation and type of company (Kerzner, 2001).

The assessment tools involves a questionnaire of 80 questions, each question has multiple answers but the respondents can only select one and has to make a choice. There are eight categories of questions, (Kerzner, 2001):

- Scope/integration management
- Time Management
- Cost Management
- Human Resource Management
- Procurement Management
- Quality Management
- Risk Management
- Communications management.

The evaluation is done against these categories where a score of 100 is available, and to advance to the next level one must score at least 60 in each category (Kerzner, 2001).

3.4.1.2 Level 2 Common process

Once an organisation has advanced from the state of knowledge about Project management to using project management it must recognize the need for creating processes that effectively uses an organisational strategy that builds upon the strengths of project management (Kerzner, 2001).

The involvement of executives in the level two work is of great importance. With the support and commitment from senior management the whole organisation is more likely to achieve a common process, while focusing on the external competition rather than internal power struggles (Kerzner, 2001).

The time it takes to evolve from level two depends on how strong the corporate culture is along with type of company, but according to Kerzner (2001) the time span is between six months to two years.

The assessment instrument for level two advancement consists of a set of questions assessing the visual benefits of project management. How well the executives promote the need for a common process and the level of line managers' support for project management (Kerzner, 2001).

3.4.1.3 Level 3 singular methodology

The level three criteria's builds upon the categories in the hexagon of excellence which consists of; Integrated processes, Culture, Behavioural excellence, informal project management, Training and education, and Management support (Kerzner, 2001).

Level three assesses the successful implementation of project management but it does not guarantee success in every project, *"successful implementation of project management does not guarantee that your projects will be managed effectively, thus improving your chances of success"* (Kerzner, 2001, p. 84). The time taken to complete level three is measured in years and depends on the acceptance of; a singular methodology informal project management and speed of cultural change.

3.4.1.4 Level 4 Benchmarking

Using Benchmarking as a part of the PMMM process is described, this part will involve the usage of benchmarking as proposed by Kerzner in a project management maturity model.

The fourth level builds upon the realization that there is always room for improvement in the methodology in use. The responsibility for this part is in some companies the responsibility of a project office (PO) or a centre of excellence (CoE). Often these two terms are seen as a description of the same function, Kerzner defines the characteristics:

Project office	Centre of excellence
Permanent line function for project managers	May be a formal or informal committee(may be a part-time)
Focus on internal lessons learned activities	Focuses on external benchmarking
Champion for implementation of the methodology	Champion for continuous improvement and benchmarking
Expertise in the use of project management tools	Expertise in the identification of project management tools

Table 6 Project office versus Centre of excellence (Kerzner, 2001, p 100).

As seen in Table 6 the choice of function requires knowledge on what the goal of the function is. Although there are differences between them there are also common aspects assessed by the offices. The beneficial aspects of this function involves aspects such as problem solving, centralized planning, centralized cost control and reporting, developing a career path in project management, and a centralized organisation in which lessons learned can be processed (Kerzner, 2001).

Benchmarking is conducted with two approaches, either with an organizational approach or a process approach, both qualitative and quantitative. The organizational approach focuses on critical success factors and the process is more closely related to project management and focuses on process improvement (Kerzner, 2001).

3.4.1.5 Level 5 continuous improvement

As an organisation reaches level five, it is not to be satisfied and relax. Level five is where the full benefits of the other four levels are explored, as well as assessing and continually improving to create long term success. (Kerzner, 2001).

Kerzner (2001) lists five areas for continuous improvement, shown in the figure below

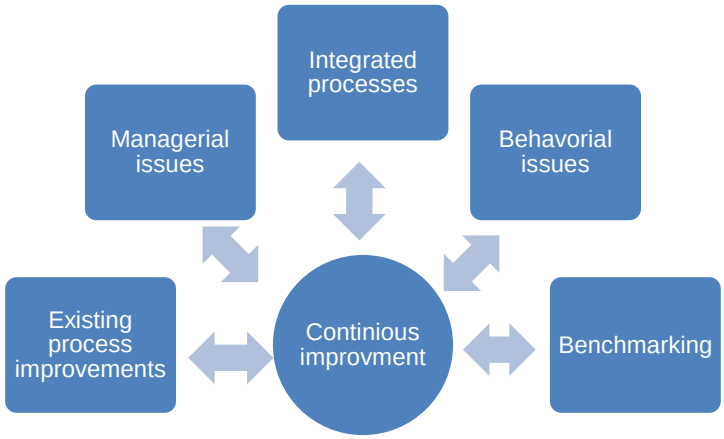

Figure 12 Factors to consider for continuous improvements (Kerzner, 2001, p 111)

These factors all adds up to the aspects necessary to consider when continually reviewing the market place for more convenient software, managing customer relations, managing the COE or the PO just to give some examples.

3.4.2 Capability Maturity Model Integration (CMMI)

As technology have evolved the products and services which companies builds and delivers have increased in complexity. In addition to the increased complexity of the products the market place is getting more and more competitive which forces companies to deliver better, faster and cheaper (Software engineering institute, SEI, 2010). According to SEI (2010) most of the approaches available for organisational development tend to focus mainly on a part of the business not understanding and addressing the system in which this part exists. The difference according to SEI is that CMMI addresses the total lifecycle of a product and therefore addresses all the components necessary to build and maintain a product (Software engineering institute, SEI, 2010).

In Figure 13 the three dimensions which organisations according to the SEI tend to focus on when improving. The key to the success of the three critical dimensions is the process. The process combines skills and knowledge with methods and business goals to provide stability and focus in the business (Software engineering institute, SEI, 2010).

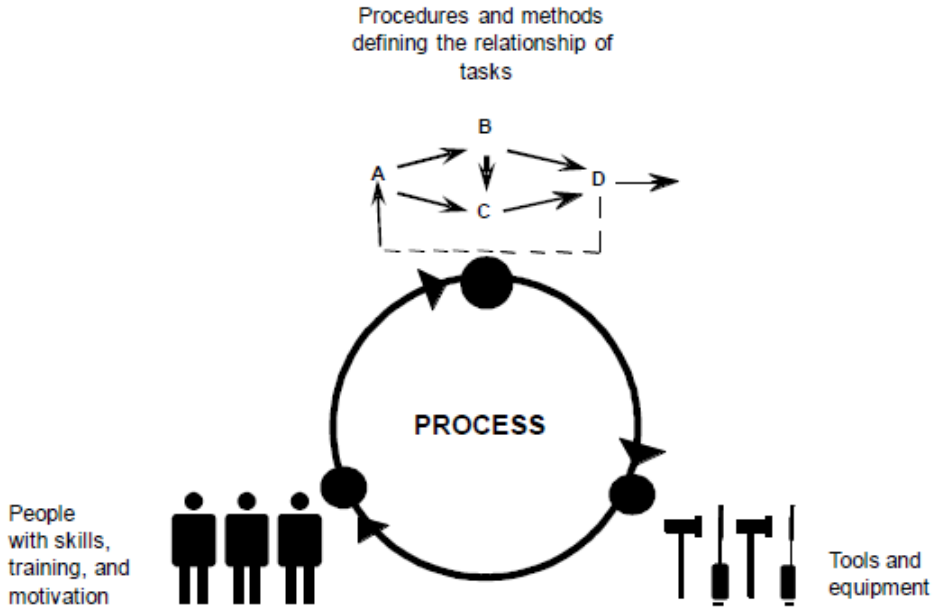

Figure 13 the three critical dimensions (Software engineering institute, SEI, 2010, p. 4)

Capability maturity models (CMM) is focused around processes. The CMM is not a set of specified processes which the company can implement to improve. Rather the SEI believes that the process design is a complicated procedure where different organizational aspects are to be taken into consideration (Software engineering institute, SEI, 2010).

"*CMMs focus on improving processes in an organization. They contain the essential elements of effective processes for one or more disciplines and describes an evolutionary improvement from ad hoc, immature processes to disciplined, mature processes with improved quality and effectiveness"* (Software engineering institute, SEI, 2010, p. 5)

The benefits of the CMM models and the accomplished improvements are among others; increased productivity, better cycle time, more accurate schedules and budgets.(Gibson 2006 in (Software engineering institute, SEI, 2010))

The CMMI, just like the PMMM, contains a number of maturity levels; the CMMI-Development (CMMI-DEV) maturity levels are the following:

Level	Characteristics
1. Initial	The processes on this level are usually ad-hoc and chaotic, the organisation manages to produce goods and service but these often exceed the budget or deadline. Often these organisations abandon their processes and are unable to repeat their successful projects. (Software engineering institute, SEI, 2010)
2. Managed	Level two is where the projects use a process and follows that process. This leads to employing the right people and providing them with the right tools. Another aspect of this level is the aspect of management control and involvement, during this level management is involved at certain milestones in the project.
3. Defined	Processes are characterized and understood well by the organisation. It describes them with regards to input, outputs, activities, roles, measures, and verification steps. The projects tailor the organisational processes according to guidelines. The processes are managed in a more proactive way by understanding the underlying relationships of the process.
4. Quantitatively managed	Addressing the performance of processes and the quality of the projects with statistical terms is the baseline for level four. These objectives are based on the customer, end users and process implementers. Some sub processes are analyzed and the interrelation of sub processes is understood to achieve process performance and quality objectives. A significant difference between level three and four is that the process performance is more predictable, and uses statistical and qualitative measures to control process performance.
5. Optimizing	This is where the experience and quantitative methods are combined and a focus on continuously improving the working methods. Improvements and innovative changes are made to processes and technological aspects to increase performance. A distinction between level four and five is the difference in what context the processes are understood, during level 4 the focus is mainly on sub processes, while level five is more focused on the performance of the whole organisation through experience collected from different projects.

Table 7 Levels of CMMI, summarized from (SEI, November 2010)

The levels are categorized around a number of process areas which will be explained below. The process areas relate to a different level and to advance to the next level all process areas of the current level must be fulfilled. (Software engineering institute, SEI, 2010).

Maturity levels are to be seen as evolutionary plateaus, where each of the levels is focused on a subset of processes, as it has been proven to be the most sufficient method. (Software engineering institute, SEI, 2010)

SEI (2010) suggests that one should focus on a specific process area of one's organisation. After the choice has been made, decide upon what maturity level to target and focus resources and improvements on reaching the desired level. (Software engineering institute, SEI, 2010)

In the table below the process areas and their corresponding maturity level can be seen. This describes where the effort is to be placed and what focus there should be to reach the intended maturity level in the process on which the organisation focuses.

Category	Process area	Maturity level
Support	Causal analysis and resolution	5
	Configuration management	2
	Decision analysis and resolution	3
	Measurement and analysis	2
	Process and product quality assurance	2
Project management	Integrated project management	3
	Project monitoring and control	2
	Quantitative project management	4
	Requirements management	2
	Risk management	3
	Supplier agreement management	2
	Project planning	2
Process management	Organisational process definition	3
	Organisational process focus	3
	Organisational Performance management	5
	Organisational process performance	4
	Organisational training	3
Engineering	Product integration	3
	Requirements development	3
	Technical solutions	3
	Validation	3
	Verification	3

Table 8 Process areas, categories and maturity levels (Software engineering institute, SEI, 2010, p. 33)

3.5 Requirements

In Software projects the reasons for failure are not in most cases due to bad engineering or incompetent staff, but the source could be traced back to poor requirements of the system (Kotonya & Sommervile, 1998). As prices on hardware have decreased and the complexity of software increases the cost of software gradually becomes a bigger part of the system cost. And as stated by Lausen (2002) software projects are hard to keep within budget, in particular if the customers' expectations are to be satisfied.

The solution to the problem is to specify customer expectations in advance and provide these expectations to the programmers and the financial managers.

To cover all of the aspects of requirements (Kotonya & Sommervile, 1998) suggest the word "requirements engineering" which gives a more holistic approach to the field, as the term engineering implies that the work should be of a more repetitive and systematic approach.

The relevance of requirements in the automation projects is essential since most of the work conducted at TPPS have the characteristics of software development. As complexity of the projects increases and the design shifts toward digital PLC instead of mechanical relays software requirements becomes increasingly important.

The relations of software requirements and projects are stated as; *"... Typically the customer and supplier (or their representatives) write in close collaboration; later programmers and other developers use it."* (Lausen, 2002, p. 3). Another way to explain it is by asking the following three questions "*what happens when the requirements are wrong?, What is an requirements engineering process? And, is there an ideal requirements engineering process?"* (Kotonya & Sommervile, 1998, p. 9). The answer to these questions are; it affects budget and planning, it is a process of structured activities where the system requirements document is constructed and simply put, there is not a general and ideal requirements process.

Combining the answers and the statement from Lausen one can identify the key aspects of requirements engineering. If it is used right it helps projects to be on budget and on time, it provides a coherent view for programmers, management and customers about what is to be delivered. But there is no ideal requirements engineering process. The field of requirements engineering is relatively new in academia but a wide range of literature and theories exists. Below a few of these theories will be presented.

The reason for writing requirements differs between organizations but a few common reasons are presented, Lausen (2002) presents the reasons from the customers' perspective. *Validation, verification, tracing and requirements management.* (Sommerville, 2005) Describe it from a requirements engineering perspective with the fundamental steps defined as; *elicitation, analysis, validation, negotiation, documentation and management.* This view is shared by (Kotonya & Sommervile, 1998) with the exception of the management perspective. Depending on whether the requirements is viewed from the customer perspective or the organisation perspective they have the commonality that they state the roadmap for the engineering process and provide material for verification of the functionality. In practice the requirements process is of an iterative nature see Figure 14

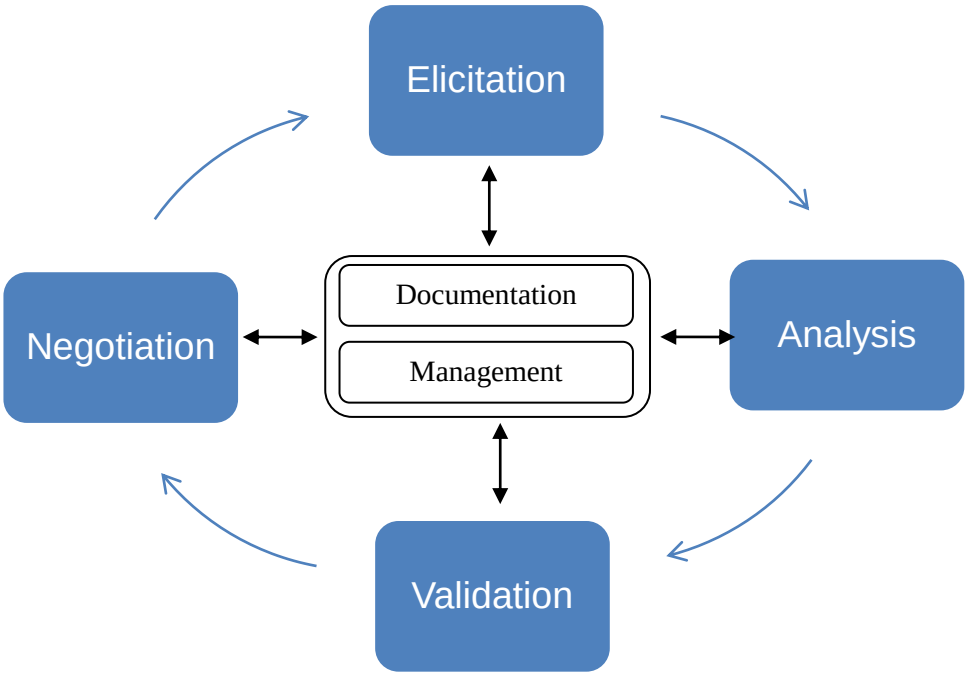

Figure 14 The Requirements Engineering Cycle (Sommerville, 2005, p. 17)

What the requirement should include is not a standardized set of topics. But the completeness of the documents affect quality, "*the software engineering research community has argued that the more complete and consistent a requirements document, the more likely that the software will be reliable and delivered on time* (Sommerville, 2005, p. 17) *".* The contents of the document should describe data requirements, functional requirements, quality requirements and other deliverables (Lausen, 2002). One thing often overseen in the requirements document is the background and the business goals of the customer, the development of these parts can provide an insight for the developing organisation to help make judgments and understand the customer viewpoint (Lausen, 2002).

Discussing the quality aspect is an important part of requirements engineering, as the customer expects the delivered solution to meet her standards. The quality grid can provide a graphical representation of the importance of the functions. As described by Lausen (2002); dividing the goals in categories for example, operations, revision and transition. Under each headline providing the goals and ranking their importance from unimportant or even ignorable to critical. The goals are not yet requirements but after the process they will be a part of the requirements. The idea of the quality grid is to provide the developers with a foundation from where the requirements can be chosen.

When discussing the requirements with the customer it is of importance to specify which kind of requirement it is. Lausen (2002) defines the different levels as Goal-level, which can be seen as business goals for the customer. Domain-level states the tasks to support. Product-level is a statement about input and output; this provides the developer with knowledge about features. Design-Level is a graphical representation of how the screen should look or how the programme should behave graphically. The levels chosen state who's responsible and *"... who you ask to do the job* (Lausen, 2002, p. 27)" However in practice it is not always easy do decide the level of the requirement and asking "*why*" could be a solution to better understand the source of the requirement (Lausen, 2002).

As explained below requirements engineering is not an easy task. A poor requirements engineering process has many potential problems and the earlier the problem is discovered the less cost is involved in changing it. Problems that may arise from such requirements involves missing the budget and schedule, the customer is not satisfied with the product, unreliable system and costly upgrades (Kotonya & Sommervile, 1998).

There are as stated before a different number of levels to the requirement from the data to the styles of the functional requirements. Representing and creating the requirements for these levels has evolved over time and a large number of methods are available. The requirements could be specified in a data-flow diagram, pseudo code, decision table, state transition matrix, etc.

To ensure quality in the individual requirements IEEE provides the definition presented in the table below

Characteristics	Definition
Correct	A [Software requirements specification],SRS is correct if, and only if, every requirement stated therein is one that the software shall meet
Unambiguous	A SRS is unambiguous if, and only if, every requirement stated therein has only one interpretation
Complete	A SRS is complete if, and only if, it includes the following elements: All significant requirements should be included. This includes all types of requirements whether they relate to functional description, design constraints or external interfaces. Definition of the responses of inputs, both valid and invalid inputs. Definition of measures and terms also full labels and references to all figures, tables and diagrams.
Consistent	Consistency refers to internal consistency, An SRS is internal consistent if, and only if, no subset of individual requirements described in it conflict
Ranked for importance and/or stability	A SRS is ranked for importance and/or stability if each requirement in it has an identifier to indicate either the importance or stability of that particular requirement.
Verifiable	A SRS is verifiable if, and only if, every requirement stated therein is verifiable. A requirement is verifiable if, and only if, there exists some finite cost-effective process with which a person or machine can check that the software product meets the requirement”
modifiable	A SRS is modifiable if, and only if, its structure and style are such that any changes to the requirements can be made easily, completely, and consistently while retaining the structure and style.
Traceable	A SRS is traceable if the origin of each of its requirements is clear and if it facilitates the referencing of each requirement in future development or enhancement documentation. Dividing the traceability info forward and backward traceability

Table 9 Quality criteria for Software requirements specifications collected and summarized from (IEEE recommended practice for software requirements specifikation, 1998)

Table 9 provides definitions of the quality requirements as described by IEEE. These quality aspects of the requirements are designed to provide a rigorous approach to the construction of requirements and to describe them in such a way that the requirements are understood and can be communicated

and used. Lausen (2002) provides some additional qualities that should be included in the analysis of the quality in requirements. The requirement should also be traceable from goals to requirement, this is the tracing of the business goals to the requirement and perhaps list the goals and the requirements related to that goal in a matrix. The requirement should be understandable both by customers and developers (Lausen, 2002).

3.6 Benchmarking

Benchmarking as a part of the PMMM is a tool for organisation at level 4 in the model, for usage in this thesis of the benchmarking the theoretical background will be described and to later on be used for comparison and intelligence service against other companies.

This model however is constructed to be used in an organization using benchmarking as a part of their learning process. The focus of this thesis is not the implementation of a benchmarking model in TPPS. There is however a focus on using practices from benchmarking to provide a GAP analysis and best-practice study focusing on findings from other organizations in which large projects are performed.

The theory of benchmarking is described in this thesis both in the context of a methodological approach and as a tool for continuous improvements.

The benchmarking can be defined in a philosophical way.

Benchmarking is the art of being open-minded enough to admit that someone is better than you and simultaneously be wise enough to learn to be as good, or better. (Andersen & Pettersen, 1997, s. 11)

The definition of the benchmarking tool and the definition of which this thesis will describe it are:

" benchmarking is a process to continuously describe and compare the company's processes with comparable processes in leading organisations to retrieve information that can help its own organisation to find and apply improvement actions" (Andersen & Pettersen, 1997, s. 11)

In the definition above there are five key aspects that should be considered when performing the benchmarking. First, it is the actual work that should be compared. Second, benchmarking should be a structured approach where lessons should be learned. Third, do not focus only on competitors, find the best in class. Also, by observing those who are best in class a lot can be learned. Finally, it is not the evaluation itself that is the goal, the goal is improvements. (Andersen & Pettersen, 1997)

There are according to Andersen & Petersen (1997) different types of benchmarking; Process benchmarking, Performance, strategic. All these kinds of benchmarking provide the organisation with different types of data. These data can then be used and compared against the companies own way of doing things.

There is an array of different benchmarking models which can be used to describe the overall benchmarking process. Andersen & Petersen (1997) suggest the following 5 step process.

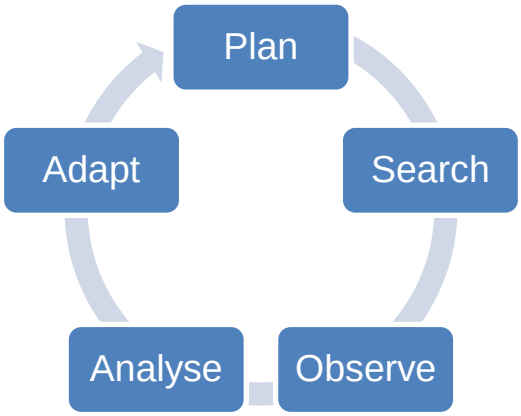

Figure 15 The benchmarking wheel, adopted from (Andersen & Pettersen, 1997)

In detail these steps are: (Andersen & Pettersen, 1997)

1. Choose and document the process which is to be studied with benchmarking and identify the measuring points
2. Find the benchmarking partner
3. Map and understand the partners process, both in the context of performance level and praxis
4. Identify differences in the performance level, praxis and also the prerequisites
5. Choose the best practice and adapt to fit the company.

Benchmarking can be used to speed up continuous improvements and is therefore a tool that is used both in the context of PMMM and LEAN software development as well as TOC.

Another benchmarking model provided in an article by (Anand & Kodali, Benchmarking the benchmarking models, 2008) is shown below.

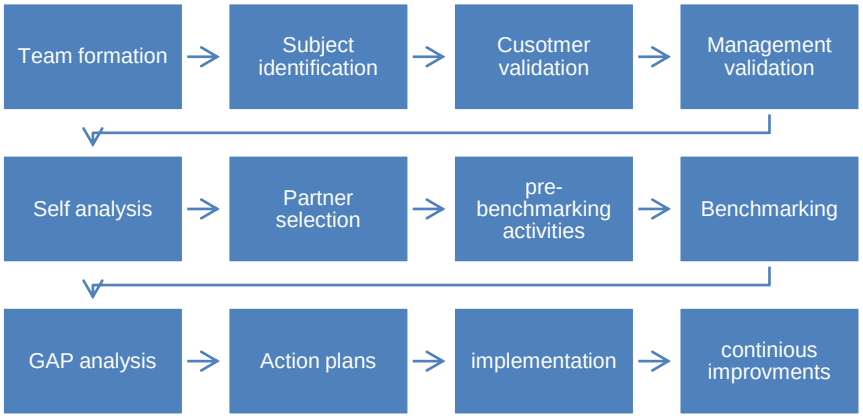

Figure 16 12 phases in a 54 step benchmarking process (Anand & Kodali, 2008)

This model has been developed when benchmarking the benchmarking models and provides a rigorous benchmarking practice that can be used.

3.7 Automation projects

In 1919 Henry Ford started an assembly-line automation to manufacture the model-T. This was the start of the era of automation, since then automation has evolved and become an integral part of the manufacturing industry (Viswanadham, 2002). The reason is that automation provides a more efficient and higher precision work than humans and also reduces costs (Sauter, Soucek, Kastner, & Dietrich, 2011).

The invention of computers and numerically controlled machines lead to an increased level of automation as new techniques was introduced and explored. (Viswanadham, 2002).

The next era was the introduction of software planning system for manufacturing, where the start was the introduction of the mainframe computer in the 1960's. This has sparked a wide range of system such as the MRP and more lately the ERP system. This aims to share the information to more people in more places and coordinating functions. (Viswanadham, 2002)

Also the use of digital PLC's instead of coils has improved the usability of automation. When LAN was invented and explored factory automation was introduced controlling individual machines. And programmable controllers replaced the analogue ones.

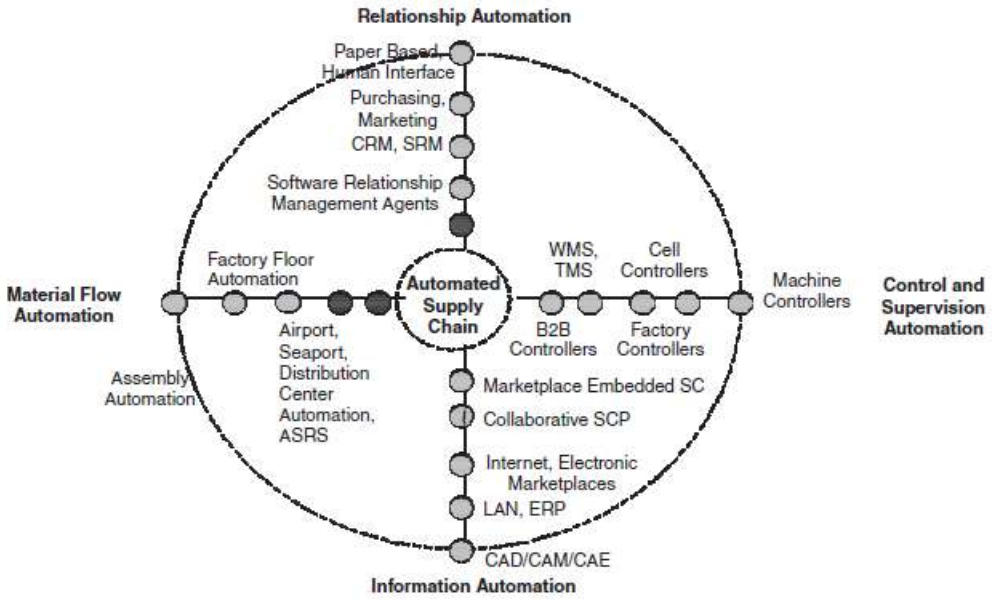

Figure 17 Progress of automation technologies (Viswanadham, 2002, p. 54)

As described in the figure above it is fair to say that since the line assembly automation in the beginning of the 20th century a lot of things have happened. The need for automation and the complexity in automation is continually increasing. As with computers where the hardware was the greatest cost and software was relatively cheap, the ratio in automation is shifting towards software and control systems becoming more expensive. Therefore this thesis will view the automation project as a software project aiming at adopting practices from software industry to automation projects.

3.8 Lean projects and Lean Software projects

In this subchapter a brief overview of the concepts of LEAN are provided to give readers not familiar with the philosophy a possibility to gain a basic knowledge. A theory which applies LEAN to software projects are then described. The description of LEAN will be based on the 22 tools suggested by Poppendieck.

3.8.1 Lean in general

The term LEAN Production was introduced in the revolutionizing book "*The machine that changed the world*". The term LEAN is a two sided coin, on the one side there is the production efficiency and on the other side improvements (Karlöf & Helin Lövingsson, 2007). The MIT project that resulted in the above mentioned book studied Japanese production facilities in America and compared them to the traditional automotive factories in America. A revolutionizing result was found. The Japanese factories proved to be an astonishing 40% higher in efficiency than its American equals. Womack and his team concluded that this was due to new thinking in the following categories:

- Responsibility of the workers
- Flexibility
- Cooperation with suppliers
- Quality
- Minimizing inventory
- Savings in all aspects.

Since the first definition of LEAN production, the definition has not only been rewritten by others but also adapted to other fields such as healthcare, construction and software projects. So what is LEAN; "*Lean is all about getting the right things to the right place at the right time the first time, while minimizing waste and being open to change* (Raman, 1998, p. 1)*".* A case study conducted by Gabriel concludes "*the lean approach to project management has worked successfully in potentially difficult and complex areas. It lead to a high level of commitment and motivation from the team, and to the satisfaction of the whole client organisation* (Gabriel, 1997, p. 209) *".* "*Lean thinking is important because it can reduce defect rates to 1 per million units* (Middleton, 2001)*"*

"In a nutshell, a Lean system is achieved by eliminating waste and unnecessary actions, and linking all steps that create value in a continuous sequence (Haque & James-moore, 2004, p. 3)*"*

The characteristics of LEAN production are (Karlöf & Helin Lövingsson, 2007):

1. Short changeover times
2. Minimum of storage and buffers
3. Small batch sizes
4. Minimal administration
5. Flexible personnel
6. High machine utilization
7. Zero error manufacturing
8. Committing to quality
9. Continuous improvements
10. Eliminating waste
11. Eliminating excess inventory

The benefits of LEAN production has been widely explored and the results are concluding that it undoubtedly at least doubles the productivity (Womack, 1990, and Ohno, 1988 in (Middleton, 2001))

Singh, Garg, Sharma, & Grewal (2010) shows that both finished goods inventory and, work in progress decreases while the productivity both per worker and overall increases significantly introducing Lean.

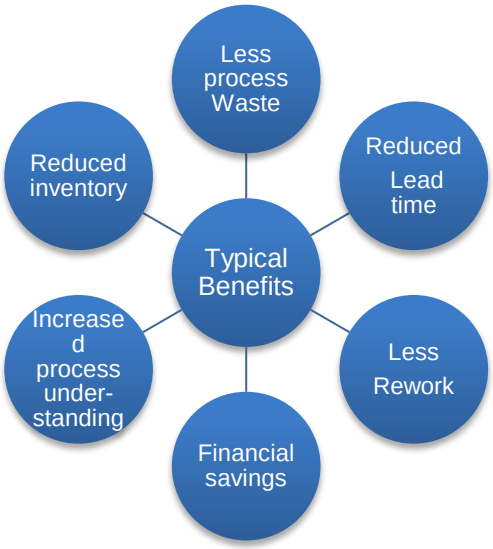

Figure 18 The benefits of Lean (Melton, 2005, p. 663)

LEAN(or TPS as it was called) was introduced at Toyota after the Second World War, to provide a tool for competition against the American factories, but at less cost. Taiichi Ohno, the inventor of the Toyota production system and the author of the book "*Toyota production system: Beyond large scale production"* explains the Toyota production system as "a *system for the absolute elimination of waste"* (Ohno, 1988, p. 4).

In Lean there are two recurring terms; Waste and Customer value. To fully understand the principles of Lean one must realise the importance of aligning its processes towards customer value and how to avoid and minimize waste (Melton, 2005). Waste can occur in different forms below shows the seven types of waste adapted from (Melton, 2005)

Type of waste	**Description**
Over production	Products without a specific customer, development of a product or a process or procedure that does not add value
Waiting	When waiting no value is added to the end result
Transport	Time spent in transportation is not adding value to the customer.
Inventory	Storing inventory costs money, without adding value
Over processing	Process step that doesn't add value
Motion	People or data being moved for no obvious reason
Defects	Errors can cause rework or lower quality which is not a value adding

Table 10 The Seven types of waste in manufacturing (Melton, 2005)

3.8.2 Lean extensions; Lean software development

It is not only the world of manufacturing and academia that has realized the benefits of applying Lean thinking. McKinsey has used the lean methodology in software projects " *in our experience, applying the principles of Lean manufacturing to ADM[application development management] can increase productivity by 20 to 40 percent while improving the quality and speed of execution* (Kindler, Krishnakanthan, & Tinaikar, 2007, p. 5)*"*

Poppendieck also concludes both in her books that explores the possibilities of Lean software development, and in her conference proceeding the usefulness of Lean. *"When correctly applied, lean software development results in high quality software that is developed quickly and at the lowest cost* (Poppendieck, Lean Software Development, 2007)*"*

Lean manufacturing has improved manufacturing based on the assumption that people are the most flexible part of the system, improving processes and focus on the staff, not forgetting about the discipline necessary in decision making. (Naftanaila & Brudaru, 2009) Poppendieck (2003) lists 22 tools that will help companies implement LEAN software development. Below the tools are described and explained with the help of different examples.

3.8.3 22 tools to help companies implement LEAN software development

3.8.3.1 Tool 1 Seeing waste

This is the basis for the Lean thinking as LEAN thinking is proposed as the ultimate way of avoiding waste (Ohno, 1988). In Table 10 the seven types of wastes in manufacturing is listed. A translation from these in to the potential waste of software development is done by (Poppendieck & Poppendieck, 2003) and the translation is described in the table below:

Waste in manufacturing	**Description of the waste**
Partially done work	The biggest problem with partially done work is that untested code has the potential of not working. There is no way of knowing before testing if the software actually works. And unless the whole system is tested there is no guarantee that the code solves the business problem. Reducing partially done code is both a way of eliminating waste as well as reducing risk
Extra processes	An unnecessary amount of paperwork is not a value adding activity. A question that is to be asked when looking at the paperwork is " is there someone waiting for this papers"
Extra Features	Adding extra features increases complexity, if the code is not needed at this point in time, do not implement it.
Task Switching	Starting several projects at one time and switching between tasks introduces change over times in the system. This leads to an increasing amount of time being spent on non value adding activities.
Waiting	Waiting for staffing, waiting for the project to be signed off and waiting for an excessive requirements document is a common waste in Software development. A principle proposed by Poppendieck (2003) is to "decide as late as possible", however if the implementation of the decision takes long time, the earlier the decision is to be made.
Motion	Is the distance to the customer representative far? Is there documents moving around and is there requirements moving from one group to another.
Defects	Is a problem solved instantly or is the problem not apparent until late in the project. Reducing the impact of defects is a matter of finding them as soon as possible and correcting them.

Table 11 The seven wastes of Software development (Poppendieck & Poppendieck, 2003, p. 4)

To be able to see waste is not as easy as one could think, the list of the seven types of waste has helped manufacturing to discover waste where they would not have looked. To be able to avoid and minimize the waste the above is a set of areas on which to look and with the help of these areas find the non value adding activities (Poppendieck & Poppendieck, 2003)

3.8.3.2 Tool 2 Value stream mapping

When a company decides to implement LEAN a Value stream map is a good way of organising the discovery of waste. The value stream map follows a product through the process from beginning to end in the value chain. And as a tool it has proved to be useful *" in industry after industry, the process of mapping the value stream has invariably led to deeper insight about how internal processes work- or don't work- to meet customer needs"* (Poppendieck & Poppendieck, 2003, p. 9). To illustrate the tool a traditional value stream map is shown in figure 19 below:

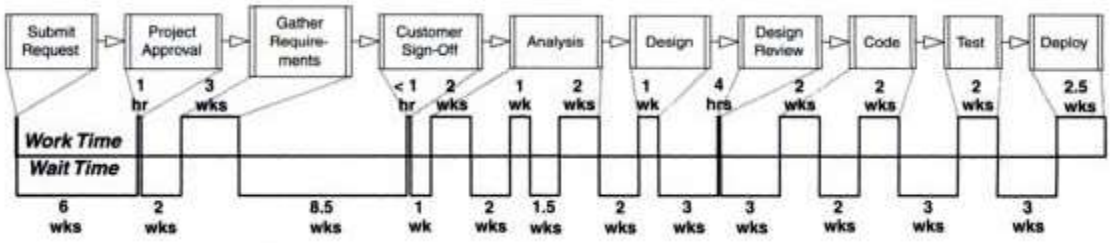

Figure 20 Traditional value stream map (Poppendieck & Poppendieck, 2003, p. 10)

As seen in the figure above only a third of the time is spent on value adding activities. The customer sign off takes a lot of time and this is probably because they do not get a second chance to review the requirements (Poppendieck & Poppendieck, 2003).

The proposed solution to this is to draw a timeline and as is done above map the activities as either work time or waiting time, then take the biggest delay and try to shorten it to half the time (Poppendieck & Poppendieck, 2003).

3.8.3.3 Tool 3 Feedback

During the development process a number of events can occur, therefore continuous feedback is needed to cope with these changes. An example is provided by (Poppendieck & Poppendieck, 2003) where they compare the use of a traditional waterfall feedback model where the feedback points are deterministic to the feedback of a cruise control. Concluding that a cruise control cannot work properly in a changing terrain if the set point is a fixed value on the accelerator. Instead one should measure the speed and variate the accelerator to reach the desired speed. (Poppendieck & Poppendieck, 2003) Proposes increased feedback and a handful of tips which involves; testing code as soon as possible, try ideas by writing code, instead of collecting requirements, visualise.

3.8.3.4 Tool 4 iterations

One foundation of the LEAN manufacturing philosophy is the just in time principle. Applying just in time to the production process is a good starting point in moving towards more lean manufacturing.

Translating this to the software process means setting milestones and developing prototypes to these milestones. This provides feedback from customers and problems regarding design. Iteration is the technique where a small portion of the software is developed during a fixed timeframe. This leads to higher quality, increased feedback and earlier discovery of problem (Poppendieck & Poppendieck, 2003).

3.8.3.5 Tool 5 synchronisation

By dividing the work and assigning a feature driven development or ownership of code one raises the problem of synchronizing these blocks of code together. Before when the Software was a small part of the system one programmer was responsible for one feature (Poppendieck & Poppendieck, 2003). But as complexity of features has increased the need for synchronizing builds also increases.

3.8.3.6 Tool 6 Set-based development

Poppendieck & Poppendieck (2003) illustrates this tool with an example of two people deciding a time to meet. One could either say a time, and ask the other to respond, then the response might be a negative response together with a new suggestion. As the iteration continues it hopefully converges. Instead of suggesting a specific time one could give a time span, and the other one could find a gap in her schedule to match your gaps.

Applying this to the software development process means to communicate constraints instead of solutions and perhaps to develop a set of alternatives and then decide on which features to use and instead of forcing the customer to choose and trying to understand what he really wants. One can develop a set of alternatives and then let the customer choose.

3.8.3.7 Tool 7 options thinking

To both manage the risk in project by planning and to fulfil the customer requirements is a delicate balance. The traditional approach has been to force the customer to as early as possible make an irrevocable decision concerning the specification of the system. The agile approach can be thought of as creating options and decide as late as possible (Poppendieck & Poppendieck, 2003). The difference between experts and amateurs is that the amateurs try to get everything right the first time and try to solve a lot of problems simultaneously and this leads to them making early decisions and often basing the later ones on them. Experts' delays decision until they have facts and are aware of the constraints (Thimbleby, 1988).

3.8.3.8 Tool 8 The last responsible moment

The tools above suggest that the approach is to start developing quickly in small iterative steps as soon as some of the requirements are done, and during the process providing feedback and correcting errors. This means postponing decision as late as possible. One is lead to think that delaying decisions makes the work easier, but it is actually harder and is against some of our natural instincts (Poppendieck & Poppendieck, 2003). The lean construction institute coined the term *the last responsible moment*. The point of the last responsible moment is at which the decision need to be made otherwise the decision is automatically made for you (Poppendieck & Poppendieck, 2003).

As mentioned above it is not a natural instinct to postpone decisions. Therefore Poppendieck (2003) suggests sharing partially complete information, providing communication channels between the ones using the system and the ones developing the system. Developing a sense of what is important, and when and about what decisions should be made.

3.8.3.9 Tool 9 making decisions

People take different approaches to making decisions, and different types of decisions calls for different rules. There is not a standard template or a set of firm rules that applied to a decision situation will ensure a good decision being made. The simple rules proposed by (Poppendieck & Poppendieck, 2003) is to

1. Eliminate waste
2. Amplify learning
3. Decide as late as possible
4. Deliver as fast as possible
5. Empower the team
6. Build integrity in
7. See the whole

These seven rules are explored and described in the tools provided in (Poppendieck & Poppendieck, 2003).

3.8.3.10 Tool 10 pull systems

The basis of the Just in time principle is the pull strategy, as to the traditional push strategy. In Manufacturing this means that instead of pushing a product through the production line in a sequential order one should not start producing until there is a request from succeeding operations. This ensures that nothing is manufactured or produced until there is a customer requesting it.

In software development the customer in the beginning of each iteration decides what to deliver at the end of that iteration, this is the equivivalent of the kanban card. The cards consist of a story or an event. This also solve one of the other problems related to development, scheduling. To avoid micro-management and not wasting time waiting for instructions one just simply grabs a kanban card with the task and develops that feature (Poppendieck & Poppendieck, 2003).

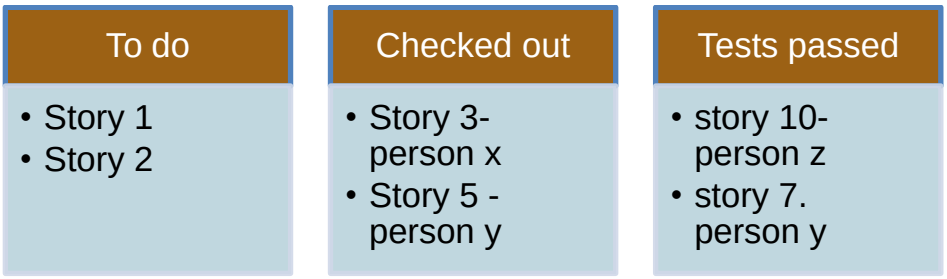

Figure 21: A software kanban system, modified from (Poppendieck & Poppendieck, 2003, p. 75)

3.8.3.11 Tool 11 queuing theory

Queuing theory has many applications. Poppendieck & Poppendieck (2003) Proposes to use queuing theory to calculate the cycle time of the processes. The definition of the cycle time is the time it takes for someone from entering the queue to leaving the queue. As mentioned before the philosophy of Lean is minimizing waste and time spent in a queue is considered as waste. Therefore minimizing the queue time is minimizing waste. (Poppendieck & Poppendieck, 2003)

To manage the service time of a queue there is two variables to manipulate, one can either increase the rate of service, that is the time it takes to complete the task to which you are queuing, the other variable is the arrival rate, if there is a decrease in arrival rate, there is a decrease in the average queue length.

Applying the queuing theory to software development suggest that the testing is to be done in small batches instead of large. This decreases the cycle time as the utilization rate increases (Poppendieck & Poppendieck, 2003).

3.8.3.12 Tool 12 cost of delay

In conventional management an investment in a tool designed to save time in engineering is justified based on comparing price of the investment against the price of hours. Taken into account the benefits of rapid development the outcome would be different. To not underestimate the benefits of rapid development is the message (Poppendieck & Poppendieck, 2003). By constructing a profit and loss analysis and comparing the cost of development by analyzing the difference in output, with and without the tool used. Comparing the costs will give an estimate of what the delay will cost in the context of potential market loss.

In all development work there are trade-offs. Thee tradeoffs in projects usually involves cost feature and introduction date. Although in project description the impression that trade-offs are possible and allowed are often not stated. According to Poppendieck (Poppendieck & Poppendieck, 2003) this leads to unclear trade-offs being made by each project individual. This results in a compromise of all the aspects.

The suggestion around this problem is to give all the team members an economic model. This gives everyone the same reference, also empowering members to figure out the business goals. This is more likely to lead to an economic success, since members now know what economic success means. (Poppendieck & Poppendieck, 2003)

In addition to the tools suggested above, Poppendieck also suggests to talk about things in the same context. "How can developer decide if it's better to save a week, save 10,000$, or add new features?" (Poppendieck & Poppendieck, 2003, p. 91). So the conclusion here is to compare apples with apples and not apples with money.

3.8.3.13 Tool 13 self determination

Poppendieck states that transferring practice is often a mistake; instead one should try to understand the system in which the implementation is to be done. When understanding your own system and understanding the principles of the practice you wish to implement there is a higher likelihood for success (Poppendieck & Poppendieck, 2003).

This is described by using an example from the GM plant in Freemont California that failed, but reopened with Toyota responsible for the production. With the same staff there were significant signs of improvement. The reason for these changes are claimed to be the belief in the employees ability to decide the best practice for their work. Toyota transfers the belief and foundation of their production system to the plant where workers, run and suggest improvements and really focusing on the workers (Poppendieck & Poppendieck, 2003).

3.8.3.14 Tool 14 Motivation

The reason behind this tool is the idea that people needs more than a list of task to become motivated. Some suggestions on how to motivate people are: start with a clear purpose, communicate a clear vision of the project. Defining an achievable purpose, see to that the team has the right competencies to achieve its on purpose. Access to customer, be sure that the team knows how the product helps the customer and understand the purpose. Commitments should be made by the team, when deciding on commitment the team should be the one deciding what to commit to. Management's role in the process is to be a support for the team; the team should ask management for resources and help to solve their practical problem. And last but not least, a sceptic telling the team why and how they will fail will decrease morale. (Poppendieck & Poppendieck, 2003)

To motivate people the following ingredients is a good way of starting. Make the team feel they belong in the team and give them credit, let them feel safe, make the team members more aware of their competence by motivation and addressing their knowledge and skills, and be sure there is a sense of that there is progress in the project (Poppendieck & Poppendieck, 2003).

3.8.3.15 Tool 15 leadership

A path to success in agile software development is the leadership style. A successful project often has a committed leader in the background. This leads to commitment. A leader should be able to cope with change as well as set the direction and align people and to enable motivation. At Toyota and 3M the chief engineer are engaged in the whole process and follows the product from start to end. (Poppendieck & Poppendieck, 2003)

3.8.3.16 Tool 16 expertise

Poppendieck suggests that expertise should be localised in to functions of knowledge and that these functions should develop standards and provide expertise and knowledge to the organisation. These people should form an internal community, much like the research community where everyone contributes to the search of new knowledge; this internal community should be based around the key factors for success. When designing these communities one could find that the critical mass needed to create a community is not fulfilled (Poppendieck & Poppendieck, 2003). When realising this one should think about how these areas are or could be potential blind spots for the company.

3.8.3.17 Tool 17 perceived integrity

Perceived integrity is the customers' view of the system, from the marketing to the installation. The optimal feeling for the customer is according to Poppendieck the feeling that the *developer must have been inside your head*, meaning that the customer feels that the system is its preferable system any day. (Poppendieck & Poppendieck, 2003)

Knowing how to design such a system is not easy, since customer perception changes and customers hardly know what they want in the beginning of a process. The customer usually has a problem or a wish of something to be handled by the software rather than the solution to this. (Poppendieck & Poppendieck, 2003)

To ensure a good relationship between customer and designer the following models are applicable. (Poppendieck & Poppendieck, 2003)

Conceptual domain model, to ensure that the user understands the domain. This can be done using a matrix structure where the entities and the actions to the entities are listed. The possibilities of the system are the number of fields in the matrix. (Poppendieck & Poppendieck, 2003)

Define the terms in the domain model. Construct use cases to capture what usability are. Also know what the qualifiers are for the system, know what are critical for stakeholder satisfaction.

3.8.3.18 Tool 18 conceptual integrity

Conceptual integrity is the construction of a final quality product, combining and aligning all the trade-offs being made during the development phase to ensure the end result is a smooth and functional whole. The product is a balance between flexibility and the responsiveness as well as efficiency and maintainability. (Poppendieck & Poppendieck, 2003). Poppendieck explains two methods used in automotive industry; first limiting the degrees of freedom by using existing parts, secondly the use of integrated problem solving. The integrated problem solving means early

information release in small portions and understanding and solving at the same time (Poppendieck & Poppendieck, 2003).

Implementing the principles in software industry means using existing parts when possible, use integrated problem solving and start writing software before design details is done, ask the customers and the users. Use experienced developers in all critical areas. Use a Master developer that has the leadership and coordinates the technical group and ensure they are synced and it is possible to integrate their solutions.

3.8.3.19 Tool 19 Refactoring

Refactoring is based on the thinking; no one could know everything from the beginning. There is limited possibility to know how to design and how to programme everything as the project starts. And to limit the perception that all the good designs are made in the beginning of the project. (Poppendieck & Poppendieck, 2003). Comparing to the lean production philosophy, which is based on continuous improvements. At Toyota a worker is encouraged to stop production if a problem is apparent. This is the basic philosophy of lean, that nothing is ever perfect. The same applies on software development which should evolve over time. This means using the iterative approach to perfect the software. The conceptual integrity is an achievable and desirable characteristic of the end result. One should therefore focus on maintaining the conceptual integrity, and as suggested by Poppendieck (ibid), if conceptual integrity is lost refactor. The characteristics of a system with conceptual integrity involves. Simplicity, clarity, suitability for use, no repetition and no extra features. This means that good code is simple code, good code is easy to understand and uses understandable standards and names, design so that it does what it is supposed to do and to do that easy, do not repeat code if a change need to be made in one place it is easier, if the mistake is copied to a lot of places it is much harder. Do not add features that are not needed because you predict that they maybe somehow somewhere are perhaps used. (Poppendieck & Poppendieck, 2003).

Readers familiar with the LEAN philosophy perhaps recognize and identify this method as rework and therefore waste. Poppendieck (2003) argues that this is not waste and it is not rework, instead it is improving design and learning as one develops.

Poppendieck suggests the following curve see Figure 22. “This is the inverse of the cost of change curve. Changes will happen. If your practices and discipline keep the cost of change low, your productivity will be sustained even when changes happen.” (Poppendieck & Poppendieck, 2003, p. 144).

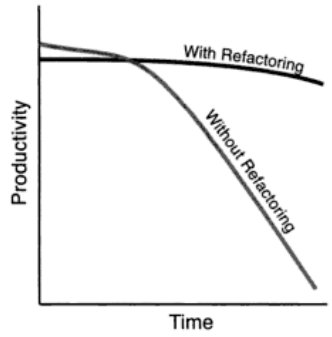

Figure 22: continuously improving design sustain productivity (Poppendieck & Poppendieck, 2003, p. 144)

This implies that if a team is not allowed to improve the design as the project evolves, the productivity will decrease. Comparing this to the Toyota production line example where a worker stops the line to find the root cause, at Toyota they know that this will in the end make the line go faster.

3.8.3.20 Tool 20 testing

Testing ensures that the customer gets what the customer needs. In software engineering each of the feature should be tested to work as the programmer developed them to do, also the features have to work together (Poppendieck & Poppendieck, 2003). The suggested vocabulary for test is developer tests and customer test.

Tests are also a good basis for communication and for feedback. The test are a great way of communicating with the customer and communication amongst the developers where the intended result of the test is a good basis for understanding what the feature is supposed to do. Also perform tests in small batches, do not wait until the end and test everything. This increases the complexity and big tests are complex and will not be runned often enough. (Poppendieck & Poppendieck, 2003)

If a test is performed this can also form the basis for the documentation of the software. The defect count in each test is also a good milestone and tells you whether the system is converging. (Poppendieck & Poppendieck, 2003)

3.8.3.21 Tool 21 measurements

To measure every part and optimizing all the parts will sub optimize a system (Poppendieck & Poppendieck, 2003). This means that the people doing the work will focus their performance and work based on what they are measured against. And if the system does not capture the whole system and just measures for the sake of measurement, this will lead to a sub optimization (Poppendieck & Poppendieck, 2003).

3.8.3.22 Tool 22 contracts

There are a number of different types of contracts; the most usual one is although a fixed-price contract. The fixed price contract lets the customer quote a lot of suppliers and chooses the cheapest one or is at least more likely to. (Poppendieck & Poppendieck, 2003). The basis for the type of contract in software development is that it should be based on trust. Poppendieck suggests a number of contracts but due to the scope of this thesis they will not be covered here.

3.8.4 The agile Approach to software development.

There are according to Poppendieck (2003) two prerequisites for a successful implementation of a new idea; it must be proven to work in practice and people adopting it must understand why it works.

So what is then the difference of LEAN software development compared to classic development? They are:

Lean architecture	Classic software architecture
Defers engineering	Includes engineering
Gives the craftsman" wiggle room" for change	Tries to limit large changes as " dangerous"
Defers implementation(delivers lightweight APIs and descriptions of relationships)	Includes much implementation(platforms, libraries) or none at all (documentation only)
Lightweight documentation	Documentation-focused, to describe the implementation or compensate for its absence
People	Tools and notations
Collective planning and cooperation	Specialized planning and control
End user mental mode	Technical coupling and cohesion

Table 12: A comparison of Lean architecture to Classic software architecture (Coplien & Björnvig, 2010, p. 5)

Implementing LEAN is not a recipe which you can follow (Poppendieck & Poppendieck, Lean software development: An agile toolkit, 2003). And the answer to *"the question whether LEAN software development is feasible is, yes"* (Raman, 1998, pp. 13-7). In an article where a company is studied when applying lean principles the authors conclude: "... We see that implementation of a lean production system in knowledge work is possible and that it changes how the organization learns through hypothesis-driven problem solving streamlined communication, simplified process architecture and, to a lesser degree, specified tasks" (Staats, Brunner, & Upton, 2011, p. 388). This article also provides a good insight in to the difficulties in deciding if the attempt is in fact LEAN: " *Finally, question arises whether as to Wipros is actually doing ´lean´ production. ... Since no definition of lean software is accepted. We rely on the fact that Wipro was consciously trying to create a lean system for software services. Their idea was inspired by Lean thinking, in any event, so we are able to learn from their attempted mapping"* (Staats, Brunner, & Upton, 2011, p. 388)

One cannot fully conclude that based on these findings there is not a Hawthorne effect. And little evidence in case studies suggests that there have been sustainable results in implementing LEAN software development. But the research indicates that the principles in production are applicable in software development, and in production lean has proven to provide a competitive advantage for companies implementing LEAN.

7 principles of LEAN software	Tools used
Eliminate waste	1. Seeing Waste 2. Value stream mapping
Amplify learning	3.Feedback 4. Iterations 5.Synchronization 6.Set-Based development
Decide as late as possible	7.Options thinking 8.The last responsible moment 9.Making decisions
Deliver as fast as possible	10. Pull systems 11. Queuing theory 12. Cost of delay
Empower the team	13.Self determination 14. Motivation

	15. Leadership 16. expertise
Build integrity in	17.percieved integrity 18. Conceptual integrity 19. Refactoring 20. Testing
See the whole	21. Measurements 22. Contracts.

Figure 23: The seven principles of LEAN software development adapted from (Poppendieck & Poppendieck, 2003)

What does it solve, in a case study performed by Middleton(2001) two teams were studied during a development phase, LEAN software proved to be effective during development although the sustainability of the method was short due to organizational barriers and also a fear of showing errors. Although there were a lot of frustration in the beginning because of the high number of errors being visible in the beginning and this lead to some de motivation, but in the end the error rate dropped (Middleton, 2001).

Another case study by Middleton (Middleton (2005) in (Petersen & Wohlin, 2010)) states that the productivity increased by 25%, the time spent on fixing errors was reduced by 65-80% and the customer were more satisfied with the product.

In a study performed at a Fortune 500 company there have found to be a significant improvement in delivery time and cost. In the pilot project there was a decrease in project duration by 40% and the project came in 10% under budget (Parnell-Klabo, 2006).

Parneel-Klabo (2006) recognized three challenging obstacles; the space for collocation, executive support and influencing the change curve. When introducing LEAN there are often some myths connected to the 7 step presented in Figure 23 they involve myths like; early specification reduces waste, haste makes waste, the job of testing is to find defects and there is one best way (Poppendick & Poppendick, Implementing LEAN software development: From concept to cash, 2007).

The sequal to Poppendiecks book *Implementing Lean software development: from concept to cash,2007* presents a 24 frame process of how the LEAN development process should work. They have cateogrized the frames in 6 categoriez; *systems thinking, technical excellence, relibale deliver, relentless improvment, Great people and Aligned Leaders.* Each of these categories are appointed to a leader who is responsible for the development of the frames (Poppendick & Poppendick, Leading LEAN software development: Results are not the point, 2010).

And as Concluded by Naftnalia et al, *" to date however there is little body of research that can guide organizationas in adopting modern software development practices, especially when it comes to LEAN thinking and principles."* (Naftanaila & Brudaru, 2009, p. 1)

There are a lot more to wright and present on LEAN software development and Agile processes, for further reading and implementation se the references, this thesis will not cover the implementation process and the tools and support necessary to succed with LEAN implementation.

3.9 TQM in projects

Total quality management (TQM) is a production and process methodology which has been developed to improve organisation (Tippet & Waits, 1994). The transfer of the principles of TQM to projects has however not been as smooth and as easy as one would expect. The main reason for this is the measurement aspect, in a production process one can measure rework and number of customers served and so on. But in a project defining a measurement is much harder. (Tippet & Waits, 1994)

To better understand TQM below a list of the principles of TQM are presented. (Choppin, 1995)

Principle	Definition
Highest priority	*Total quality must overtly be the highest priority of the organization/company/individual*
Quality definition	*Any definition of quality must include meeting/satisfying/conforming to agreed/negotiated customer needs/requirements/wants/expectations*
Customer definition	*The concept of customers include investors/employees/stakeholders/suppliers/the community and every interpersonal relationship*
Customer satisfaction	*Long term satisfaction of customer needs will be an aim of any total quality organization*
Aim	*A total quality organization will have a clearly stated, widely understood and generally accepted direction/aim*
communication	*A total quality organization will openly and clearly communicate its principles/beliefs/values/ mission statement/policy for quality*
Ethos	*Total quality management embodies the values/beliefs/ethos of the organisation and, thus, total quality is intrinsic to every activity decision and action*
Values	*The highest level of integrity, honesty, trust and openness are essential ingredient of total quality management*
Mutual respects and benefits	*There is an implicit mutual respect of all stakeholders involved with a total quality organisation, which assumes that long term business is intended to be mutually beneficial to all concerned*
Health and safety	*Health, safety and environmental issues have a high priority within a total quality organizations since the welfare of all investors/employees/suppliers/the community as stakeholders in the enterprise, is intrinsic to the future wellbeing of the organisation*
Commitment	*Leadership of total quality management stems from the top of the organization and enlists individual and team commitment throughout.*
Participation and ownership	*Total quality offers each individual the opportunity to participate in, and feel total ownership of his/her activities, and jointly share a sense of ownership for the success of the entire organization*
Continuous improvement	*Total quality management involves continuous and measurable improvements at all levels of the organisation. Ranging from a company performance to individual employee performance, such that continuous process improvement, forever, becomes an essential ingredient of success.*
Performance	*Total quality management requires consistent/predictable/accurate/precise performance to high standards in all areas of the organisation thus measurement, assessment and auditing are common TQM activities*
Resources	*An aim of every total quality organization is to use resources better, to achieve greater success, financial and/or otherwise*
Investment	*Total quality management will always require sufficient/appropriate investment to ensure that planned activity can occur*

Table 13: The principles of TQM from (Choppin, 1995)

From the table above one can derive that one of the essential ingredients in TQM is measuring, and as concluded by (Tippet & Waits, 1994) "*... measuring project efficiency is a much more subjective and difficult undertaking".*

One of the arguments put forward by (Tippet & Waits, 1994) is the focus on performance, time and cost the lead to project managers focusing on achieving success in those areas. Not optimizing the organisation and project but delivering a successful result but only in the short-term. The solution is a long term measurement which involves team effectiveness, motivation, and attitudes and so on. (Tippet & Waits, 1994)

3.10 Managing Risks in projects

As a project is defined as a temporary endeavour and the risks of the project is not known, one must conduct a risk assessment. PMI (2008) has 6 steps for managing risks in a project.

1. Plan risk management
2. Identify Risks
3. Perform qualitative risk analysis
4. Perform quantitative risk analysis
5. Plan risk response
6. Monitor and control risks

This can all be summarized as defining how to plan for the risk assessment, finding the risk and responding if an event occurs (PMI, Project Management Institute, 2008)

The plan risk Management is a process which is to be designed to identify and manage risks in projects. Planning the risk management process in detail enhances the probability of a successful risk assessment (PMI, Project Management Institute, 2008).

Below the inputs outputs and tools for the plan risk management process can be seen.

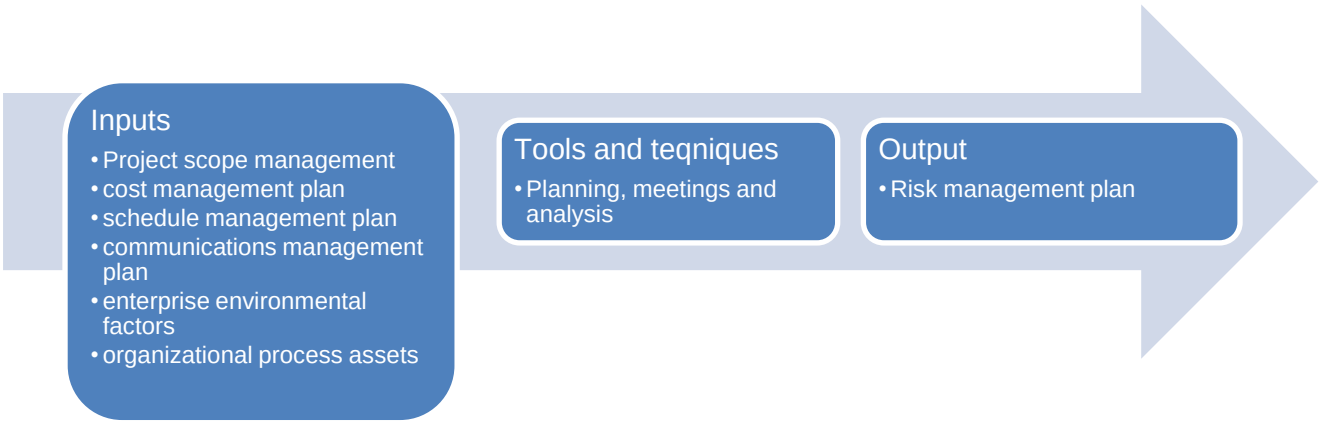

Figure 24: Plan risk management: Inputs, Tools and Techniques, and outputs. Adopted from (PMI, Project Management Institute, 2008, p. 277)

After finishing the risk management process one should begin to identify the risks. In analogy with Figure 24 there are inputs, tools, and outputs to this process. The inputs involve studying some key

documents, such as; the risk management plan, activity cost estimates, activity duration estimates and other planning documents (PMI, Project Management Institute, 2008). The tools to use for this work are among other SWOT analysis, expert judgment, and checklist analysis.

The output from this is a register of the risks. (PMI, Project Management Institute, 2008).

The third and fourth phase involves a risk matrix and basically techniques for presenting and calculating the impact factors for the risks identified in the second phase. (PMI, Project Management Institute, 2008)

After the risks is identified, tool and techniques is developed to be able to respond in the event of a risk occurring. And deciding how to manage these risks can be seen as a process where the inputs is the risk register, project management plan, work performance indication and the performance reports (PMI, Project Management Institute, 2008).

Then via meetings, audits, and document analysis one assess the situation of the project and can identify if the risks are increasing of even becoming reality. The Output from this process is updating of the project documents and also updating the risk register, since the risk has a tendency to change as the project evolves. (PMI, Project Management Institute, 2008)

3.11 Processes and process orientation

Every endeavour undertaken by an individual is governed by processes (Ko, 2009). There are different kinds of processes but normally one can divide them in to three categories: Management processes, business processes and administrative processes (Karlöf & Helin Lövingsson, 2007). Some different definitions of Processes exist, the ISO 9000 definition is; "*A process is a set of activities that are interrelated or that interact with one another and transform inputs into outputs."* (Karlöf & Helin Lövingsson, 2007, p. 273).

Often processes are described in the context of Business process management (BPM)

A definition is provided by Van Der Alst in (Ko, 2009, p. 11): *"Supporting business processes using methods, techniques and software to design, enact, control and analyze operational processes involving humans, organizations, applications, documents and other sources of information"*

Although there could be some confusion between BPM and the process orientation, the simple answer is that one is designed to control the other.

The reason for a process focus in the organisation is described by (Karlöf & Helin Lövingsson, 2007) and can be seen as focusing on the customer and coordinate functions. The traditional organisational approach is to focus the organisation around a matrix structure where resources are located in the functions and the processes are cross disciplinary and customer focused (Karlöf & Helin Lövingsson, 2007).

There are some questions raised regarding the term process organisation as processes are a flow of activities as to an organisation which is basically dividing work (Karlöf & Helin Lövingsson, 2007). Processes are used extensively in industry and some issues relating to the introduction of a process focus can be seen. They can basically be described as an unclear responsibility both in the economic context and in the decision context (Karlöf & Helin Lövingsson, 2007).

Concluded one can say that a process is a managing and responsibility question rather than an organisational structure (Karlöf & Helin Lövingsson, 2007).

3.12 KPI

KPI is a set of measurement that aims to measure and evaluate an indicator that is the most critical for the future success of the organisation (Parmenter, 2007). According to (Parmenter, 2007) few organisations actually measures their true KPI, claiming that the reasons are a missing exploration of what KPI really is.

To categorize and fully understand what a KPI is (Parmenter, 2007) starts with defining a few other performance measures.

And in order to define KPI one must now the difference between KPI, KRI and PI (Parmenter, 2007). Defining them in the following way:

1. " Key result indicator(KRIs) tell you how you have done in a perspective"
2. "performance indicators(PIs) tell you what to do"
3. "KPIs tell you what to do to increase performance dramatically"

Some examples of KRI often mistaken as KPIs are; customer satisfaction, Net profit before tax, employee satisfaction. They are a measure of many actions shows whether the company is travelling in the right direction but they do not tell you what you need to improve (Parmenter, 2007). They merely measure the symptom and not the cause.

In between the KRI and KPI is PI they should be complementary measures providing additional knowledge to the KPIs. Examples of PI are, profitability of top 10% customers and net profit on key product lines (Parmenter, 2007).

When these have been clarified and understood one can move focus towards understanding the KPI of the organisation.

The seven characteristics of a KPI (Parmenter, 2007)

1. Nonfinancial
2. Measured frequently(daily or 24/7)
3. Acted on by the CEO and senior management team
4. Understanding of the measure and the corrective action by all staff
5. Ties responsibility to the individual or the team
6. Significant impacts (affects most of the core critical success factors, and more than one balanced scorecard perspective
7. Positive impact(affects all other performance measures in a positive way)

The sample time of the measurement is an indicator whether the measurement can be said to qualify as a KPI.

The measurement has to be measured frequently because if the measurement is done monthly or yearly it is not something that is key to the business (Parmenter, 2007). And therefore it does not qualify as a KPI. (Parmenter, 2007) Recommends a 10/80/10 approach that is an organization has 10 KRI, 80 PI and 10 KPIs.

"What get measured gets done" (Parmenter, 2007, p. 12)

In the specific case of performance measures for project control the following is suggested by (Shtub, Bard, & Globerson, 1994)

Measurement	Category affected
Critical tasks not started on time	schedule
Critical tasks not finished on time	schedule
Non critical task becoming critical	schedule
Milestones missed	schedule
Due date changes	schedule
Price changes	Cost
Cost overruns	Cost
Insufficient cash flow	Cost
High overhead rates	Cost
Long supply lead time for material required	Resources, schedule
Low utilization of resources	Resources, cost
Resource availability problems	Resources, schedule, cost
Change in labour cost	Resources, cost
Changes in scope of project	Performance, cost, schedule, resources
Changes in scope of project	Performance, cost, schedule
Lack of technical information	Performance, cost, schedule
Failure in test	Performance, schedule
Delays in client approvals on configuration changes	Performance, schedule
Errors in records (inventories, configuration, etc.)	Performance, cost, schedule

Table 14: Measurements for project control (Shtub, Bard, & Globerson, 1994) s460

3.13 The Pareto principle

The Pareto principle or as it often called 80/20 rule was first mentioned by an Italian economist named Vilfredo Pareto (Flaum, 2007) . Pareto noted that 20% of the people owned 80% of the wealth and later found that this rule applied to many other applications.

In 1930 Joseph Juran extended the principle and called it "vital few, trivial many" (Flaum, 2007).

There is no formal definition of the principle although as it is defined by hardy (2010) gives a clear view of the fundamentals of the principle:

"80% of all effects result from 20% of all causes" (Hardy, 2010, p. 38)

The Pareto principle is today valid for many applications and can therefore be said to be a good way of improving your business. If 80 % of your revenues come from 20% of your customer, the question is whether there is a need for focusing on 80% of the customers, if one instead can focus on 20% and gain a lot more in revenue increase.

4 Empirics phase 1

Projects have been assigned for this study by Tetra Pak, in this first empirics chapter data from the initial semi-structured interviews are presented. These interviews have been conducted to explore perceived bottlenecks and get insights on potential parameters affecting efficiency.

TPPS provided 7 projects on which the evaluation should be based on. These seven projects are listed and characterised in the table below. For obvious reasons the customer names are anonymized and the projects presented with P1-P8.

Project	Type	Location
P1	Revamping	Sweden
P2	Greenfield	United Kingdom
P3	Greenfield	Romania
P4	Greenfield	Thailand
P5	Greenfield	Pakistan
P6	Greenfield	Pakistan
P7	Revamping	Norway
P8 (ongoing)	Greenfield	Vietnam

Table 15: A short introduction of the projects

4.1 Parameters Found to affect efficiency

This chapter aims to describe and conclude the results that were found in the interviews.

The Start of this project was the search for efficiency reducing parameters. The available material is a sporadic set of documentation with a varying grade of quality and accessibility. Therefore the main source for information was decided to be based on interviews. These interviews were conducted with resources from the seven projects chosen.

The questions asked where the following.

1. Describe what you would say is a typical project here at TPPS – size, scope of work, complexity, project process?
2. What is your background – experience, training and education
3. Explain your role and your tasks in a typical project.
4. Different formulations of the same question about problems in projects
a. What would you say is “flaskhalsar” bottlenecks in a typical project.
b. Explain the “speed bumps” from the start of functional description to Test
c. During projects a number of events can occur, these events can affect the productivity in your project. What are your experiences from different kinds of projects are there any common events in your past projects
d. Does it often occur situations where there are long waiting times and is there times when the projects are placed on hold and your time is wasted. Answer this in the context of both external and internal factors
e. Communication between different processes in projects, like for example process or electrical, both internal and external.
f. Missing requirements, or unclear requirements from marketing companies or customers
g. Unclear project specifications, do you fully understand the customer value
5. Multiple questions, management and control aspects
a. Is there a support and understanding from management about the work conducted at your level.
b. How is the efficiency measurement IOs per hour in your opinion.
i. How would you like to measure?
c. Do you find your work processes helpful and do they provide you with the information you need.
6. Multiple questions
a. Is there a coherent view on what adds customer value, i.e. is customer value something that is addressed in projects
b. How are the contacts with customers and your role in the overall process.
7. How do you use lessons learned.
8. What are your three lessons learned from your time as a (PL/SL/AE), do you have examples from other companies
9. If a problem is apparent, are you encouraged to provide suggestion for improvements
10. What about client review, approval of your engineering or documents, i.e. how is continual feedback from customers collected.
11. How close is your contact with the end customer,? (Who is your customer – purchaser or staff in operations?) Who do you contact at the customer site.
12. Culture gaps between your team and customer, influencing the productivity?
13. Anything you wish to add.??

Table 16: Questions asked during the first set of interviews

4.1.1 Introduction of the interviewees

The first question was constructed to see whether there were differences in the answers depending on what the interviewee thought was a "typical" project. Mostly the answers pointed out that GP handles big projects, which is called L3 projects. Projects are sold by the market company and often the market company is involved either as a customer contact or performing technical work. Complexity does not lie in the individual parts of the project but in the size and interrelation between modules and report functions.

Background for the interview group was quite different ranging from electricians to MSc in Electrical Engineering, and experience of 5 months to more than 30 years in the company. Comments made on the internal education were positive and pointed out a strong curriculum in technical courses.

Project leaders pointed out scope, time and cost as responsibilities also some comments about well being and quality were made.

The presentation of the answers will focus around a number of topics that was mentioned during the interviews. All of the opinions presented in this chapter are opinions from the interviews, a summary of the answers is provided in appendix A.

4.1.2 Functional Description

The answers on both the question regarding bottlenecks and speed bumps were answered with the Functional description. The Process Functional Specification (PFS) is constructed based on the Functional Description (FD). The system-leader in the projects is responsible for writing the functional description. The main problem with having no functional description can be divided in two categories; problems relating to whether the engineers are aware of what task to perform, and problems relating to the customer management.

The task an engineer is supposed to perform can be found in the FD. The FD is created to describe how to technically programme the system to automate the plant. The less experienced engineers that have not been involved in many projects indicated that it was harder to know what to do. The experienced engineers tended to have a view of how to solve the problem and didn't need a FD.

Comments regarding the customers and their input to the FD; the customer is supposed to sign off on the FD, but the FD is a technical document which the customer has a hard time understanding. If the customer has not signed the FD the variation order process and charging for changes made late in the project is hard. Since the customer always can point towards not having signed the FD and therefore not having agreed upon the specs delivered.

Comments were also raised were thoughts and experiences about changes in the process design not being marked as the automation team receives them. Meaning that if the market company for example is to redraw the process design, because of customer change, then the changes in relation to the old version needs to be marked.

4.1.3 TPM and AS

TPM has been created to standardize the integration of TP modules and Automation design. The idea is that with TPM a lot of functions are prebuilt and therefore the programming and design is to be done faster and with less variations between projects. Some problems concerning the usage of TPM have been raised during the interviews. The focus of AS which develops TPM are viewed as focusing more on technical solutions when they should focus more on standardization. During the past 5 years there is a feeling that TPM has gone in the wrong direction.

Regarding the complexity of TPM, this is viewed to be mainly because of the size of the templates. When dealing with big templates and the customer demands there is sometimes a need for deleting code and parts of the templates to keep the system from having unused code consuming memory and slowing down the system. This has also been commented in the context of a missing FD, and the view here was that when the FD is not done properly or at all it is harder to break down the templates and rebuild them, because you simply do not know what the desired state after rebuilding is.

When a project is ongoing changes in the templates are a factor that will affect the project. Changes made to templates in-between the projects can affect the reusability of code if these changes are not documented.

The learning curve for TPM is quite step and when the department has a lot of projects the time when inexperienced resources can be up to speed and actually produce more result then they consume from experienced is long. This leads to troubles when resources are allocated to other projects and more time needs to be spent on a project.

When changes are made in the templates by the engineers there is more need for testing. The system is tested by AS before being deployed, the main concern here was that the tests are too small to provide significance for the real projects. As the scale of the project increases so does the complexity, and in the case with the TPM problems that doesn't occur during small scale testing may arise during large scale tests.

Since these problems are apparent and a real concern from the engineers the need for feedback is essential. The technical feedback can be provided via the tech gate from where the AS can find feedback and prioritize the changes to be made. Sometimes problems occur at site and the feedback to AS is not provided in the same extent.

All the above has lead to the feeling that management does not support the projects in their feedback to AS. There was also a feeling that the relationship between AS and GP is not very healthy although most of the comments regarding the engineers working there was positive and understanding. Some frustration can be detected when the discussion concerned the fulfilment of customer value and the comment was:

"We are held back due to the usage of TPM"

4.1.4 Resources

As concluded by one of the respondents during the interviews:

"The experience of resources is one of the biggest bottlenecks"

As concluded in the above chapter the time it takes to learn the TPM is usually around 2 projects. The complexity of the automation work both in the context of software and in the context of project work itself is quite high and this induces a start-up time of around 2 projects. Comments during the interview regarding the FD and resources was mainly focused around the need for a FD for more inexperienced engineers and that the experienced engineers has a wider competence which allows them to perform the work despite the lack of an FD.

This Difference in experience can also be noted in the context of different design steps. Engineers more experienced in automation work often has a competence in process and electrical design which gives them a better understanding of those in relations to the Automation design. Within automation projects a number of tasks or features for the automation can be identified, such as PLC design, HMI

and programming. During bigger projects engineers normally focuses on one feature i.e. works horizontally but one comment was made that to gain more knowledge engineers should be instructed to work vertically.

As the project is initiated and to be planned the APL will construct a time plan based on the resources available and preferred. When the project is due to start there can be changes made to the allocated resources and the experience of the new resource may differ from the planned and therefore the time plan has to be reconstructed. Comments regarding the exchange of resources during the projects was also made, where the main concern was that this either leads to overtime or the appointment of a new resource that are not up to speed with the work. In the context of FD and in the absence of an FD the start up time for a new resource can be quite long and affect the time plan of the project negatively.

4.1.5 Customers

One of the strengths of the GP office in relations to the customer was that the engineers could communicate with both the operators and the production manager. The unprestigious communication is perceived to be a strength.

Delays relating to the customer can occur for many reason, although there were two main trends that could be identified; feedback on documents and Construction delays. Feedback delays can occur when an engineering document is sent to the customer for approval. Depending on the technical knowledge of the customer and the hierarchy delays can take place because of the internal communication of the customer. Technical documentation can be hard to answer because the customer simply do not understand for example the FD or are not experienced with automated plants.

Problems that are caused by delays in the construction work involves that resources are not pushed towards a deadline and the work pace therefore decreases, a potential increase in the testing of code and the time spent thinking about design is also induced. The impact of the delay is therefore not only seen as a negative impact but there are potential drawbacks such as productivity decrease and the allocation of resources.

To be able to understand the customers, communication of customer preferences is essential. If one knows about the potential blind spots for the customer the communication can be based to overcome the technical barriers. Receiving technical documentation from the customer can also be a potential bottleneck.

4.1.6 Modules

As GP only provides the knowledge in automation, process and electrical design they buy modules from internal Tetra Pak companies. These modules are often sold as standalone and GP only accounts for a small amount of sales from module companies. The market companies are responsible for the contact with the customer, and GP contacts the MC to access the customer. During the interviews the MC was seen as a communicating partner and the end customer was perceived to be the customer for GP. The interviewees concluded that the module companies perceived GP as the customer and therefore did not feel accountable for the problems configuring the modules. Resources that were used by GP from Module companies to configure the modules are paid by GP.

Configuration time is said to be around 2-3 weeks but should be around 2-3 days. The awareness and concern from module companies regarding the perceived problems is limited.

4.1.7 Market Companies

Tetra Pak is organized around clusters which contains the market companies. These market companies are located geographically near the customers to provide cultural knowledge as well as closer contact with customers. The market companies have their own resources with mixed competencies, and the market company sometimes does part of the work for the project. Responses from the interviews pointed out that the processing solution performed at the market companies didn't always reach the standard required for the automation design to be realizable. This can lead to rework and sometimes the standard of the market companies is a simple design that does not meet the TP standard.

The communication was also raised to be a problem both in the context of dividing the project team, as well as potential language barriers. But the main concern regarding communication was raised in the context of geographical distance, which leads to a social distance.

4.1.8 Functional designer process focus

According to the process the FD should be done before the PFS and the FD should be the basis for constructing the PFS. Therefore the PFS must be realisable in the terms of automation, during the interviews comments about the process-focus was made and perceived to limit the automation design.

The TPM is mainly an automation solution template, TPM has some limitations when designing the control system. Therefore the Process design must be compatible with the templates provided by AS.

During design a number of trade offs are to be made. During the process review meeting the automation project leader should be present to gain knowledge about the tradeoffs made in the process design. When the process design is finished and the automation starts, the process engineers starts working on another project and aren't up to speed with their old project when receiving questions and also has to take time away from the current project.

4.1.9 Time plan rush

When the project is sold to the customer one of the first things agreed upon is the delivery date. If the project is delayed because of iterations in the contract phase the delivery date is not changed. Therefore the project is rushed:

"We are told to start program even though we are not finished with the FD, we are then told to perform the FAT even though we are not finished with the programming, and we are told to go to site even though we haven't corrected the errors commented during the FAT".

The budget is often limited as well and the cost calculation doesn't support projects which have a short delivery time. One concluded that:

"*The unsuccessful projects are the one where it feels like you're always a bit behind"*

The business process is perceived to be impossible to follow if you're to finish on time. If the APL is not involved in the quotation process the time spent often exceeds the calculated. This leads to decreased margins.

4.1.10 Technical problems

During the interviews a number of technical aspects were raised. They can be divided into System speed, Customer integration and platform compatibility. Speed of the system was commented in the context of the PLC, programming simultaneously on the PLC was believed to be slow. Customer integration was a comment raised in the context of integrating the Program with the customers ERP

system. The problems here mainly involved domain access and customer knowledge about its own system. Platform compatibility is a problem when using different software that has different platform requirements. These requirements have to be taken in to consideration and the version of some software revised to be able to integrate to one platform.

As the systems are slow and the engineers increase the pace at which they work the bottleneck is the system speed, as concluded:

"Even if we increase our efficiency we are slowed down by the speed of the system platform".

4.1.11 Documenting code

When programming is done based on experience, which is the case in the absence of an FD. Then the programmers find innovative ways to solve problems and the design is not fully documented. When the documentation is not performed fully during the project the testing gets more complicated and the reusability is not possible. Keeping in mind the comments made about the potential exchange of resources the need for documentation regarding the code increases.

4.1.12 Variation orders and scope changes

As the customer is supposed to sign the FD and when the FD is signed any changes initiated by the customer is to be handled as a variation order. Variation orders are to be paid by the customer if no other agreements are made. These VO are believed to affect the overall efficiency of the project since there is a need for reprogramming or adding functions. The cost of the variation orders are the number of hours calculated to programme the function.

The reason why VO occurs was believed to be two. The first is a knowledge limitation from the customer, the other one was based on the organisation of the customer. As concluded the customer may not have the experience needed to understand the FD fully. As the project evolves the customer may realise that the project is not evolving as he expected. This can lead to discussion where a number of VO: s is initiated. Customer has different organisational structures when initiating a project of this size. If the customer has appointed the project to the board or senior management and the operators are not involved. As the project is handed over to the operators the operators is perhaps confused of the design as it is not in line with their current work style.

To be able to handle VO effectively changes is to be handled quickly. In communication with the customer oral agreements can be made or oral explanations from customers can be given. These should be listed and communicated in written form to match the expectations and understanding.

As the FAT is finished and the engineers travel to site they get involved with the operators and better understands the needs. If there are spare time an indication was that often extra features are added. These features are sometimes not documented and are not charged for.

4.1.13 Sales organisation

The goal of the sales organisation is of course to bring projects to the organisation. Responses from the interviews pointed out some opportunities and suggestion of improvements. The main thing was that the focus of the sales org should be around the plant and focusing on the end result. Some concerns were raised that this is not always the case. Focus seems to be on version of the PlantMaster and other technical details instead of convincing that TP will know what tools are best to develop the end result which will make the customer satisfied.

"*There is a feeling that the salesperson sells a specific version of the PlantMaster instead of focusing on selling a solution to a problem."*

Also stating that: "*A good salesperson can raise the discussion from technical details to the appropriate level."*

Contracts is the basis for other documents, but in the contract phase discussions as mentioned above is sometime focused on small technical details. There are some concerns raised regarding the contracts, sometimes a contract does not exist and a general feeling that the contract does not state "*what we sell"*. In general one can say that in the contract phase the focus should be on sorting things out.

As the contract phase is done and the contract is signed a handover should be done to the project organisation. The comments here concerned that the handovers are not as good as they could be and that the sales person should stay longer in the project. The knowledge they can provide to the project is knowledge about the customer and experiences from negotiations.

4.1.14 Kick off agenda

The purpose of the internal kick off is to discuss information regarding the contract, the systems used and other planning related issues. In the interviews the feeling was that a lot of times the discussions ends up in other social topics and travel tips instead of focusing on the customer characteristics. The Kickoff was pointed out to be an opportunity for sales to provide customer information as stated in the chapter above and to discuss customer value. Customer intelligence was to be provided and also the insight from the market companies.

4.1.15 Project finished when leaving for site

As the FAT is done and the issue list is to be finished the time is sometimes the biggest issue. When arriving to site some of the issues may not have been sorted out which leads to programming work being performed at site. Comments on this was that the programming on site is 3 times more time consuming and the cost is 3 times higher per hour.

4.1.16 Addressing customer Value

When the interviewees were asked about the customer value different views of customer value was given. The main opinion was that the customer value was to give the customer something extra that wasn't ordered and that was given away as a bonus.

Comments regarding how well the customer value was addressed in the projects mainly stated that there is sometimes a tendency to focus on the technical parts. A design issue was often compared in a technical context instead of focusing on the customer needs and expectations. During the project tradeoffs are constantly made. If the trade offs are made based on technical comparisons there is a risk that this is not something preferred by the customer. Arguments involved that tradeoffs will be in favour of the customer if the trade offs are discussed in the context of customer value.

During the interviews statements regarding the technical level of the plant were raised. There were some concern about that the customer is perhaps not in need of a "top of the line" plant and would have done just fine with a more simple one.

There was an agreement that the focus on customer value will benefit the project in many aspects. As the focus move towards functions rather than code and the tradeoffs are being made based on what will favour the customer, alignment is more likely. This comment was explicit during one of the interviews but comments that circled around the same philosophy were given.

4.1.17 Management support

The organisation has two types of managers, project managers and line managers. These comments will mainly focus on the line managers and if it is not stated explicitly the comments is made about line managers.

Line managers are perceived to be an administrative function. The support from management was not satisfying and a sceptic view of their intentions. Although the feedback climate seems to be good, no encouragement on providing feedback is felt. Comments regarding the number of managers were made and the feeling was that the number of managers has increased and is almost exceeding the number of engineers. This was commented in the context of increased overhead costs. Where there is a feeling that the engineers are "to expensive" internally and this is mostly due to the OH cost.

The general feeling was that the visibility of managers in the organisation was too low. Their focus was mostly on creating tools and administrative control systems and not connecting them to the projects daily troubles. The comments in general where focusing on the control systems such as the balanced scorecard which was seen as inefficient.

"Managers *want to set their own mark on the tools therefore they develop new tools but do not take away old ones"*

"Just because you get appointed an administrative title doesn't mean you have the monopoly on good ideas"

A general feeling about the future of GP was also commented. Where the feeling was that the future is uncertain and that the need for a GP office is perhaps not as extensive as today since the market companies knowledge will increase.

4.1.18 Lessons learned

Lessons Learned (LL) session is to be performed after the end of every project. Knowledge gained and improvements for the future are to be collected and written down. This is not done extensively and the responses varied about how well familiar they were with the collection of these.

When they are collected there were questions who were the intended receiver of LL. Knowledge about how they are used after being written down was not significant and there does not seem to be a formalized process for communicating LL.

Questions whether they looked at old LL when they performed a new project for an old customer or in the same region was asked. Answers explained that LL is not used in this way.

4.1.19 Who is your customer and End customer

Depending on the customer there are different types of relationship between GP and the end customer. There could be a consultant company in between or a global organisation responsible for ordering new plants. A general opinion was that it affects what kind of middle hand there are. No answers regarding what was the most common could be given. In general the comment was that it is important to have access to the end customer and the operators intended to use the plant.

When there is a market company involved it is of great importance that the projects can have access to the customer and doesn't need to use the MC as a source of information.

4.1.20 Pre project quality

There were comments raised about the importance of the pre project and as one concluded.

"You can always trace the problems backwards".

The pre project should be done at site and the access as stated before to the users is important. Also a validation of the customers' technical details if it is a revamping project is important.

"*Pre-projects take time and that is necessary."*

4.1.21 Process and project tools

The processes are presented in a tool called point; the processes are not seen as controversial and are described by how the work is conducted. This is the general opinion; there is however some complaints made on how well the tool works. And that the information is not available when it is needed.

Processes are perceived to be something that the APL should focus on and the AE does not feel the need to understand them. The drawback of the Processes is that there are no shortcuts and there are no quick exits if you cannot follow them.

More education would be appreciated and more information on what changes are made would also be helpful. But most of all the lack of arguments why processes are helpful is the main concern. And one concludes

"*It does not focus on the right things"*

The tools used for showing the processes was mentioned and is perceived to be clumsy and like a black hole where nothing is found when you need it. This tool therefore didn't assist the projects in their work.

The reuse of code was also mentioned as something not explored in a great extent and for this to be possible it calls for a unified tag numbering system.

4.1.22 Tests and Fat

The Factory acceptance test is performed before going to the site. FAT is performed to guarantee that the functionality is working properly and the customer can point out certain errors or features that do not work properly. Comments regarding the agenda of the FAT were made, it was perceived to focus too much on operator pictures instead of functionality. Programming is to be finished before the fat otherwise problems during FAT will occur that is not functionality related.

Comments regarding other types of tests were made, for example the testing of functionality before duplicating this functionality is of great importance. One project pointed out the use of a process engineer that tested the functionality as the project evolved and this was something that had improved the work flow.

Pre-FAT was sometimes performed. Different types of pre-Fat was mentioned, some focusing on operator picture and some mentioning it as an internal FAT. The agreement was that the better tested the code is, the easier the FAT and eventually the start-up.

4.1.23 KPI

The KPI currently used is Hours/IO and this is not perceived as an efficient measurement of the efficiency of automation projects. Measuring the progress of a project was not possible with this indicator and the evaluation of projects was not possible based on this.

4.1.24 Project team location

Preferably the team should be located in the same place. When teams are not collocated there are request for face to face meetings which is believed to decrease the social distance caused by geographical distances.

Telephone meeting are not as effective as the normal meeting and the distance will sometimes create cultural barriers.

The answers found during these interviews is to form the foundation for the evaluation, the answers given have shown a conclusive but broad picture of potential areas of improvements

5 Analysis phase 1

In this first analysis chapter the empirical data from chapter 4 is analysed with the intention to provide information to the evaluation model. The data are to be compared between interviews and the recurring patterns are analysed.

5.1 Analysis of empirics from first set of interviews, the construction of the model

The answers from the first set of interviews presented topics and conclusions on which the basis for evaluating the assigned projects can be made. These topics and returning opinions can be found in the first empirics' chapter. However all these parameters are not directly affecting the efficiency and some of them have big commonalities. Often the visible symptoms are not the cause. Instead the symptoms are merely a visible sign of the underlying problem.

To create the model an analysis must be conducted based on the symptoms and opinions presented in chapter four.

An opinion which returned in almost every interview was the functional description. Since the work is built on a traditional waterfall approach one must finish the FD before the programming starts. Since this in some cases is not done and there is a great amount of experience needed to be able to programme without guidance.

The basis for the FD is the intelligence collected during the pre project. The quality of the pre- project can be seen as an input of the project itself. *Quality of the pre project is to be defined as how much it differed from the actual project when finished and how well it captures the customer requirement. Also how well the estimated costs and times matched the outcome of the project.* During the interviews the pre-project has been mentioned quite a lot of times, if not explicitly it has at least been touched upon in some sense.

Figure 25: The project is viewed as a production line and the input/raw material is the pre-project

Contracts were often mentioned in some context either if it didn't exist at all or if there were quality issues in the contract. In the context the quality issue of the contract was addressed during this question was whether it provided the information necessary to perform the project.

This thesis is to investigate the parameters affecting the efficiency. Parameters are defined as both external and internal. The relationships and cooperation that GP is involved in is also both external and internal. Internal Relationships is therefore seen as potential parameter to be assessed by the model. Possible parameters involve cooperation with; Market companies, Automation solutions, Process design, module companies, sales organisation, and line organisation line-managers.

Tools used and their usability for the project team is also essential. The tools available will be studied in the following contexts.

1. Use of tool, what tools are used.
2. Competence in use of that tool, how skilled are the personnel in this version of the tool
3. Right situation to use that tool, has the appropriate version been used.

Tools in this case is especially focused on the Template Plant Master but also other systems such as the PLC interface and the software used.

Something also pointed out during the interviews as a potential parameter was variation and changes initiated by the customer. This leads to rework and speed loses according to the interviews. Therefore the changes and variations supplied by the customer are to be addressed in the model.

Scope-creep is uncontrolled changes in the scope; this was mentioned during several interviews, both in the context of the size of the templates ,as well as in the context of giving the customer something extra for free.

Meetings and their agendas was brought up as a suggestion for improvement and also a potential bottleneck. The model is to assess and investigate the meeting agendas and the minutes from these meeting to explore the topics covered.

The awareness of customer value and addressing customer value in the project was discussed during interviews. Customer value and how it has been addressed in the project is therefore to be evaluated in the model.

Lessons learned are not something that is familiar to all the interviewees. There have been comments about the lessons learned and sharing of lessons learned. The model will investigate if a Lessons learned report exists, and if so what are the key issues and topics in the report.

Administrative tools were mentioned during the interviews. Both directly addressed in questions, and indirectly in the answers of the support from management. Especially focusing on managements understanding about how work is conducted. The model will especially assess the document structure and also use a survey proposed by Kerzner.

Tests both in the sense of self testing code, and in the sense of customer tests was addressed in the interviews. The model will focus on hours spent on testing and the agenda of the FAT.

In the chapter below questions have been created to assess the content of the parameters described in chapter four. all questions are to be asked during an interview session and to provide more comparable results the questions are to be answered with predefined answers.

6 Evaluation model

In this chapter a model for further evaluation is listed, from the first and initial parameters found questions designed to assess the aspects of the parameters are listed. The model is created to find information using both data gathered from interviews and archive material of the assigned projects.

As Mentioned in the report and during the first set of interviews a second round will be conducted. The focus is here to provide data from the projects studied, and also to provide additional information to the results generated by the evaluation model.

To provide the reader with information on the work conducted in this thesis the process is shown below. The fields marked in green is the one that has been performed, the square marked in blue is the current process step to be assessed, and the read are steps that will be performed in the following chapters

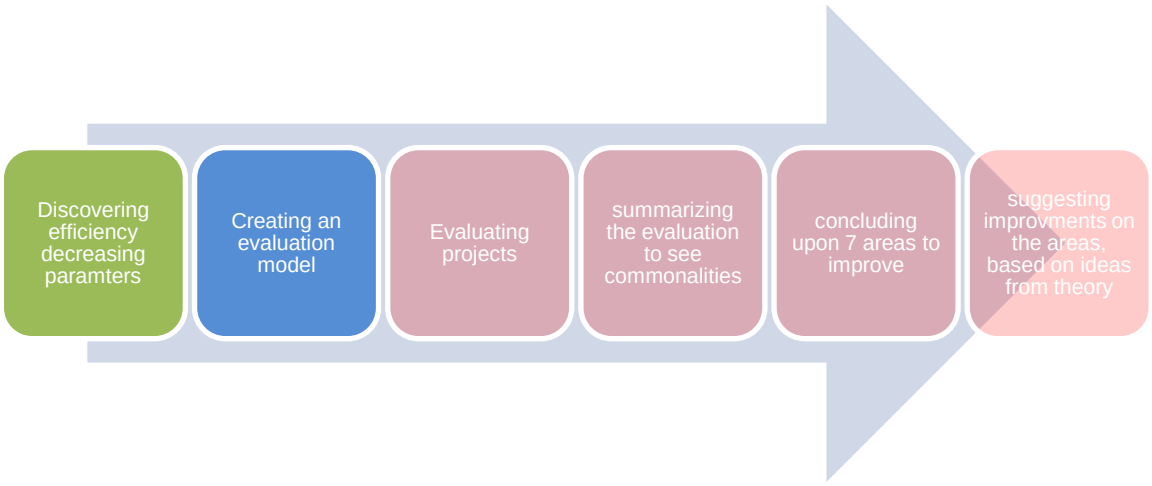

Figure 26: A brief overview of the progress of this thesis

6.1 General questions

Below is a list of the questions asked during the interviews, the left most column shows what area the question assess. These questions have been created based on the analysis performed in the previous chapter where areas from interviews have been described and emphasised. The area on the left is the topic of the parameter chosen and the questions are designed to assess the topic to investigate the underlying layers of that topic.

Area	Question
Contracts	1. Did you find the contract helpful when you had questions regarding the scope of the project.
	2. Was there any feedback from the customer regarding the contract during your engineering work.
Market companies	3. Was there any differences in the tool and standards used by the market companies and GP
	4. Was the market company involved during the whole project, and what was their task.
Aut sol	5. Did AS provide support with problems regarding TPM during the project.
Process design	6. Did the PFS provide the adequate information for specifying the automation design.
	7. How was the cooperation with process engineers during this project.
	8. Did the process engineers finish their task and then disappear from the project.
	9. Was the process design in line with the limitation of TPM?
	10. Was the process engineers located In Lund.
Modules	11. Were there problems with the integration of modules.
	a. If yes what kind of problems was present during the project.
	b. How much did these problems add to the total time.
	12. To whom did you feel that the module company delivered. I.e. was your relationship with the Module Company as a customer or a partner.
Sales org	13. Was the APL involved in the sales phase.
	14. Was the adequate information about the customer and its knowledge collected during the sales phase and handed over to the project phase.
Location and cultural differences	15. Where was the automation team located.
	16. Where was the rest of the project team located.
	17. What kind of productivity affect did you experience during the project due to the location of the project team.
Technical problems	18. What technical difficulties did you encounter in the context of 3rd part suppliers of software systems.
	19. How did this affect the overall project time plan.
TPM	20. What problems did you encounter with regards to the TPM
	21. Why did you use this version of the TPM.
	22. Was any code from the templates removed?
	23. Was there features that were given to the customer because it was a part of the template.
resources	24. Did you get the competencies you wished for
	25. Was the resources on the project involved in other projects, and where you?
Perception of customer	26. Who was perceived to be the customer of the project
	27. What was the knowledge of the customer, i.e. how technically skilled where the customer.
Customer contact	28. How and when did the project team meet with the customer
suppliers	29. Were there any delays from your suppliers.

	30. Did they affect the overall time, and if yes, how did they affect the overall time.
Variation order	31. What was the reason for this variation order.
	a. Unclear contract
	b. Changes by customers regarding the scope
	c. Technical knowledge of the customer.
	d. other
Scope creep	32. Was there something included in the scope that wasn't delivered?
	33. Was there any added functionality due to the template size.
	34. Where there any variation orders that wasn't formally handled(i.e. a written order with a price)
	35. What was the reason for the scope creep(for example did you feel guilty towards the customer or were you delayed.)
Meetings	36. Was these meeting valuable
	37. Did your expectations of the meetings match the outcome.
	38. Are there other meetings that is not documented and what are the agenda of these meetings.
Kick off	39. What was your impression of the kick off meeting, was the agenda informative.
	40. Was there anything that you feel should have been addressed that wasn't
	a. Customer value
	b. Expectations on the project team
	c. The strategic importance of the project.
	d. other
Telephone meetings	41. What is your impression of telephone meetings during this project
	a. They are valuable
	b. They do not add anything to my knowledge
	c. They could be improved
	d. other
Customer value	42. Did you feel that you knew enough about the customer to be able to make decisions regarding tradeoffs and designs.
	43. In the context of this project, what is customer value?
Lessons learned	44. What was your top one lesson learned from this project.
KPI	45. Are you satisfied with this KPI?
	46. Does this KPI describe your feeling of the project outcome.
Documentation	47. What sort of documentation do you feel necessary(interview q)
	48. How many pages of text(non code related) did you produce during this project?
	49. How much time did you spend on non customer related documentation.
Test and FAT	50. How was continuous testing done
	51. Who test your code
	52. Did you feel that the system was tested enough as you started the FAT.
	53. How much time did you spend on testing code in this project.
	54. If problems were found during tests, how long time did it take before you corrected the code.

Table 17: The evaluation model questions asked during interviews

As a part of this study there are questions that should be answered by studying documents and archive material. By focusing on different types of data a broader view of the picture can be obtained. These parameters are also described in areas and will be addressed as above by focusing on finding the underlying layers of the parameter.

Area		Question to answer
Pre-projects	1.	How much time was spent on the pre project.
	2.	Who were involved in the pre project.
	3.	What was the scope of the pre project, and was that scope covered in the project
Modules	4.	What modules were used?
Technical problems	5.	What was used during the project(Siemens, Rockwell, intouch, Wonderware, ABB 800xa)
TPM	6.	What version of TPM was used.
	7.	Had this version of TPM been used on another project before
Resources	8.	Where there any changes in resources.
Customer Contact	9.	Who did you contact at the customer site
Variation and changes	10.	When did they arrive and how where they handled
	11.	How was the cost of changes calculated.
	12.	Was there a contract in place
Scope creep	13.	Was the delivered product in line with the contract plus the VO
Meetings	14.	How many of these were telephone meetings.
	15.	Where there meeting that were not documented and why?
Kick off	16.	Who was at the kick off.
	17.	Were expectations in the project addressed during the kickoff.
Customer Value	18.	How was the customer value addressed in this project.
	19.	What was the customers' opinion of the project.
Lessons Learned	20.	What are the key issues of the lessons learned debriefing.
	21.	How was the lessons learned performed, who attended the meeting, who lead the meeting
Tests And FAT	22.	What was discussed and tested during the FAT.
	23.	What was the agenda of the FAT.
	24.	What was not handled during the FAT
	25.	Was the project approved after FAT.

Table 18: Evaluation model questions to be found in an archive study

By searching for documents on the project server the structure of documentation and the consistency can also be observed. Documents that are not located on the project server will not be studied, thee documents are not official and not shared.

7 Empirics phase 2

As the evaluation model was used the answers are presented in this chapter. The answers are divided into two subchapters, one describing questions answered with a yes or no, and one describing the answers to the other questions. Also a survey which is designed by Kerzner is used to assess the areas of management support, informal project management and integrated process.

7.1 Results from interviews

A second set of interviews have been conducted. During the interviews 54 questions have been asked and the respondents have been asked to answer the question, keeping a specified project in mind. Answers to these questions are therefore project specific and the summary is based on the sum of 6 projects.

Interviews with 5 automation project leaders, 2 system leaders, and 6 automation engineers have been conducted. The choice of the interviewees was based on if they have been involved in any of the assigned projects. The numbers of respondents in each of the projects are presented below

Project number	Number of respondents in each project
P1	2
P2	1
P3	2
P4	3
P6	2
P7	1
P8(Ongoing)	2

Table 19: Number of respondents from each of the projects

The questions where to be answered with a yes/no answer or in some cases another brief answer like bad/good, satisfying/not satisfying. The respondents had the opportunity to elaborate on some of the questions if they felt that the answer could not be given briefly and answered fully with a yes or a no.

As the answers have been summarized, the questions have been divided into two sub-categories. Category one; question which have been answered with a yes or a no, And Category two; describing questions not answered with a yes or no.

7.1.1 Questions answered with a yes or no.

The questions below are the questions answered with a yes or a no. On some of the questions the respondents have elaborated on their answer, mainly if there are circumstances to the answer that needed to be expressed. That elaboration is presented later in this chapter.

1. Did you find the contract helpful when you had questions regarding the scope of the project.
2. Was there any feedback from the customer regarding the contract during your engineering work.
3. Was there any differences in the tool and standards used by the market companies and GP
4. Was the market company involved during the whole project, and what was their task.
5. Did AS provide support with problems regarding TPM during the project.
6. Did the PFS provide the adequate information for specifying the automation design.
8. Did the process engineers finish their task and then disappear from the project.
9. Was the process design in line with the limitation of TPM?
13. Was the APL involved in the sales phase.
14. Was the adequate information about the customer and its knowledge collected during the sales phase and handed over to the project phase.
22. Was any code from the templates removed?
23. Was there features that was given to the customer because it was a part of the template.
24. Did you get the competencies you wished for
25. Was the resources on the project involved in other projects, and where you?
29. Was there any delays from your suppliers.
30. Did they affect the overall time, and if yes, How did they affect the overall time.
32. Was there something included in the scope that wasn't delivered?
34. Where there any variation orders that wasn't formally handled(i.e. a written order with a price)
36. Was these meeting valuable
37. Did your expectations of the meetings match the outcome.
39. What was your impression of the kick off meeting, was the agenda informative.
42. Did you feel that you knew enough about the customer to be able to make decisions regarding tradeoffs and designs.
45. Are you satisfied with this KPI?
46. Does this KPI describe your feeling of the project outcome.
52. Did you feel that the system was tested enough as you started the FAT.

Table 20: The questions which the respondents have answered with either a yes or a no

The distribution per question summarized for all projects is listed in the figure below. On the question where the sum of answers does not correspond to 11, one or more respondents have chosen not to give an answer, these answers are not included in the figure.

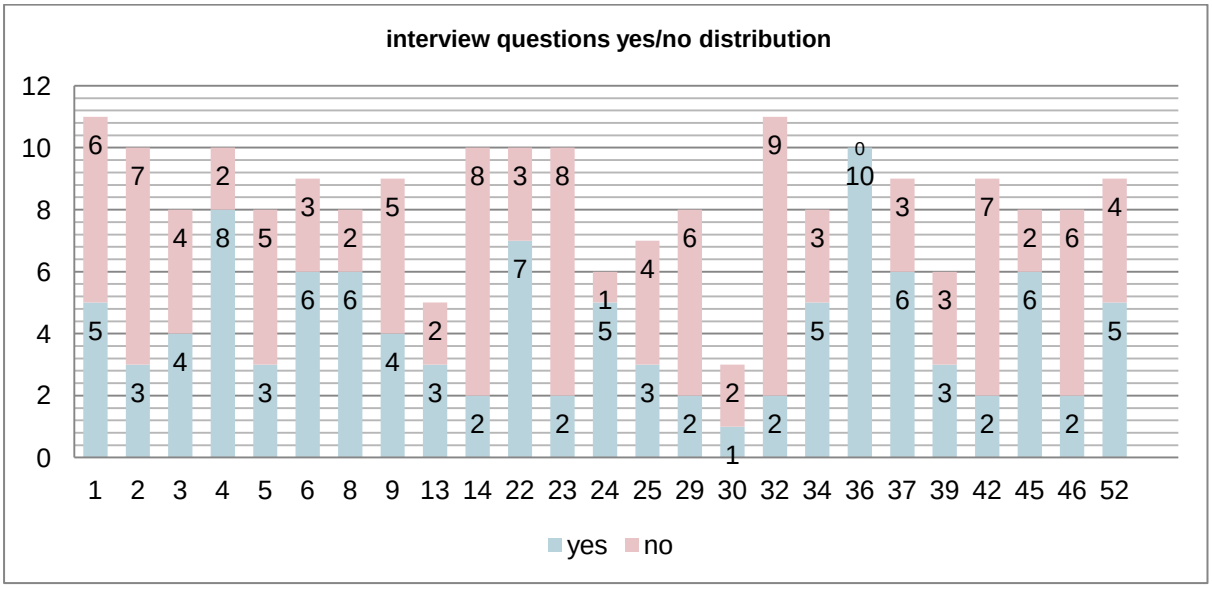

Figure 27: Answer distribution for all projects, questions answered with yes or no

Above the sum of answers are presented. Interviewees have been conducted with 13 persons. Two of these interviews have been conducted with persons from the ongoing project, and these are not included in the figure. Due to the size and characteristics of the projects there are a different number of interviewees available, therefore the number of respondents per project is not the same, for example on project 4 there are 3 respondents and on project 2 there are 1 respondent.

In the figure above one can observe that on question 4,23,32,36,42,and 45 the opinions of the respondents does not differ that much, many of the respondents in the projects have chosen the same alternative and therefore the sum of the projects describes a more general opinion. The questions on which the opinions does not differ are; market company involvement, scope creep due to template size, functionality not delivered, value of the meetings, knowledge about the customer, and the opinion of the KPI value. Where the respondents answer that the market company is involved during the whole project, functionality is not given to the customer due to template size, the pre decided scope is often delivered, meetings are in all cases valuable, and the respondents does not feel that they know enough about the customer to be able to make tradeoffs.

On the contrary those questions that shows differences are 1,3,9,25,39, and 52. The responses on these questions are not conclusive in the sense that there are a clear yes or no trend. The questions that are inconclusive cover the following aspects; if the contract was helpful, differences in standards and tools between MC and GP, realisable process design with TPM, if resources on projects where involved in other projects, if the agenda of the kick off was informative, and if the system was tested enough when reaching the FAT.

If studying the answers per project one can see that on some of the projects the answers are more similar and in others they differ, on project 1,6,7 the answers are the same on a majority of the questions. On project 3,4 answers are inconclusive in a greater extent. When comparing the projects to the majority of the answers the data shows that the main differences between each of the projects and the summarized data are:

Project 1: one of the respondents felt that he knew enough about the customer to be able to make trade-offs, one respondent felt that he couldn't say anything about the KPI, and both respondents concluded that there were no kick off. The elaborations showed the following; there where feedback from customers regarding the scope of the project, the customer provided the process design since this was a revamping project, and regarding the variation orders the customer did not sign all of them.

Project 2: the respondent felt that features had been given to the customer, and no answer was given to whether he knew enough about the customer to make trade-offs or if he felt satisfied with the KPI. The elaboration made on this project stated that the customer changed their mind as the project evolved, that in this project the engineers where resources to the market company, and that the reason for not being able to make tradeoffs was that the customer did not know what they wanted.

Project 3: Where inconclusive on whether the market company where involved, the elaboration on this projects are mainly that the market company did the process design and were responsible for customer contact. And that there were some scope creep due to the time effort needed to create a variation order.

Project 4, the question about market company involvement and if features were given to the customer due to template size was inconclusive, and on question 42 one felt that he knew enough about the customer to make tradeoffs. The elaborations states that there was too few meetings with the customer and process designers, and that a real kick off was missing.

Project 6: Stated that there was something in the scope that was not delivered and one was satisfied with the KPI as and one wasn't. The elaboration on these projects are that there was something included in the scope that wasn´t delivered; the quality assurance part and the some of the hardware which the customer chose to provide themselves

Project 7: differed on the KPI satisfaction, where the respondents stated that he where not satisfied with the KPI. The elaborations made on these projects states that the project received feedback regarding the scope, that the project manager was from the market company, the project where given material about the customer, and that partly one could make decisions about trade-offs and design changes.

For a presentation of the data per project, please consult Appendix 2.

Combining the project specific analysis with the sum of the individual answers, the inconclusiveness comes from both differences in the projects but also the viewpoints of the individuals, where the opinions within projects differs between the respondents.

On some of the questions the respondents have felt the need to elaborate their answer. In the figure below the questions on which the respondents have chosen to elaborate on are presented, the contribution from each individual project is also described. The number of respondents in each of the projects are not the same. The colours of each bar correspond to a specific project and the height corresponds to the number of persons which have chosen to elaborate.

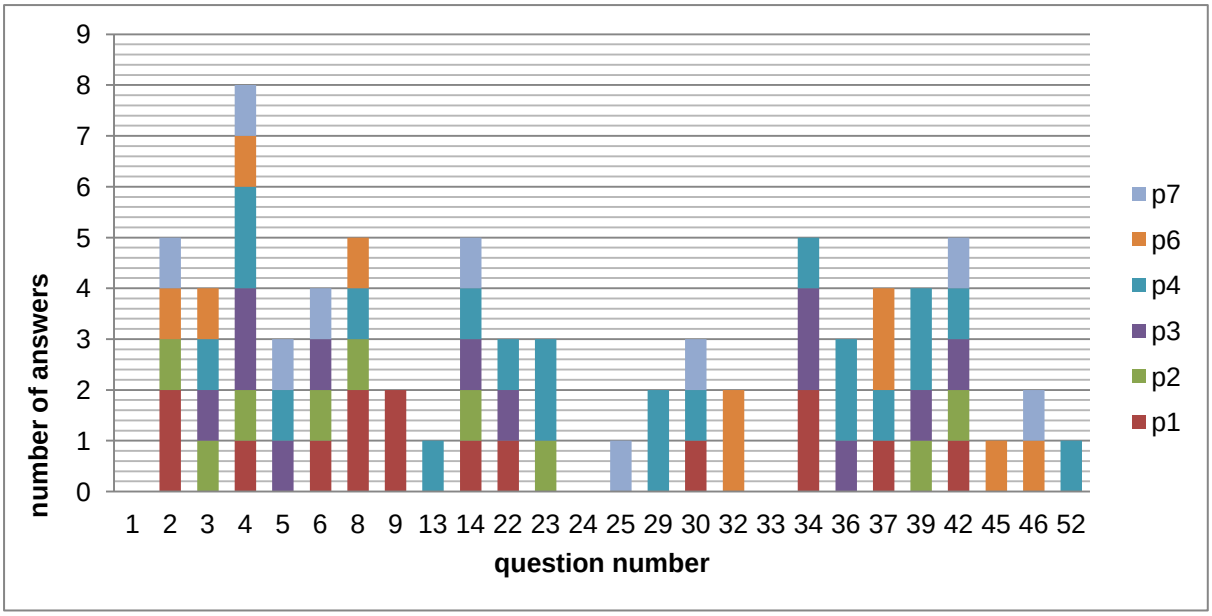

Figure 28: Distribution of which answers respondents have chosen to elaborate on, yes or no questions.

Listing the elaboration one can see that many of the answers describe the similar topics but elaborated on different questions. For example on question number 13, where the questions was asked whether there were adequate information about the customer collected during the sales phase and handed over to the project. The majority of the answers are no, and the elaboration shows that this is the case on most projects and that it is not uncommon for the projects to have little knowledge about the customer. This statement about customer intelligence is a returning opinion on other questions as well.

On question 42, “did you feel that you knew enough about the customer to be able to make decisions regarding design changes and tradeoffs”, the answers is mostly no and the elaboration often states that there is not enough information about the customer and the customers business goals at all. The statement is still valid if the APL has been involved in the sales phase as many of the respondents feel

that there is still not enough information handed over even though they've on question 13 have answered that the APL was involved in the sales phase

Question number 4 is about market company involvement, the nature of this question is elaborative and the elaboration describes the market company involvement which differs depending on the project and market company.

Question number 8 was asked if the process engineers finished their task and then disappear, the elaboration shows that it´s not uncommon for the process engineers to start with another project as their task is finished and no longer be an active part of the project. When the automation them have questions regarding process design they have to rely on existing relationships with the process engineers.

Question 34 asks the question whether there were changes that were not handled as a formal VO. The elaboration shows that one often uses a "change list" and at the end of the project they decide whether the sum of changes on that list is to be handled as a formal VO. This due to the time consumed from the project by handling a VO formally. All the elaborations and answers to the questions can be found in Appendix C.

7.1.2 Questions not answered with a yes or no.

On the following questions the respondents was asked to provide answers which were short and where quantifiable.

7. How was the cooperation with process engineers during this project.
10. Was the process engineers located In Lund.
11. Was there problems with the integration of modules.
12. To whom did you feel that the module company delivered. I.e. was your relationship with the Module company as a customer or a partner.
15. Where was the automation team located.
16. Where was the rest of the project team located.
17. What kind of productivity affect did you experience during the project due to the location of the project team.
18. What technical difficulties did you encounter in the context of 3rd part suppliers of software systems.
19. How did this affect the overall project time plan.
20. What problems did you encounter with regards to the TPM
21. Why did you use this version of the TPM.
26. Who was perceived to be the customer of the project
27. What was the knowledge of the customer, i.e. how technically skilled where the customer.
28. How and when did the project team meet with the customer
31. What was the reason for this variation order.
35. What was the reason for the scope creep(for example did you feel guilty towards the customer or were you delayed.)
38. Are there other meetings that is not documented and what are the agenda of these meetings.
40. Was there anything that you feel should have been addressed that wasn't
41. What is your impression of telephone meetings during this project
43. In the context of this project, what is customer value?
44. What was your top one lesson learned from this project.

Table 21: List of the questions which have not been answered with a yes or a no

The questions above have the characteristic that they cannot be answered with either a yes or no. Although the answers on a majority of the questions are quantifiable, there are some qualitative questions as well. The quantitative answers have been summarized and presented in a pie chart per question. Answers that where of a more qualitative form have been summarized and are available in Appendix C.

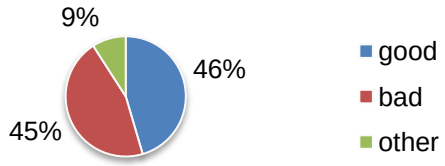

Figure 29: question 7

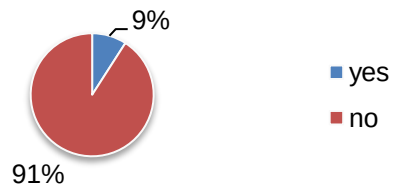

Figure 30: question 10

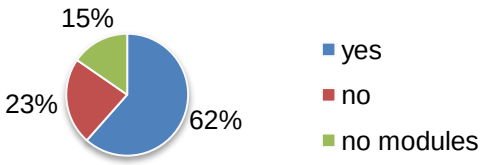

Figure 31: question 11

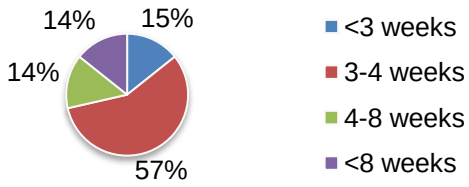

Figure 32: question 11 b

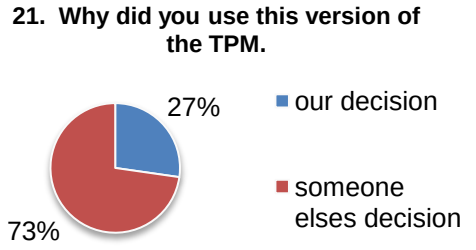

Figure 33: question 21

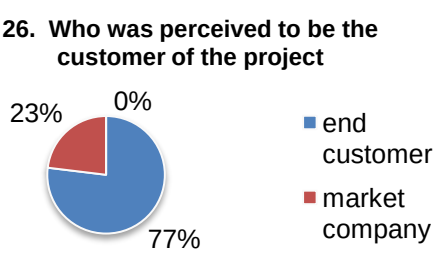

Figure 34: question 26

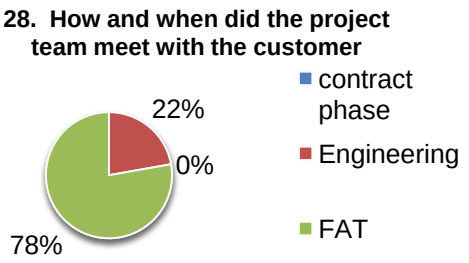

Figure 35: question 28

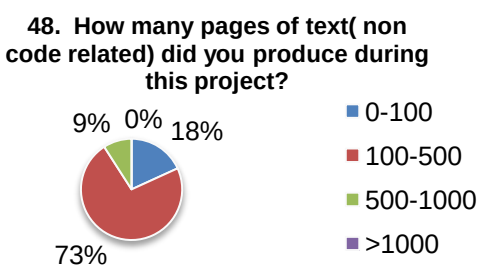

Figure 36: question 48

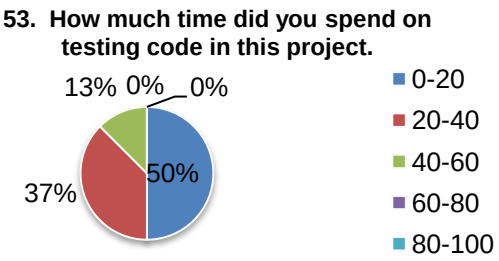

Figure 37: Question 53

A number of questions have been answered and some of them provide additional information about the parameters, these questions are presented below. After the data presentation in the pie charts below the quantitative and the qualitative answers are presented.

In the figures above information about the answers to 9 of the questions asked are presented. These questions provide some data that the reader should be aware off, in Appendix C data from all questions are provided.

Around 45 % feel that there is not enough cooperation with process engineers during the project. A possible explanation could be the next question which states that only 9% answers that the process engineers are located in Lund.

Module integration is a problem in many of the project and combined with the other answers one can say that they add around a month to the total time. Although it does depend on the number of modules and the size of the project.

In 73% of the cases the choice of what version of TPM were to be used is someone else's decision. Most of the time GP views the end customer as the customer, even though that it is to the market company that GP delivers.

The engineers of GP often does not meet with the customer until FAT. And not a lot of time is spent on documentation, and around 100-500 pages of text is produced in the projects.

The qualitative answers provide information about the following; the problems with the integration of modules are described in different ways but they all relate to functionality or a lack of knowledge about integration from the ones designing the module control system.

The location is not something that is addressed as a big issue in the projects, some additional work in coordinating code and designing communication paths are addressed in these answers.

On the question of the TPM there are a lot of different issues raised and specific examples for the projects are described. But a trend can be observed which shows that much of the problems relate to; bugs in the system, the templates not being finished, and that the templates need to be customized to be usable.

7.2 Results from documentation

Documents on the project-server was then analysed, documents that were not found on the server was considered as missing or not existing. On the project server there is a consistent structure which is to be used in all of the projects. If the documents were not located in the folder which it is supposed to exist, the search continued in other folders. Documents does not have the same naming structure on all projects and in what document the information is located differs depending on what project was studied.

The document analysis are presented in a table below. In Appendix B the questions which were to be answered by studying documentation are found. All questions are categorized based on the affecting parameters in chapter four. Below a table is to describe if the documents in a certain category exists. The categories each have some questions that are asked, these are in this table summarized and presented per category.

Categories from documentation	P1	P2	P3	P4	P6	P7
Pre project	-	-	yes	-	-	-
Modules	-	yes	yes	-	-	yes
Technical problems	yes	yes	-	-	-	yes
TPM	yes	yes	yes	yes	yes	yes
Resources	-	-	-	-	-	-
Customer contact	yes	-	-	yes	yes	-
Variation order and changes	yes	-	yes	yes	yes	-
Scope creep	-	-	-	-	-	-
Meetings	-	-	-	-	-	-
Kickoff	-	-	-	-	-	-
Customer value	Xx	xx	xx	xx	xx	xx
Lessons learned	-	-	-	yes(TPM feedback)	yes	yes
Internal tests and FAT	-	-	-	yes	yes	-

Table 22: Summary of the studied documentation, a minus sign means that no documentation were available (Tetra Pak)

During the first set of interviews the respondents emphasised on the importance of a good functional description. The functional description have been evaluated against the criteria in the IEEE standard. Evaluations of the functional description is presented in the table below. To see the full evaluation please consult Appendix 3. The 5 categories on which the evaluation is based are:

1. Unambiguous
2. Complete
3. Ranked for importance and/or stability
4. Verifiable
5. modifiable

For each of the categories the projects have been evaluated in the table below

Criteria	P1	P2	P3	P4	P5	P6	P7
2	Yes	No FD	Yes	Yes	No	Yes	No
3	Yes	-	Yes	Yes	No	No	Yes
5	No	-	No	No	No	No	No
6	Yes	-	Yes	Yes	No	-	No
7	Yes	-	Yes	Yes	Yes	Yes	No
sum	4/5	-	4/5	4/5	1/5	2/5	2/5

Table 23: description of the FD quality based on an requirements specification classification from IEEE

Scoring 5 out of 5 means fulfilling all categories of a good software requirements specification.

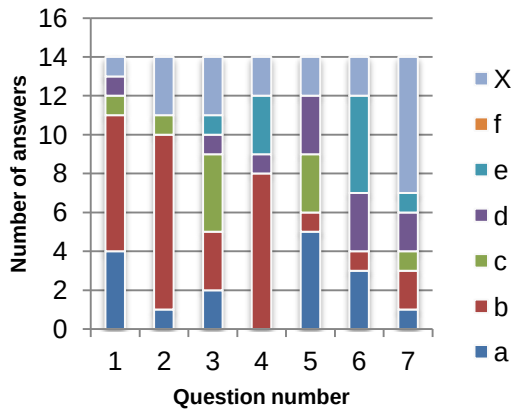

Figure 38: First survey, Management support , All respondents

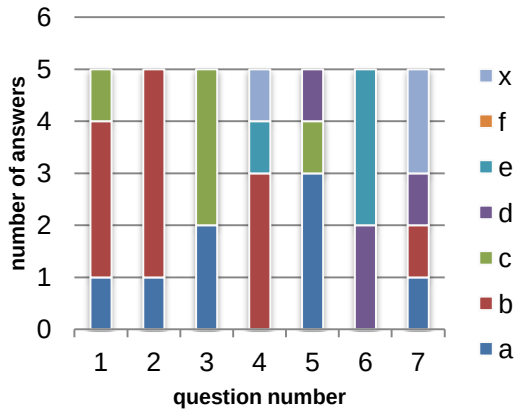

Figure 39: First survey, Management support, Only APL responses

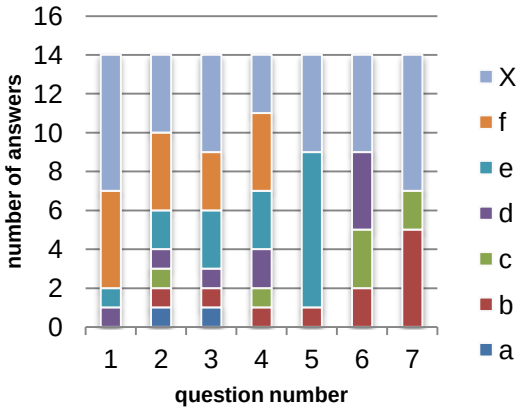

Figure 40: Second survey, Integrated process, All respondents

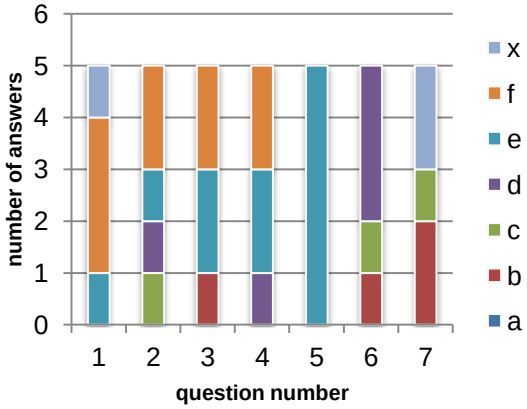

Figure 41: Second survey, integrated process, Only APL responses

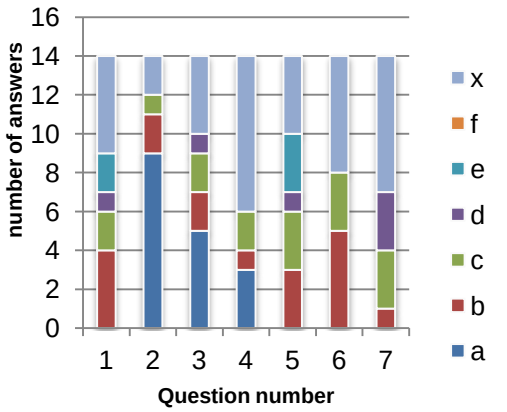

Figure 42: third survey, Informal project management, all respondents

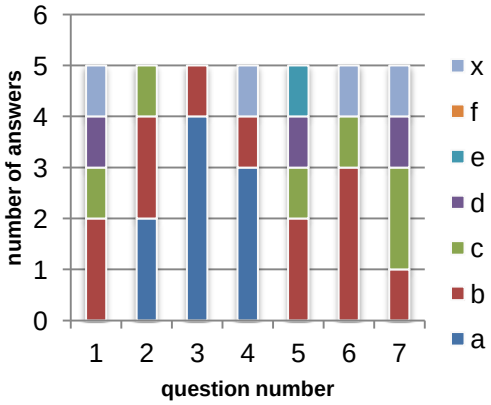

Figure 43: third survey, Informal project management, only APL responses

7.3 Results from the PMMM Kerzner scale

In the theoretical framework a maturity model for project management is presented. After the interviews a survey was handed out and the respondent was asked to provide answers to the survey. The survey consisted of three of six survey categories from Kerzner, assessing management support, integrated process and informal project management. Below the distribution can be viewed, both for all engineers and also separately for the 5 APL. What can be observed in the figures is the number of blank answers which is higher for the whole group than for the APL, also a greater consistency in the answers can be observed in the APL figures. The legend describes any of the multiple choices available, either a,b,c,d,e or f. An x indicates that the question was left without an answer.

In Appendix 2 the questions, point per question and the content of the multiple choice alternatives is presented.

Kerzner has proposed a ranking scale based on six surveys. An adoption of that ranking scale has been made to fit the purpose this thesis and therefore the answers will be given in percent. As the respondents were given the possibility to skip questions there are some blank answers, marked by and X in the figures above.

The percentage, including blank answers as a 0 was 41%, if the blank answers were not counted the percentage was 59%.

Score with blank answers included	41%
Score without blank answers and the maximum score adjusted	59%

Table 24: Scores for all project member categories summarized, with and without blank answers included

The majority of the blank answers comes from the automation engineers. They are more technically focused and therefore not as interested in the project management process. Therefore the project team categories have been divided and below one can see the scores for each of the individual categories.

Automation Project Leader:	**70,7%**
System leader	**56,2%**
Automation engineer	**45,0%**

Table 25: Scores(in percent) for each of the project member categories

In the table above the differences in the answers between different employees can be observed. The lowest score is given by the engineers, and the highest score by automation project leader.

8 Analysis phase 2

The aim for this chapter is to analyse the answers given in the second set of interviews. This analysis will focus on the quantitative answers as well as the qualitative answers with the intention to focus on what aspects of the parameters that affects. Furthermore it will provide analysis of what can be observed from the documentation and the maturity scale created by Kerzner.

8.1 Project analysis

In this chapter the answers both from interviews and documents are analyzed to compare the affecting parameters of the projects.

8.1.1 Interview answers from projects

In the first empirics chapter the parameters where summarized and in the model they are elaborated and addressed in a more project specific manner. In the second empirics chapter the answers are summarized categorised and presented. In this analysis-chapter the aim is to provide the reader with conclusions from the second empirics' chapter and finally analyse the data all together.

All the projects except for project five has been included. Project number five is not included since both the documentation is not satisfying in that project, and that there were no available person to interview. The project itself was also not comparable and similar to the other projects to provide a coherent analysis. The other projects have been included due to their comparability and availability.

All of the questions asked, was as described above a sub question addressing a certain parameter. One can conclude the following; the answers from the yes or no question showed that there are different views between project leaders and Automation engineers due to their roles. These differences are mostly in the planning and customer contact part, where the project leader experience a closer contact with the customer and also feels that they have more knowledge about the customer. Engineers are more technically focused and the problems experienced from the engineers mostly focuses on appropriateness of tools and templates and the performance and quality of those tools.

Many of the respondents have chosen to elaborate on some of the questions. The elaborations have been analysed and provides additional information to the scores and ranking of the parameter-affect and also deeper insight on the background of the answers given during the interviews.

When studying the answers in the second empirics' chapter there are some returning issues. One can observe that there is not enough information collected about the customer during the sales phase, also the team does not meet with the customer until FAT, when the system have already been designed. This leads to engineers not being able to make decisions regarding tradeoffs and design changes which question number 42 indicates where around 70% do not feel that they knew enough about the customer to be able to make decisions regarding tradeoffs and design changes.

Questions 9 and 22 provide information about the technical tools, which implies that there is sometimes a problem with the design limitations from TPM, causing limitations to be put on the process design leading to the process not being designed in the best possible way. The size of the templates is quite large which leads to code having to be removed from templates during the engineering phase. When studying the answers from the questions regarding the TPM one can observe that the quality of the code and also how the TPM is implemented in the modules creates problem for the evaluated projects.

Information about the internal relationships between Tetra Pak companies can be observed when studying question 5,11, 21, and 26. Where one can observe that AS does not provide the support

asked for by the projects. The module company does not deliver to the GP and they do not provide the support necessary when integrating the modules. Often someone else decide what version of the TPM the projects should use. Automation solutions provides new TPM releases relatively often. Making it difficult for the projects to reuse code from other projects, especially as the changes made to the templates are not logged. As GP delivers to the market company, and not to the end customer, the buyer is clearly the market company, but no coherent view of who the customer are have been presented during the interviews..

Process design and project-processes are described in question 7,8, and 10. Where there are both positive and negative experiences from cooperation with process engineers, but in the elaboration to these answers the good cooperation's are mainly based on personal relationships. On many occasions the process engineers are not located in Lund and also a lot of times the process engineers finishes their task and then disappear from the project.

Two parameters are different from the other in the sense that they do not affect the engineering efficiency during the project, they affect the engineering efficiency in the sense of a companywide understanding. The lessons learned and the KPI. Regarding the Lessons learned one can observe that there is only one complete Lessons learned report, and one that is partially conducted. Which implies a lack of learning and a lack of seeing the benefits of conducting a lessons learned session. During the interviews 75 % of the respondents felt that the KPI value are satisfying but only 25 % feel that the KPI describe the outcome of the project implying that the KPI does not capture the result of the project.

There are some differences between the projects. In most cases however the parameters found to affect is not project specific, although some of the projects experience less affect from the most significant parameters.

8.1.2 Documents from projects

In the document study, the projects servers where investigated to find documentation that could provide additional information. What was found was that the documentation structure was very rigid. The structure is not used in the same way if it is used at all, documents which would be necessary for follow up is not present and also documents are not found in the same place and version handling is not done in a structured way.

On the project server some information in the documents have been found, but they do not provide information to all the questions raised that where to be answered studying documentation. Also in many of the projects documentation which is said to be provided are not provided which leads to unanswered questions. The documentation has provided some additional information to the interviews.

8.2 Analysing affecting parameters

The main purpose of this thesis are identifying the affecting parameters. As described above during the first set of interviews the parameters where identified. The evaluation model was then created to address each parameter in more detail. Below the information is put together per project and ranking the effect each individual parameter had on the project. In appendix D the motivation for the score of each parameter is provided. The scores given are 0,1,and 2. Where 0 is seen as not affecting, 1 is seen as affecting, and 2 is seen as a significant affect. The effect to be observed is either in time or cost of the project.

Below a summary of each of the projects are presented with their score in each of the category. The last column is the sum of all points in the project divided by the number of projects, this gives the average score of the parameter.

Parameter	P1	P2	P3	P4	P6	P7	Average score
Contracts	0	2	1	1	0	1	**0,83**
Market companies	1	0	1	1	1	0	**0,67**
Automation solution	0	0	0	1	1	0	**0,33**
Process design	1	0	0	2	1	2	**1**
Modules	0	1	2	2	1	2	**1,33**
Sales organisation	1	1	1	1	1	0	**0,83**
Location and cultural differences	0	0	0	1	2	1	**0,67**
Technical problems	2	0	0	1	0	1	**0,67**
TPM	0	2	1	2	1	2	**1,33**
Resources	0	0	0	1	0	1	**0,33**
Perception of customer	2	2	0	1	0	1	**1**
Customer contact	0	1	1	1	1	1	**0,83**
Suppliers	0	0	0	0	0	0	**0,0**
Variation order	1	2	0	1	0	1	**0,83**
Scope creep	1	1	0	0	0	0	**0,33**
Meetings	2	0	0	1	0	0	**0,5**
Kick off	0	1	0	2	1	1	**0,83**
Telephone meetings	0	0	0	0	1	0	**0,17**
Customer value	1	2	1	1	1	1	**1,17**
Documentation	1	0	1	2	1	1	**1**
Tests and FAT	0	0	0	2	1	2	**0,83**
Functional description	0	0	0	0	2	2	**0,67**
Pre-propjets(planning)	2	1	0	1	1	1	**1**
	0,33	**0,35**	**0,2**	**0,54**	**0,37**	**0,46**	**0,37**

Table 26: Parameters per project scored for the negative impact they have of project outcome

In Table 26 a point has been given to each of the projects on each of the parameters, these scores are then summarized and provides a total efficiency affecting score on each of the projects. Comparing the results to outcomes and observations made during the writing of this thesis the parameter tools captures the main parameters affecting and also scores the dependency per project in accordance to the outcome of the project.

As described above some parameters are affecting in an organisational learning perspective and prevent mistakes from being repeated and are intended to capture the evaluation of a project. These parameters are summarized below.

Parameter	P1	P2	P3	P4	P6	P7	Average score
Lessons learned	1	0	2	1	0	2	**1**
KPI	1	0	0	2	1	0	**0,67**

able 27: Parameters which affects the organisation and not individual projects

In able 27 the organisational parameters are scored, one can observe that there are only Lessons learned performed in two of the projects fully, and in one of the projects a semi version of the lessons learned have been performed. Although this parameter does not analyze the feedback on the lessons learned and how well the organisation uses the findings from lessons learned. Once again there is

evidence that the KPI does not capture the outcome of the project and does not provide management with the insight and measurements that one would expect.

Calculating the percentage from each of the projects as the sum of the score from each parameters divided by the maximum score of 46 one can observe that many of the projects have a score of over 30% and that some projects experience a higher score, below the projects are ranked based on their score.

Project number	Percentage score
P4	54%
P7	46%
P6	37%
P2	35%
P1	33%
P3	20%

Table 28: Projects sorted on affecting value

The last column in the parameter table indicates that some parameters affects more of the project and are often scored as affecting significantly. When summarising the mean efficiency affect and sorting them based on the size the following table reveals. A high score indicates that the parameter has a high impact on the project outcome.

Parameter	Efficiency affect
Modules	1,33
TPM	1,33
Customer value	1,17
Process design	1,00
Perception of customer	1,00
Lessons learned	1,00
Documentation	1,00
Pre-projects(planning)	1,00
Contracts	0,83
Sales organisation	0,83
Customer contact	0,83
Variation order	0,83
Kick off	0,83
Tests and FAT	0,83
Market companies	0,67
Location and cultural differences	0,67
Technical problems	0,67
Functional description	0,67
KPI	0,67
Meetings	0,50
Automation solution	0,33
Resources	0,33
Scope creep	0,33
Telephone meetings	0,17
Suppliers	0,00

Table 29: The parameters sorted by size, the most affecting parameters has the largest value

A comment must be made on the supplier parameter in Table 29, during the interviews these haven't been found as affecting as delays from suppliers are normally not a problem since the project is late. Therefore the score of this parameter is 0, so when aligning the project process and decreasing the efficiency affect of other parameters one should be aware of the potential impact of supplier delay.

8.2.1 Kerzner PMMM scale

When analysing the data based on all project-members the score is 50%, using Kerzners scale this means that there are minimal support for project management. When focusing only on the APL, the score is 70%, meaning that the company is heading in the right direction in project management and learning.

This supports some of the answers given in the interviews as well as the findings from studying the documentation

When studying the answers left blank from both the APL and the AE,SL one can find that the Engineers tends to be more technically focused and are not aware of the management terminology and methods. Therefore the answers given by the APL is the ones providing most of the information about maturity in projects. And based on the survey and examples the ranking is a level 3.

8.3 Parameter analysis

After analysing the results above and dividing the results per project, these are the questions that should be asked when using the evaluation model. To obtain the scoring in each of the categories the following areas were assessed.

- Contracts
  - Was it a well performed contract?
  - Was there enough time spent on the understand phase?
- Market companies
  - Was the market company involved in the customer communication, and did the team have access to the customer?
  - What maturity does the market company have in procedures and guidelines?
- Automation solutions
  - Was there any support from automation solutions?
- Process design
  - Did the Process functional specification provide adequate information.?
  - Was there automation “thinking” in the PFS.?
  - Did the team have a good cooperation with process engineers during project/ handover from process design phase?
- Modules
  - How many different kinds of modules were used?
  - Had the market company included integration when ordering the module from the module company?
  - What version of TPM that was used in the modules?
- Sales org
  - Was the APL involved in the sales phase?
- Cultural differences and location
  - Was there cultural differences in communication and the need of documentation?
  - Managing communication between collocated teams?
- Technical problems
  - Was there compatibility issues when deciding the OS, between different soft wares?
  - Was there other limitations in the software that affects the intended way of working?
- Template Plant Master
  - What amount of code needed to be removed?
  - Was this version a tested version or had it never been used?
  - Have the problems found in previous versions been corrected?
- Resources
  - were the recourses competencies satisfying?
  - were the resources involved in other project?
- Perception of the customer
  - Who was perceived as the customer, if the cooperation with the market company is as a partner or as a customer.?

    - How cooperative was the customer?
- Customer contact, end customer access
    - Did the project team understand customer needs and to what extent was the customer reachable?
- Suppliers
    - Was the ordered products delivered on time or where they delayed?
    - did this delay actually affects the outcome of the project?
- Variation orders
    - When did the VO arrive in the automation phase?
    - When VOs derive from poor customer understanding they often impact the project in a greater extent?
    - Sometimes the VO can be positive since it can increase the budget of a project with a sum that is not proportional to the time taken to deliver the VO?
- Scope creep
    - Was there features added to the customer which they did not pay for, or was there functions which the customer did not receive?
- Meetings
    - Did the expectations of meetings match the outcome?
    - Is there documentation from meetings and how informative is the agenda?
- Kickoff
    - Was there an adequate kickoff which had an informative agenda?
    - An adequate agenda should include, customer value, expectations, economical decision, milestones for the project and meeting the other of the project?
- Telephone meetings
    - Is the project based on telephone meetings or is it based on physical meetings?
- Customer value
    - Do the project team understand the customer and why the customer wants a new plant?
    - What is the customer intention with this plant and has the sales phase collected enough information so that tradeoffs can be made?
- Lessons learned
    - Did the project provide a lessons learned report?
- KPI
    - Does the KPI describe the outcome of the project?
- Documentation
    - Has the documents been structured in a coherent way?
- Tests and FAT
    - How are tests done, is there someone else dedicated to testing your code?
    - Is the system tested enough as FAT is reached?
- Functional description
    - What value does the IEEE standard give?
    - Is the PFS the document they are looking for. Should there be another document?
- Pre project planning
    - Has the project understood the customer?
- Line organisations
    - Does the line organisation provide resources and support?
- Processes
    - Does the process provide adequate information?

One can observe that there are similarities in the answers and that the answers can be joint and summarized in to four main categories on which the cause of the affecting parameters rest.

1. A well performed Understand phase
2. The right technical tools
3. A cooperation internally instead of a seller/buyer focus
4. Cooperating in the project as a whole not sub optimizing the parts.

A well performed understand phase means looking at the customer needs and what is the purpose of the plant and so on. When studying many of the answers the understand phase is a missing

component. This can be observed when studying the answers of question 1, where the conclusion is that about 50% of the respondents feel that the contract does not give them the appropriate information, and that not a single individual felt that they were able to make decision about tradeoffs and design changes. Also that there were about 80% that felt that there was not enough information from the sales phase handed over to the project team. Also other comments from the elaboration shows that the understand phase is not performed as adequate. So when describing the following parameters

Customer value, contracts, sales organisation, variation orders, pre projects, and functional descriptions can in some senses be related to a poor performed understand phase.

Having the right technical tools is critical for the success of a project. If a company standard exist that is to be used. But in this case the company standard is not an appropriate tool. In many of the cases the choice of which version of TPM that is to be used was not the decision of the project team. There are also a majority of the time when the process design are not in line with the limitations of the TPM. On every project except for one there were problems with the plant master, the project which did not experience any problems with the TPM has a version of TPM which they develop themselves and that is owned by the team which then uses it. Problems with TPM are significant and there are much time spent on removing obsolete code. More over there are some problems experienced with the integration of modules in the technical sense. These modules uses the TPM and they are built as standalone modules which controls input and outputs. The preferred way in this case by the engineers would be that the module would be told to start and when finished returns a signal. There is also comments about missing tools for auto generating code. When studying the documentation one can also notice the need for a coherent documentation standard and standard documents for project planning. The parameters covered by this category is; TPM, Modules, technical problems, documentation.

To be able to best fulfil customer needs and expectations cooperation between internal companies is essential. Many of the questions shows that the cooperation between market companies and GP is not satisfying, there are sometimes differences in the tools and standards used by the Market Company and GP. Around 60% feel that AS does not provide support to the projects. On the question on whether they experienced problems with the integration of modules 63 % felt that they had problems and 15% did not have any modules. The elaboration on the answers revels that there is a problem with the module company and their focus around stand-alone thinking for the modules. Also on the question whether the collaboration with the market company was as a customer or as a partner the responses have been neither in many of the cases and the answer has instead been that they are an outside integrator. Meaning that they have to handle the problems with integration of modules without support from module companies and moneys from MC. Putting this together implies that there is no consistent view about how to optimize the value adding activities so that all internal companies benefits from the project. The parameters covered in this category is; Market companies, Automation solutions, modules , perception of the customer, customer value.

The last category that has been found to describe these parameters are the project process, a coherent process which describes the whole project and the cooperation of each individual part. The risk of not describing this part and having a structure is sub optimisation. Many of the process engineers are located in other places than Lund, only on 9% of the answers the process engineers where located in Lund. On some projects the process design is not realisable with the TPM, also the knowledge transfer from the market company is described as a potential problem. There is on some projects not a kick off meeting and on those projects the kickoff agenda does not cover customer expectations and

customer related intelligence. The category is mainly described in this thesis as to focus around process design and handover of that design to the automation. This category covers; process design, sales organisation, modules, kick off, functional description.

These results are also supported when studying the Kerzner scale where the result from the survey are 70% and according to Kerzner this means;

" *Your company is going in the right direction, but more work is still needed. Project management is not totally perceived as a profession. It is also possible that your organisation simply does not fully understand project management. Emphasis is probably more toward being non project driven than project driven" (Kerzner 2001, p97).*

When studying Table 26 there is a mean score of 45% the highest scoring project is number 4, which is also the biggest. In project number four there are both a lot of affecting parameters and number of parameters affecting significantly. Project 3 was a project which was on budget and where the customer was satisfied. Looking at the points the modules and the TPM are the most affecting, also studying the customer value and process design one can observe that these are affecting in a greater sense, As well as perception of the customer, documentation and pre-projects. These are the 8 most affecting parameters.

9 Analysis summary

The chosen disposition in this thesis has divided the analysis into two different chapters. To remind the reader of the first analysis and link the chapters together a summary of the analysis are given below. Some of the areas pointed out in the first analysis is not as apparent in the second analysis.

As the analysis have been conducted separately this chapter aims to connect the analysis from the first set of interviews with the second set of interviews and the other data gathered.

Functional description	Sales organisation
Template Plant Master and automation solutions	Kick off agenda
Resources	Contracts
Customers	Project finished when leaving for site
Modules	Addressing customer value
Market companies	Management support
Functional designer process focus	Bureaucracy
Time plan rush	Tools for engineering work
Technical problems	Customer / end customer perception
Documenting code	Pre project quality
APL absence	Processes helpful
Customer change	Tests and FAT
External factors	KPI
Waiting times	Project team location

Table 30: A list of the initial parameters found during the first set of interviews

These were the parameters concluded from the first set of interviews. When doing further analysis and interviewees there are some parameters not addressed in the second set. The parameters that where found most surprising is the FD, the FD has been addressed in the first set of interviewees but in the projects studied there are only a few projects where the functional description actually had an effect of

the outcome. Question number 6 also states that in 60% of the cases the PFS provided the adequate information when specifying the process design.

Another outcome which was focused on in a greater detail during the first interviews where the resources and their competencies this has not shown to be a problem in the studied projects. On the question if the project received the competencies they wished for 83% said that they got the right competencies.

Results not as surprising as the two above is that the PlantMaster affects, this was something addressed very explicitly in the first set of interviewees and in the second interviewees there are a lot of comments about added time due to the template size, quality and other bugs in the system

Modules was mentioned in the first set of interviews and in the second set of interviews the results was quantified and on many of the projects the module integration has added more than 3 weeks in 85 % of the cases and in some projects investigated there is no modules. 62% says they have experienced problems with the modules. The first set of interviews which pointed towards an module integration problem has been verified in the second set of interviews.

Another factor that affected is topics which related to customer perception, customer knowledge, and contact. This has also shown in the second set of interviews and involves the handover from sales phase, addressing and understanding customer value, access to the customer and also perception of the customer. This have shown in the first and second set of interviews.

One question that was focused around during the first set of interviews is the management support. In the projects there is not the same focus around support from management and the potential effects of this.

The document study revealed that Lessons learned sessions are not conducted in many cases and during the first set of interviews it has not been mentioned that the absence of lessons learned reports where this big.

Customer change was covered in the first interviews but has not been found to affect that much during the second set of interviews. In many of the cases this is not affecting at all since many arrive before it is critical for the automation project.

10 Conclusions

The conclusion can be divided into two areas, first conclusions regarding parameters directly affecting projects, and secondly parameters which in an organisational aspect affects efficiency. The directly affecting parameters are divided into four subcategories involving a coherent value stream, well designed process, having the proper tools, and a well performed understand phase. The Organisational parameters are divided into three subcategories involving, organisational learning, project success and management support.

10.1 Directly affecting

When studying the analysis, there are parameters that have an effect on many of the projects. The parameters with the highest impact are TPM, modules, customer value, and process design. As the first and second interview empirics and analysis are studied, the mentioned parameters are part of a bigger dependency. When looking at elaborated answers and the first set of interviews, four areas are found as affecting areas:

1. A well performed Understand phase
2. The right technical tools
3. A cooperation internally instead of a seller/buyer focus
4. Cooperating in the project as a whole not sub optimizing the parts, a coherent project-process.

The above mentioned four areas will be addressed in depth in the following chapters.

10.1.1 Well performed understand phase

A well performed understand phase is of great importance, especially in a project such as project number one which is a revamping project. Although the affect can be observed from many of the projects where the stated U phase in the Tetra Pak UCCD process is not covered to that extent it should be. This means that the project lack information about the customer and the customers' needs, leading to changes being made and not delivering the intended customer value. One of the possible explanations for this is that the project team does not meet with the customer until FAT and are therefore not aware of how the customer operates. Another possible reason is the lack of document describing the intended business goals for the customer, and the sales organisation not providing customer intelligence to the project team.

10.1.2 The right technical tools

A question raised during the first set of interviews was the importance of proper tools and being able to reuse code to increase efficiency. The TPM should be a tool designed to provide the project team with templates making work easier and faster for the project team. Although there are a factors in the design of the TPM that prevents the tool from providing the efficiency needed for the engineer and causing the templates to provide more work than they save. The aspects of the TPM is both in the quality of the code and in the size of the templates, as well as the generic setup for the process design in the templates. Firstly the quality of the code is something that expresses itself as bugs in the code and leads to extra work rewriting code of the templates. Secondly the size of the templates, one could explain it with an analogy. If you were to rebuild the kitchen in your house, you would perhaps order a module based kitchen from a retailer, installing these modules in your house, and building your

kitchen. When transferring this analogy to the TPM; if you order a kitchen, someone would deliver a complete house, which you in turn would have to deconstruct to take out the kitchen, and then installing the deconstructed kitchen in your own house. If you later decide you need a new bathroom, the process would be repeated and a new house delivered which you would have to reconstruct again.

10.1.3 Coherent value stream

Tetra Pak has chosen to have local market companies which caters to certain markets. The market companies are the contact towards the customer, and buys modules from the module company, and the design of a control system from Global projects. As described in the above chapters the cooperation with module companies, automation solutions, and market companies is not of a satisfying kind. I believe that the reason for this is a sub optimizing system where the internal profit margins, and communication paths limits Tetra Paks ability to succeed within these kinds of big projects. Just to provide a brief explanation, the market company pays global projects for the design of a control system normally with a fixed price, the module company charges the market company for a module, the market company wishes to pay as little as possible so that their initial margins are the highest possible. This is not a coherent value stream towards the customer and the internal struggle is not a positive foundation on which to base cooperation. As one respondent stated during interviews, " during an evaluation with the customer, one feedback was: "It does not seem like you are one company"". This is clearly an efficiency affecting parameter that does impact the engineering work at GP, and moreover impact the customer opinion of Tetra Pak.

10.1.4 A well designed process

One of the first conclusions I drew was the lack of a coherent project process which amplifies learning and provides guidance to the engineers in their work. When conducting the interviews and studying the documentation this was something that was a returning issue raised both in the context of a lack of consistency in documentation and structure and also in the ad-hoc nature of which the projects are managed. This conclusion involves a structured cooperation with process designers and also with the sales people. To receive customer intelligence being able to make decisions regarding design changes, tradeoffs, and also know the business goals of the customer can help in delivering more customer value. There is a lack of communication between the process design team and the automation team, both can benefit from each other as one process design could increase the design complexity of the control system, and vice versa. I believe that the cooperation could be increased and since the process engineers are sometimes located within the market company one would need to create a process that allows a coherent handover phase and the usage of the same tools, standards and procedures. Closing the GAP between the process design project and automation project is also something I believe is necessary. This also increases both the process engineers' knowledge in automation and the automation engineers' knowledge in process design.

These are the main parameters that have been found to mainly affect efficiency in the projects. But as described in the analysis chapter there are an organisational aspect which I think should be mentioned.

10.2 Organisational parameters

It is not due to a well designed process or an organisational learning perspective that the projects are actually delivered somewhat within time and budget. This accomplishment is due to the experience of the engineers and their individual knowledge of designing large complex control systems. I believe that the organisation lacks a learning perspective and does not mature in project management and processes at all. This conclusion is based on the first set of interviews where the usage of lessons learned where covered, and most of the answers referred to individual lessons learned. Furthermore when studying the documentation I found that many project haven't even performed a lessons learned session. When the lessons learned session have been performed there have been little feedback from management about the results, and few changes can be derived from these reports. Organisational learning and maturity in project management and project-processes is not a focused area within GP.

During this thesis it has been clear that there is a lack of a tool that captures project success, the KPI is not found to reflect the actual outcome of the project. But the main problem I believe is the lack of a strong definition of what a successful project is, which in turn provides a benchmarking point for project leaders. This leads to engineers guessing whether the project where successful or not. Both because of the lack of a project success definition, but also that the feedback from customers are not shared in a structured way to the project teams. Finally when comparing the KPI to the theory it does not fulfil some of the basic criteria's for it to be a KPI, mainly involving it measuring finished results and not continuously measuring project evolvement.

Another thing that was raised was the management support , especially support from line managers. I truly believe that the intentions and ideas of line managers are good but somewhere on the way the ideas are distorted. One of the main comments where that there are too many ideas of; management structures, measuring tools and processes that the project teams feel does not help them nor do they feel that they can impact the design of them.

To better deliver value to the customer and to increase efficiency these are some of the areas which I believe is to be addressed. I would say that one of the conclusions is the most critical, and that is the communication with automation solutions and module companies addressing a better template system for the projects.

11 Suggestions for improvements

This chapter gives three main recommendations of how ideas and philosophy from theory can be implemented to assess the affecting parameters found in the previous chapter. These suggestions explores the possibility of implementing LEAN, TQM and CMMI to better develop a mature project process which aligns responsibility and provides a clear value stream. Moreover some general recommendations are given.

In this thesis the parameters have been explored and later concatenated into areas of improvement, below three suggestions will be given to assess some of the areas of improvements found. The main goal is to increase efficiency in projects by finding relevant theories from literature and implementing them at GP.

1. **Apply the principles of LEAN to find waste and benefit from the philosophy of a non waste organisation. Especially focusing on the ideas of LEAN software development, as the projects are similar to software projects.**

The core of a LEAN philosophy is minimizing waste, since waste is not a value adding activity. In the theory chapter some tools from Poppendieck have been listed. A brief overview of them will be given to show the potential for this implementation.

First of all waste that has been observed during this thesis are, extra processes, waiting, motion of documents, non existing documents, and miscommunication. These areas of waste all has a potential for improvement, aligning the work to better add value will increase the time spent value adding activities.

Using the principals of LEAN of visualising the work, the project work and progress could be visualised with a board or a system which shows progress of the project, publicly. Some examples of this is provided in the LEAN chapter where Poppendieck suggests something called a software Kanban system.

Furthermore another area found to be interesting in this is the motivational aspect explored in this theory. Stating the need for a clear vision of the project and clear objectives, this lack of goal focus have been commented during interviews.

Finally, exploring the theories on how to measure and measuring the right thing is described in LEAN software development, basically saying, " *What you measure is what you get".* And in addition to measuring or as a part of measuring, the contract structure needs to be studied. Although some work is performed on finding other forms of contracts , pursuing this is highly recommended.

As described in the conclusions chapter there are seven main areas to assess to improve efficiency. If Global projects is to develop a better project process a philosophy that is the foundation for aligning the organisation towards that process is necessary, LEAN software development can provide that guidance. LEAN assess a clear value stream, and the software theory in particular provides hands on examples and suggestions from which one can start designing the workflow. By implementing LEAN a better alignment between automation solutions is possible, also providing a mentality in involving every employee in improvement suggestions.

So therefore the recommendation is to explore the LEAN software development philosophy especially focusing on the areas described above to assess the efficiency affecting parameters found in the previous chapter.

2. Pursuing the thought of Total quality management to find a clear and consistent complementary philosophy which can coexist with both LEAN, CMMI and process orientation.

The philosophy of TQM is that the responsibility of quality is the task of everyone. To be able to focus everyone towards a goal of quality a clearly stated quality criteria must be created and set as the goal. In projects this is also to be done when defining the scope, where a definition of requirements should state the intended value creation In chapter 3.9 a short description of the areas of TQM are described.

One of the potential areas of improvements is focusing more and coherently on the customer. The current structure does not provide a clear focus and alignment of resources towards delivering good quality to the end customer. By using the principles of TQM and involving the whole value chain in delivering quality to the customer a better alignment is provided. As described above there is no coherent view of who the customer is, some say it is the market company, and others say the end customer. There is a need to define who your customer is and aligning this view in the whole value stream.

Cooperation is also essential in the TQM now the focus is not as cooperative as it could be, rather it is a business relationship which does not encourage cooperation. Another aspect of the TQM is the commitment aspect. In a TQM organisation it is essential for the entire organisation to commit against delivering a quality product that satisfies customer needs. Another ingredient which also is a part of the LEAN and CMMI models is the focus on continuous improvements. TQM also describes the need for measuring performance and performing auditing activities, which is an area of weakness identified at GP.

The recommendation on implementing the philosophies of TQM is made based on the appropriateness of the framework and that it aligns and measures how well the organisation deliver quality and satisfy customer needs. Finally it provides the organisation with a mutual focus and it encourages improvements.

3. Increasing maturity in projects by assessing the CMMI-DEV model, and the process steps necessary to reach level 3.

CMMI is based on a number of process improvement steps which when assessed is designed to find and improve company processes. It is important to emphasize that the processes described in CMMI is not a set of processes which can be implemented and replace the current processes of the company. The processes described involve assessing a number of steps to, based on the maturity of the organisation assess the steps necessary to increase maturity. PMMM and CMMI is both based on the same philosophy of maturity in organisation, however the levels described in the model are not the same.

GP should assess the steps necessary to reach a level three maturity in this model. This involves, and integrated project management process, an organisational process focus, and an organisational process definition. The benefits of this model are that it provides GP with a model of designing a process which can increase maturity in projects and at the same time align process focus.

In the conclusion chapter a few areas of improvements have been addressed, where a potential solution is the implementation of a CMMI model. These areas are; finding the right tools in the project as maturity is built in to the process, forming a coherent project process which can better allow handover from phases and also encourage a wider cooperation in the whole project. The project process has been described as not usable and not providing a good way of working. Therefore assessing the processes based on experiences and a methodology from software industry is believed to provide a good guidance.

"*CMMIs focus on improving processes in an organisation…. And describes an evolutionary improvement from ad hoc , immature processes to disciplined mature processes with improved quality and effectiveness"* (Software engineering institute, SEI, 2010, p. 5)

To improve organisational learning and increase efficiency, addressing the CMMI-dev model will provide GP with the tools and methodology to create processes which will amplify organisational learning.

This is to be done both in the aspect of collecting lessons learned and performing lessons learned sessions but also in general gather documents from projects which can be analyzed to provide information and learning perspective to the organisation.

General Recommendations

During this thesis work a few areas of improvements have been found, these thoughts and conclusions are shared below.

In the first set of interviews some focus was spent on the management support aspects. The comments mainly involved visibility of managers in the projects. To provide better understanding of management control systems and to collect feedback a higher visibility and perceptiveness are recommended.

Scope creep is not found in the studied projects, although in the first set of interviews there are evidence of scope creeps. The reason for this is believed to be an unclear definition of the scope and what is to be delivered. Finding a way to communicate the impacts of scope creep is another recommendation.

Another observation that was made during this thesis is the lack of a definition of project success. Defining success will provide the project teams with a clear goal and align the aim of the resources towards succeeding in projects.

Due to the frequent updates of the TPM and the lack of coherent structure on the project server the reusability of code is not explored and code is not reused. Creating an internal team of experienced engineers with the intention to provide examples and suggestions on how projects can reuse code is recommended.

12 Discussion

This last chapter of the thesis will compare the results towards the objectives stated in the first chapter. The aim is to discuss if the objectives have been fulfilled and whether the indented deliverables were meet. The chapter also list areas of research which can be further pursued and gives the personal reflection of this thesis.

12.1 Comparing the end result towards the objectives.

The main purpose of this thesis is to find the parameters which affects the automation engineering efficiency. When studying the first result, more than twenty parameters have been found, which in some sense was perceived to affect efficiency. When creating the evaluation model the results have been used to further develop questions which would identify the content of each of the parameters. And the results concludes 7 areas of parameters which are perceived to be efficiency decreasing. Another objective was to provide suggestion on improvements. Both of these overall objectives has been fulfilled in this thesis and the results has the potential to increase efficiency at GP.

Deviations from the initial objectives have been done on three parameters. Firstly the benchmarking study. Since GP was not as mature in projects as one would expect the time spent on finding relevant information was much greater than planned. More focus have been put on interviews than on studying archive material, and since the documentation was project specific and no coherent structure was apparent the need to focus more on finding the parameters were done. Benchmarking questions was distributed to companies but the answers have not been submitted on time.

Secondly the evaluation model was to be created based on findings in theory. After performing the first set of interviews and an initial theoretical exploration no theories where found to match the intention. The evaluation model was therefore created based on initial findings from interviews.

Finally, the definition of efficiency that was to be transferred from theory to automation projects have not been found. There is not enough repeatability and documentation in projects at GP to provide material that can be studied and compared. Therefore a definition have not been stated.

A part from the mentioned deviations the result and recommendations are in line with the objectives and deliverables of stated in the first chapter. Examples from LEAN, CMMI and TQM has been used to provide suggestion of improvements. A maturity assessment of GP has been performed and the difference in perception based on the roles of the individual are assessed.

In the introduction chapter one of the objectives of the study was stated ass, provide a summary of lessons learned and analyse the repetitiveness. This was not done due to the lack of lessons learned reports and due to the focus being turned towards more qualitative interview answers.

12.2 Authenticity, validity and traceability

In the methodology chapter the choice of methods and possible pitfalls has been discussed. The methodology provides guidance during the thesis work.

- **Authenticity**. The majority of data for this thesis is collected during interviews performed with employees at GP. These interviews have then been compared against each other and the individual answers have been analyzed. The number of respondents have not been large enough to provide a statistical significance in a quantitative sense. However since the interviews have been performed independently and answers are returning both individually

and project specific, and are supported by examples from theory; The authenticity of this thesis is perceived as satisfying.

- **Transferability**, this study has both been conducted at a company which in itself has a special structure, and the projects studied are in itself special. Transferability is not an area which has been a focus of this thesis. However if one would like to transfer the results, the conclusions can be compared to other companies to find commonalities. Transferring the suggestion of improvements should be done carefully.
- **Dependability**, this thesis studied affecting parameters by focusing on some projects, the choice of projects was done by company representatives. Respondents were chosen based on their availability and if they were involved in any of the studied projects. However the dependability of this thesis is not seen to be a problem. The factors presented are recognised by the company. Furthermore the process of this thesis has been documented extensively and there is a possibility to redo the study. Project number five was removed from the study since it did not provide additional information to the project, the study was not dependent on including project number five.
- **Validity**, the validity of this thesis has been guaranteed by discussing the results with the employees and with the tutor at GP. By keeping a dialogue of the findings and observing and ongoing project the conclusions of this thesis have been guaranteed to be valid Also a mixture between qualitative and quantitative approaches has been used which further adds a validity aspect.
- **Traceability**. The work has been divided into two main data-collecting stages and also the deviated results have been documented and commented. Therefore the results are believed to be traceable.

The results have been tested on employees at TPPS and all documentation has been kept along with summaries of the interviews. Potential areas of critique could involve misunderstanding during interviews and also misinterpretation of answers deriving from the lack of a common language. The potential pitfalls mentioned in chapter 2.2.2 involves; the modified action research approach, connections to theory, documentation, ethical aspects of interviews; firstly the modified action research approach has not been used in a great extent, mainly because the projects spans over a great amount of time, and the implementation of changes can therefore not be observed.

The connection to theory has not been explored extensively, the results however is found to be described in theories. Also other studies which indicated similar trends have been found.

Documentation was one of the identified pitfalls that has proven to be true. This has been overcome by conducting interviews in a greater extent and using these results for more of the analysis. This is one of the potential weaknesses of this thesis.

All interviews have been conducted anonymously, and efforts have been made to prevent the possibility of tracing answers to individuals. Which allows the individuals to speak freely and be more open minded in their answers

12.3 Comparing the results to theory

As mentioned above the results from this thesis is not directly connected to theories. However when studying the documented improvements of CMMI there are results from which GP could benefit. Also embracing the need for a coherent organisational learning process as described in PMMM could improve efficiency. So the connection to theory can be found mainly in the recommendations. The

connection to other research is the widely described difficulty to perform projects on time, within budget and delivering to the performance requirements.

12.4 New areas of research

During this thesis some new areas of research have been found, also further studies that GP could initiate.

Further research could involve finding a definition of productivity and efficiency for projects, finding how to incorporate a measurement for efficiency on a temporary endeavour such as a project.

Studies which can be initiated by GP involves defining a coherent project process for the engineering work. Deliverables, milestones and tollgates are not extensively described in the existing process and exploring the implementation of these project goals in the process is an interesting study.

To study the actual cost of a project from a value chain and life cycle perspective, providing insights about the potential drawbacks of the current structure.

Defining project-success and creating a key performance indicator which can continuously measure automation projects.

Further potential areas to emphasis is the commissioning part where the affecting parameters found in this thesis can be observed from a commissioning perspective, meaning that the affect of parameters identified can be observed in their impact on efficiency in commissioning work.

Other subprojects such as electrical- and process-design can also be observed in the same context as this thesis. And as this have been conducted an comprehensive approach can be conducted for assessing the full plant design project. Implying that eventually a full mapping of parameters affecting plant design projects can be done and conducted.

Conducting this study on the market companies and benchmarking the results against the parameters found in this thesis. Finding good practice examples which can be used as suggestions for improvements.

These studies further explore the areas pointed out in this project. To optimize the implementation of the suggestions made in this project, pursuing the above mentioned studies will improve project efficiency.

12.5 Personal reflections

When starting this study my personal belief and perception was that the parameters was to be technically oriented, that the results and finding were to come from the effect it had on time plan and work conducted. As the thesis evolved it became apparent that there was a lack of documentation and that a coherent project process did not exist. This made it hard to find repetitiveness in the project and

comparisons between projects have been difficult, the time spent on finding parameters have been longer and less time have been spent on the improvements suggestions . However I still think that this thesis have made a contribution and that GP can make a choice of what project philosophy to pursue, and by doing so increase project maturity.

A lot of data was available, however the accuracy of the data and the consistency of naming, location and standard for documentation was not as high as expected. A lot of time has been spent on investigating what documents that existed, only to find that in the next project the document-structure is different. This ad-hoc documentation process was surprising.

It has been a long road and a lot of times I have questioned my possibility to contribute and if I would ever be able to finish. As I reach the final chapter of this thesis I feel that I have made a contribution and that the results will be beneficial for GP.

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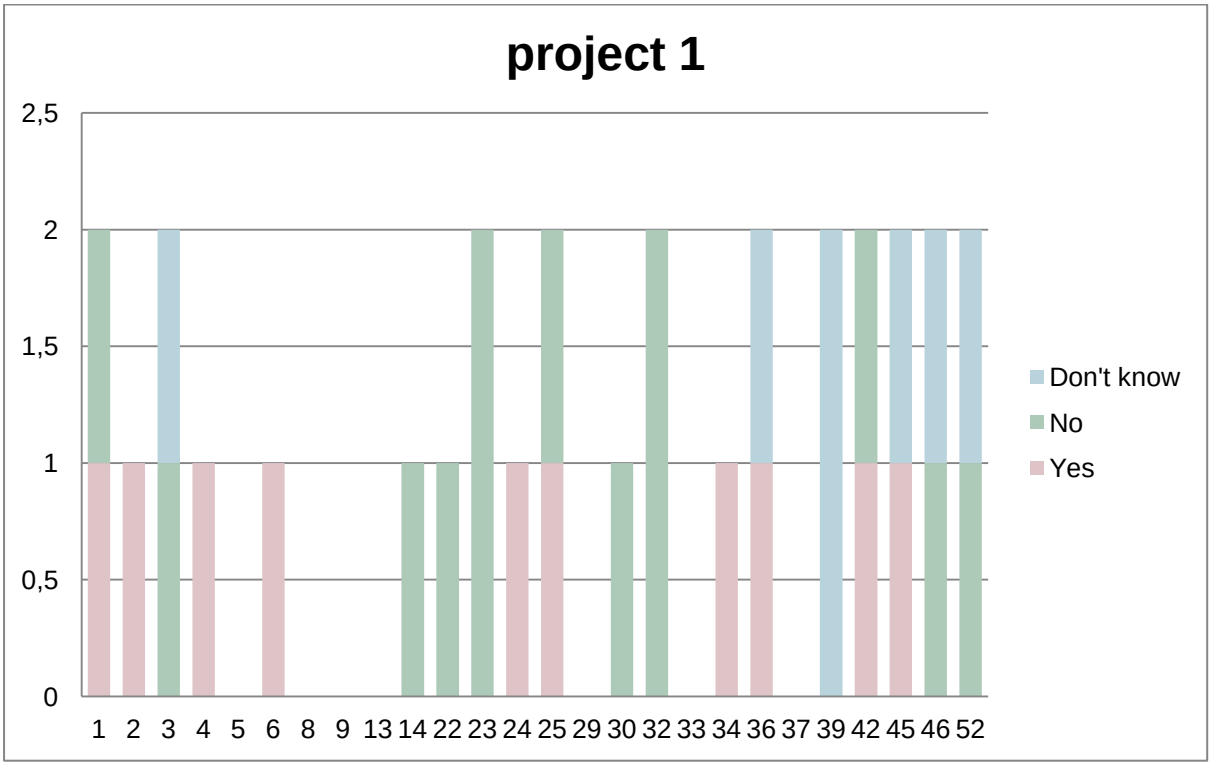
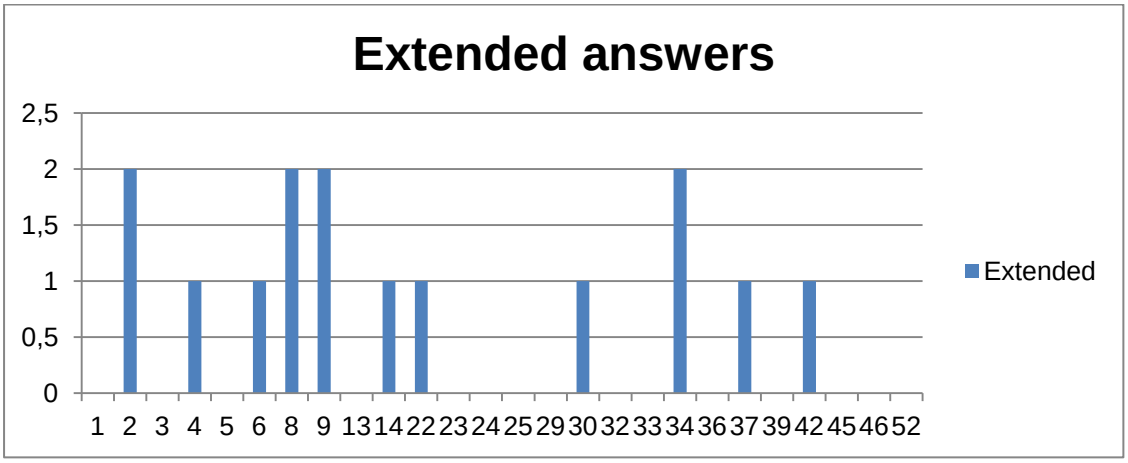
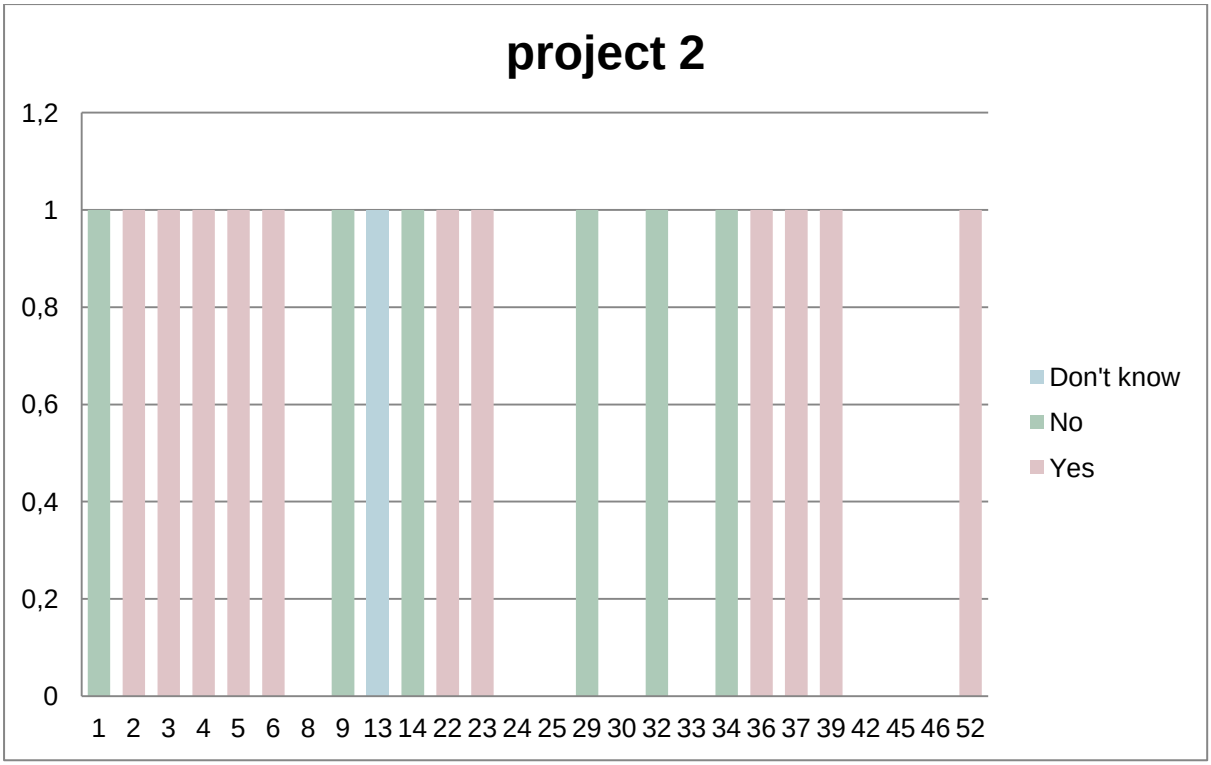
Appendix

Appendix 1



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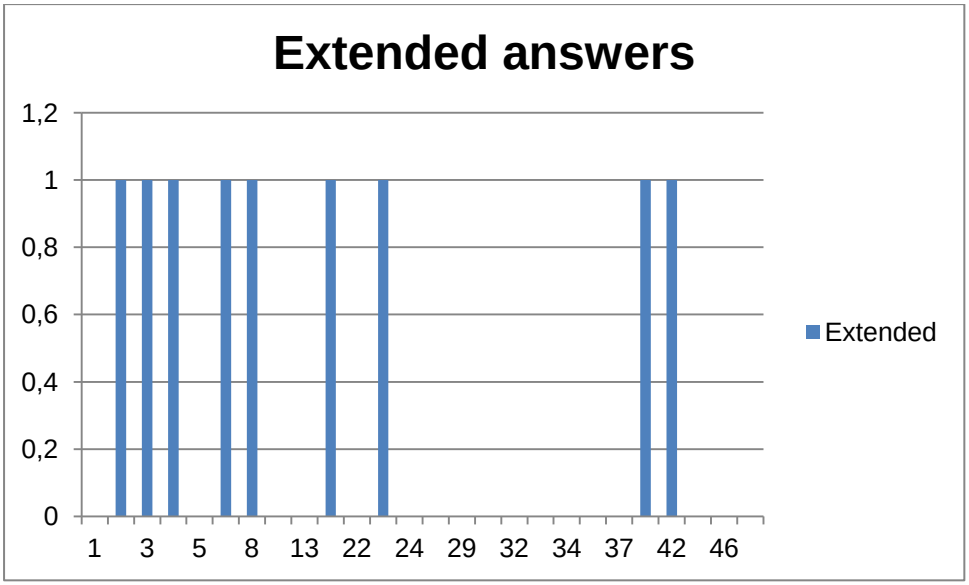
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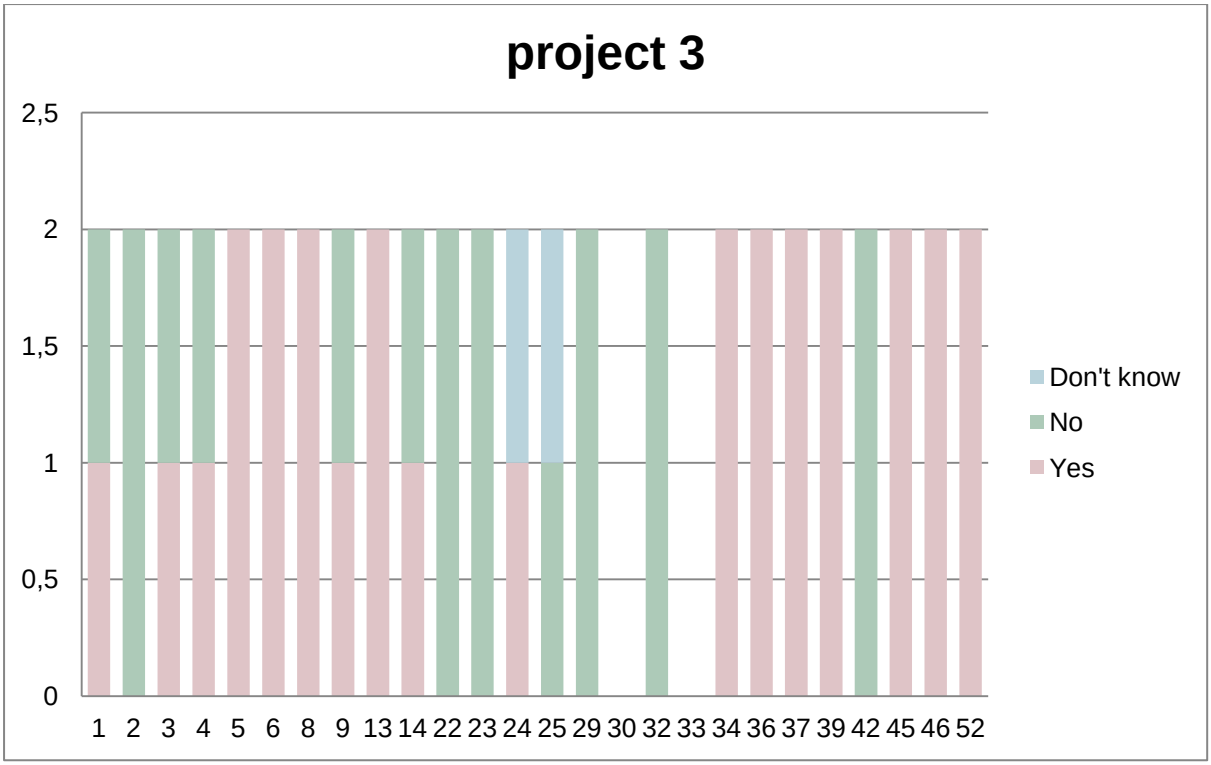
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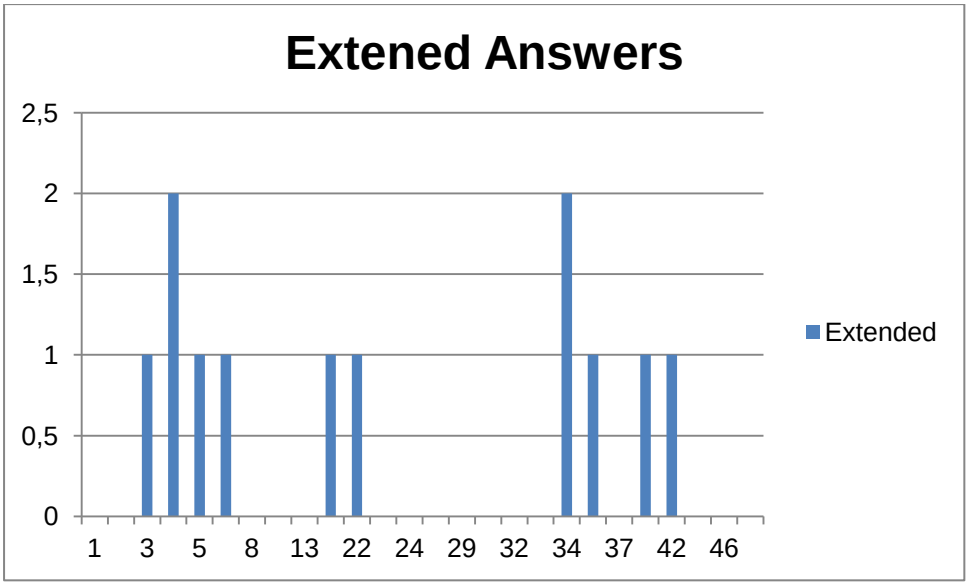
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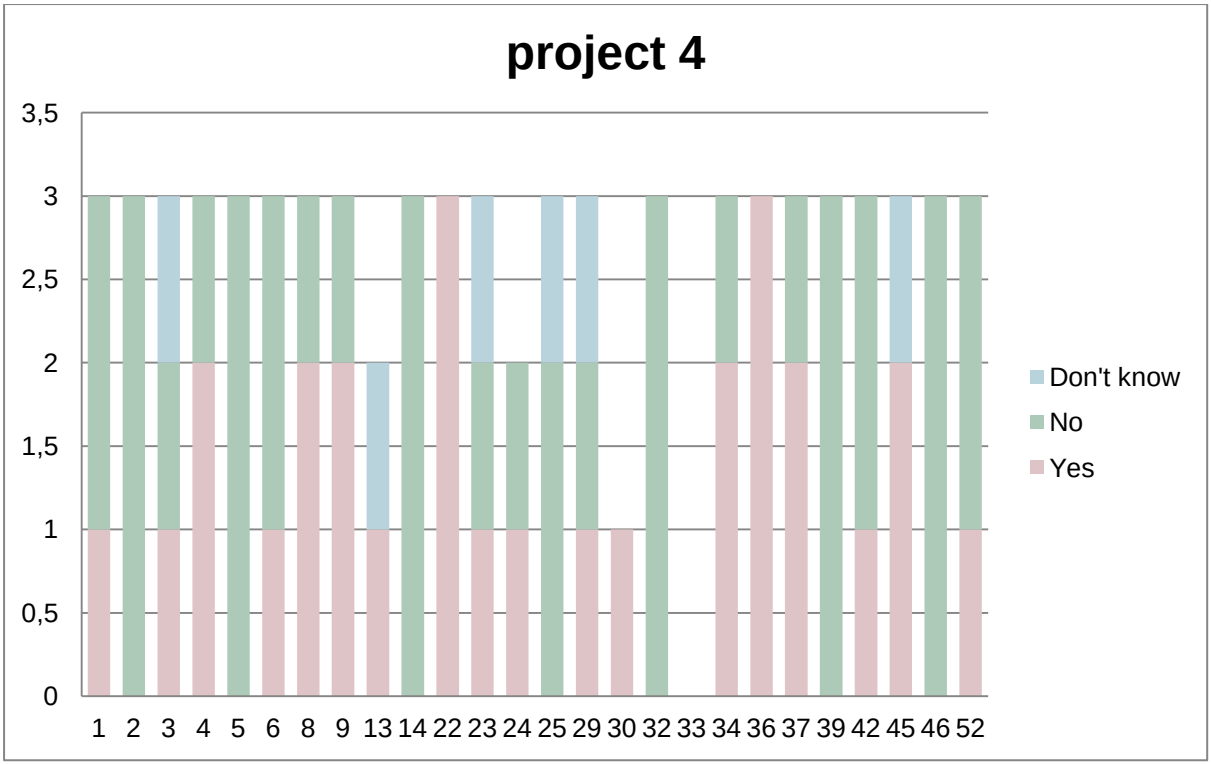
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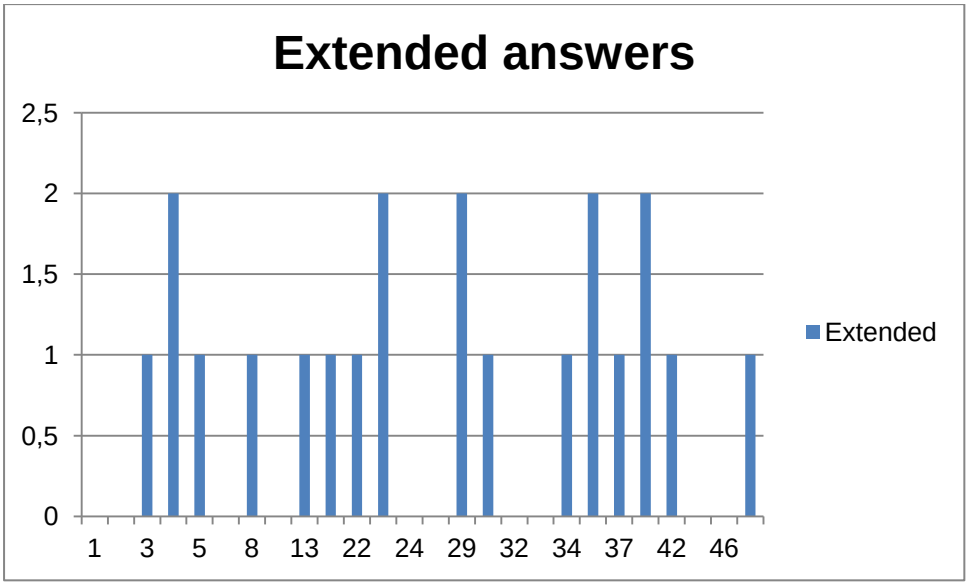
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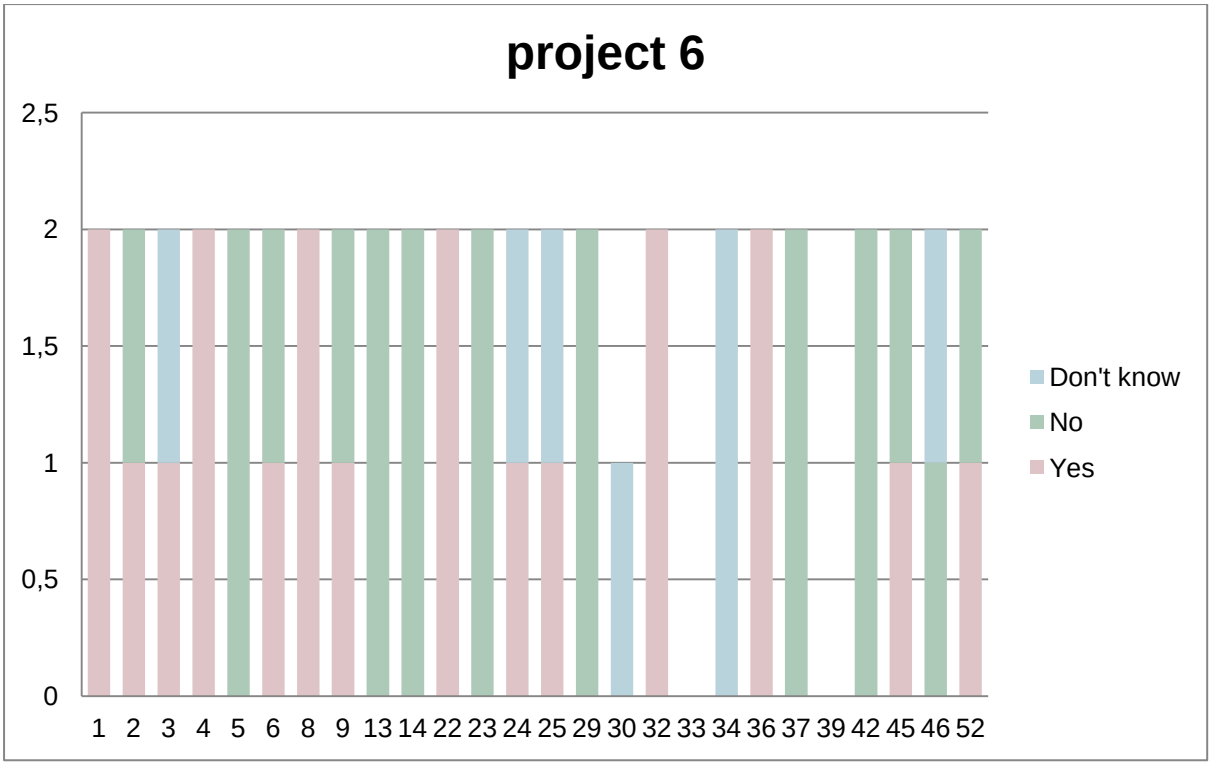
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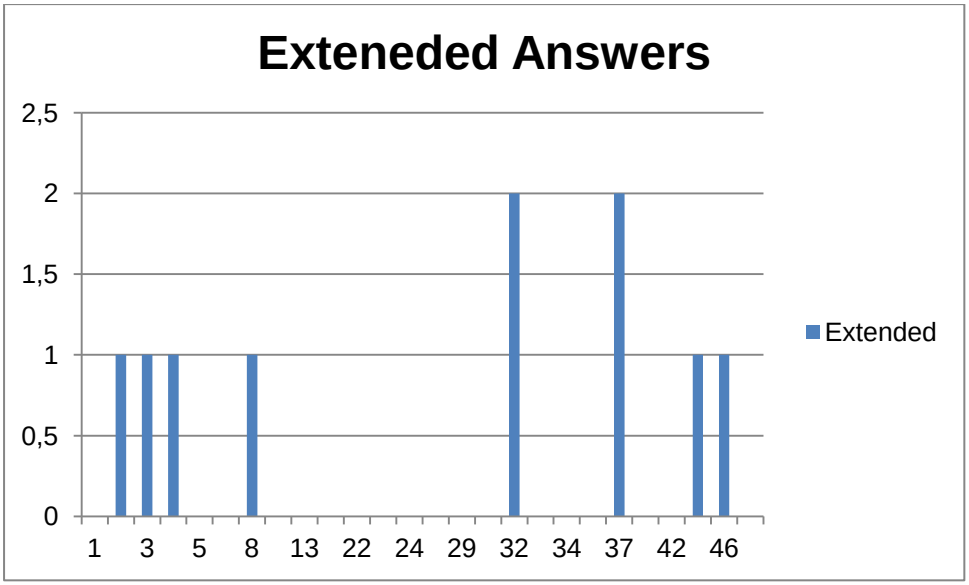
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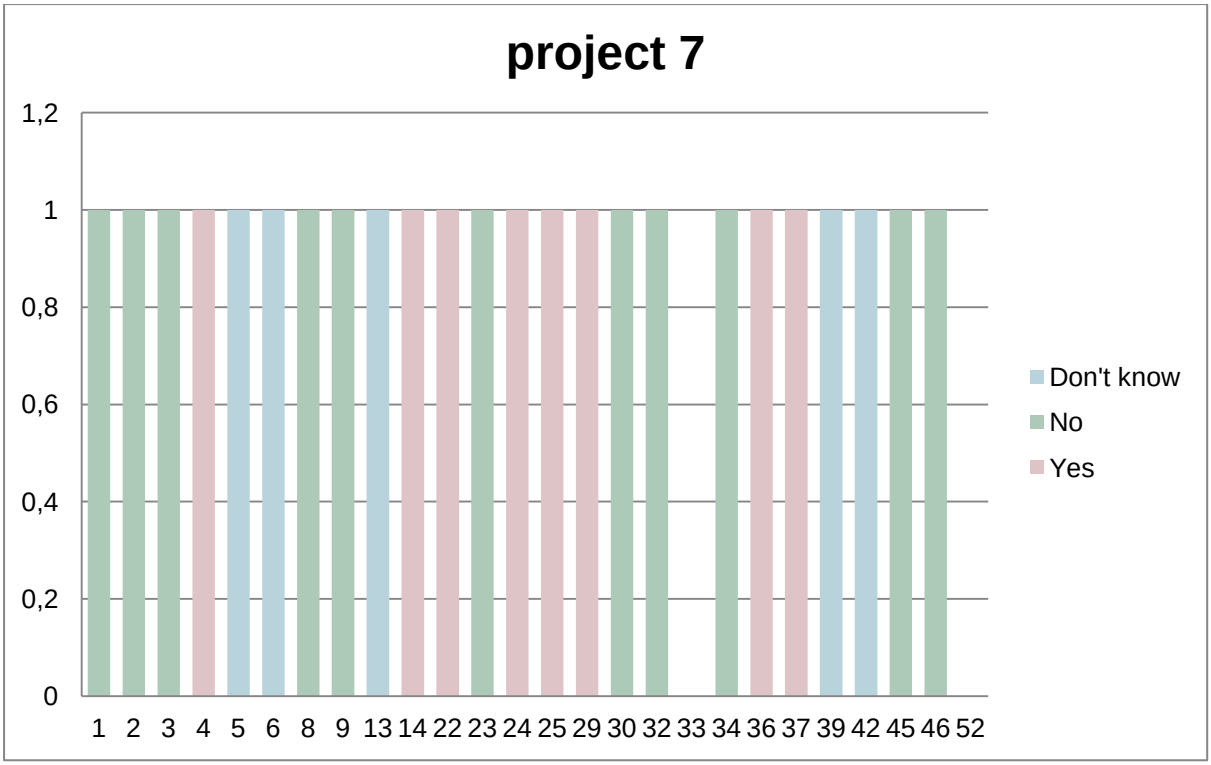
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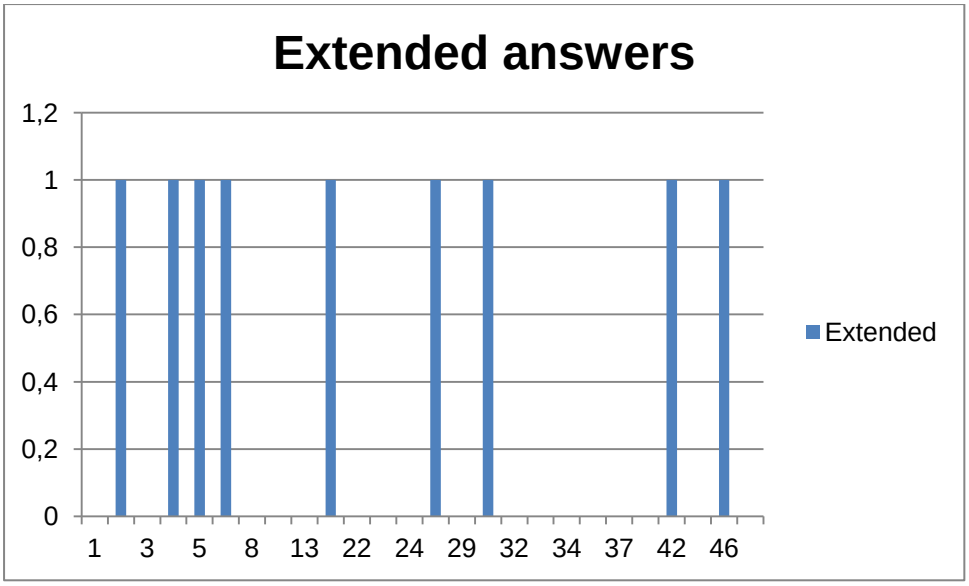
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Appendix 2

Kerzner have 6 categories each with a maximum score of 35, since the maximum score of each question is 5. For a deeper description of the PMM model by Kerzner please consult the Theoretical framework and the chapter on PMM.

So the maximum score in the surveys are 6*35 which is 210. Kerzner have used a a 4 step model for intepretating the answer. Below a table is found of the stepts, their point and the according percentage of that answer.

Level	Point	percentage
Level 4, high performance	169-210	80-100%
Level 3, right direction	147-168	70-80%
Level 2, minimal support	80-146	38-69%
Level 1, no understanding of project management	<79	0-37%

Since only 3 categories of 6 were used a recalculation. Since there was an option for the interviewee not to respond to the question the according points was withdrawn from the totalt and the percentage was calculated. on the following pages the point of each question can be viewed. And also the answers provided by the respondents.

Person	Score	Percentage(the blank answers taken away)
APL1	71	71%
APL2	65	72,2%
APL3	83	79,1%
APL4	44	58,6%
APL5	76	72,3%
AE1	16	40%
AE2	10	28%
AE3	0	0%
AE4	41	54%
AE5	23	46%
AE6	28	56%
SL1	56	74,6%
SL2	54	54%

3 surveys from kerzner

1. Our organizational structure is?
    a. Traditional (predominantly vertical)
    b. A strong matrix(i.e. project managers provide most of the technical direction)
    c. A weak matrix(i.e.) line managers provide most of the technical direction)
    d. We use collocated teams
    e. I don't know what the strucute is. Management changes it on a daily basis.
2. When assigned as a project leader our pm obtains resources by:
    a. "fighting" for the best people available
    b. Negotiating with line manager for the best people available
    c. Negotiating for deliverables rather than people
    d. Using senior management to help get the appropriate people
    e. Taking whatever he or she gets no questions asked.
3. Our line managers:
    a. Accept total accountability for the work in hteir line
    b. Ask the project managers to accept total accountability
    c. Try to share the accountability with the project managers
    d. Hold the assigned employees accountable
    e. We don't know the meaning of the word accountability; it is not part of our vocabulary
4. In the culture within our company, the person most likely to beheld accountable for the ultimate technical integrity of the final deliverables is/are:
    a. The assigned employees
    b. The project manager
    c. The line manager
    d. The project sponsor
    e. The whole team
5. In our company, the project managers authority comes from:
    a. Within himself/herself, whatever he or she can get away with
    b. The immediate superior to the project manager
    c. Documented job descriptions
    d. Informally through the project sponsor in the form of a project charet or appointment letter
6. After project go-ahead, our project sponsors tend to:
    a. Become invisible
    b. Micromanage
    c. Expect summary-level briefings once a week
    d. Expect summary-level briefings every two weeks
    e. Get involved when a critical problem occurs or at the request of the project manager or line managers
7. What percentage of your projects have sponsors who are at the director level or above:
    a. 0-10
    b. 10-25
    c. 25-50
    d. 50-75
    e. 75-100

1.
2. My company actively uses the following processes
    a. TQM only

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b. Concurrent enginnering only
c. TQM and concurrent engineering only
d. Risk management only
e. Risk management and concurrent engineering only
f. Risk management, concurrent engineering and TQM
3. On what percentage of your projects do you use the principles of project management
a. 0
b. 5-10
c. 10-25
d. 25-50
e. 50-75
f. 75-100
4. On what percentage of your projects do you use the principles of risk management
a. 0
b. 5-10
c. 10-25
d. 25-50
e. 50-75
f. 75-100
5. On what percent of your projects do you try to compress product deliverable schedules by performing work in parallel rather tahn in series
a. 0
b. 5-10
c. 10-25
d. 25-50
e. 50-75
f. 75-100
6. My company's risk management process is based upon
a. De do not use risk management
b. Financial risks only
c. Technical risks only
d. Scheduling risks only
e. A combination of financial, technical, and scheduling risks based upon the project
7. The risk management methodology in my company is:
a. Nonexistent
b. More informal than formal
c. Based upon a structured methodology supported by policies and procedures
d. Based upon a structured methodology supported by policies, procedures and standardized forms to be completed
8. How many different project management methodologies exists in your organisation(i.e consider a system development methodology for MIS projects different than a product development project management methodology)
a. We have no methodologies
b. 1
c. 2-3
d. 4-5
e. More than 5

1. In my company employees are promoted to management because
    a. They are technical experts
    b. They demonstrate the administrative skills of a professional manager
    c. They know how to make sound business decisions
    d. They are at the top of their paygrade
    e. We have no place else to put them
2. A report must be written and presented to the customer. Neglecting the cost to accumulate the information, the approximate cost per page for a typical report is:
    a. I have no idea
    b. 1000-2000
    c. 2000-5000
    d. More than 5000
    e. Free; exempt employees in our company prepare the reports at home on their own time
3. The culture within our organisation is best described as:
    a. Informal project management based upon trust, communication, adn cooperation
    b. Formality based upon policies and procedures for everything
    c. Project management that thrives on formal authority relathionships
    d. Executive meddling, which forces an overabundance of documentation
    e. Nobody trusting the decisions of our project managers
4. What percentage of the projects managers time each week is spent preparing reports
    a. 5-10
    b. 10-20
    c. 20-40
    d. 40-60
    e. 60-100
5. During project planning most of our activites are accomplished using
    a. Policies
    b. Procedures
    c. Guidlines
    d. Checklists
    e. None of the above
6. The typical time duration for a project status review meeting with senior management is:
    a. Less than 30 minutes
    b. 30-60
    c. 60-90
    d. 90-2 hours
    e. Greater than 2 hours
7. Our customers mandate that we manage our projects:
    a. Informally
    b. Formally but without customer meddling
    c. Formally, but with customer meddling
    d. It is our choice as long as the deliverables are meet.

Ranking scale

Kerzner has the following scales(Kerzner 2001, s96)

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Below 79 *perhaps you should change jobs or seek another profession. The company has no understanding of project management, nor does it appear that the company wishes to change. Line managers want to maintain their existing power base and they feel threatened by project management*

80-146 *the company is probabli just porviidng lip service to project management. Support is minimal. The company believes that it is the right thing to do, but has not figures out the true benefits or what they, the excecutives should be doing. The company is still a functional organisation.*

147-168 *your company is going in the right direction, but more work is needed. Project management is not totally perceived as a profession. It is also possible that your organisation simply does not fully understand project management. emphasis i probably more toward being non project driven than project-driven*

168-210 *your company compares very well to the companies discussed in this text. You are on the right track for excellence, assuming that you have not achieved it yet. Conitnious improvement will occur.*

13.1.1 Score

category		a	b	c	d	e	f	
Management support	1	1	5	5	5	0	-	
	2	2	3	5	0	2	-	
	3	4	2	5	1	0	-	
	4	2	3	5	0	3	-	
	5	1	2	2	4	5	-	
	6	1	1	3	4	5	-	
	7	1	3	5	4	4	-	
Integrated process	1	2	2	4	2	4		5
	2	0	0	1	3	4		5
	3	0	0	3	4	5	-	
	4	0	1	3	4	5	-	
	5	0	2	2	2	5	-	
	6	0	2	4	5	-	-	
	7	0	5	4	2	0	-	
Informal project management	1	2	4	5	1	0	-	
	2	0	3	4	5	0	-	
	3	5	2	3	1	0	-	
	4	3	5	4	2	1	-	
	5	2	3	4	5	0	-	
	6	4	5	3	1	0	-	
	7	3	4	3	5	-	-	

Figure 44 3 questionnaires and the points given for each answer a minus sign means that this alternative did not exist.

	APL1	AE1	AE2	APL2	AE3	APL3	AE4	SL1	APL4	AE5	APL5	AE6	SL7
1	b	b	d	a	x	b	b	b	b	a	c	a	a
2	b	b	x	b	x	a	b	b	b	x	b	b	b
3	a	b	x	c	x	c	b	d	a	x	c	b	e
4	e	b	b	b	x	b	b	b	x	e	b	e	b
5	d	b	a	c	x	a	c	c	a	x	a	a	d
6	e	b	a	d	x	d	a	d	e	e	e	x	a
7	a	x	x	x	x	d	x	c	x	b	b	x	e
1	f	x	x	x	x	e	d	f	f	x	f	x	x
2	c	x	a	e	x	d	f	x	f	b	f	x	e
3	b	x	a	e	x	e	e	x	f	x	f	x	d
4	f	x	f	e	x	d	b	x	f	f	e	e	d
5	e	x	x	e	x	e	x	e	e	x	e	e	b
6	d	x	x	d	x	c	b	d	b	x	d	x	c
7	b	x	x	x	x	b	x	b	x	c	c	x	b
1	x	x	x	b	x	c	e	b	d	b	b	x	e
2	b	a	x	a	x	c	a	a	b	a	a	a	a
3	a	x	x	a	x	a	a	b	a	x	b	c	d
4	a	x	x	a	x	a	x	x	x	x	b	x	c
5	c	e	x	b	x	d	x	c	e	b	b	x	e
6	b	x	x	b	x	c	x	c	x	x	b	b	b
7	d	x	x	c	x	b	d	x	x	x	c	x	d

Figure 45 the answers presented per question and person

Summarized:

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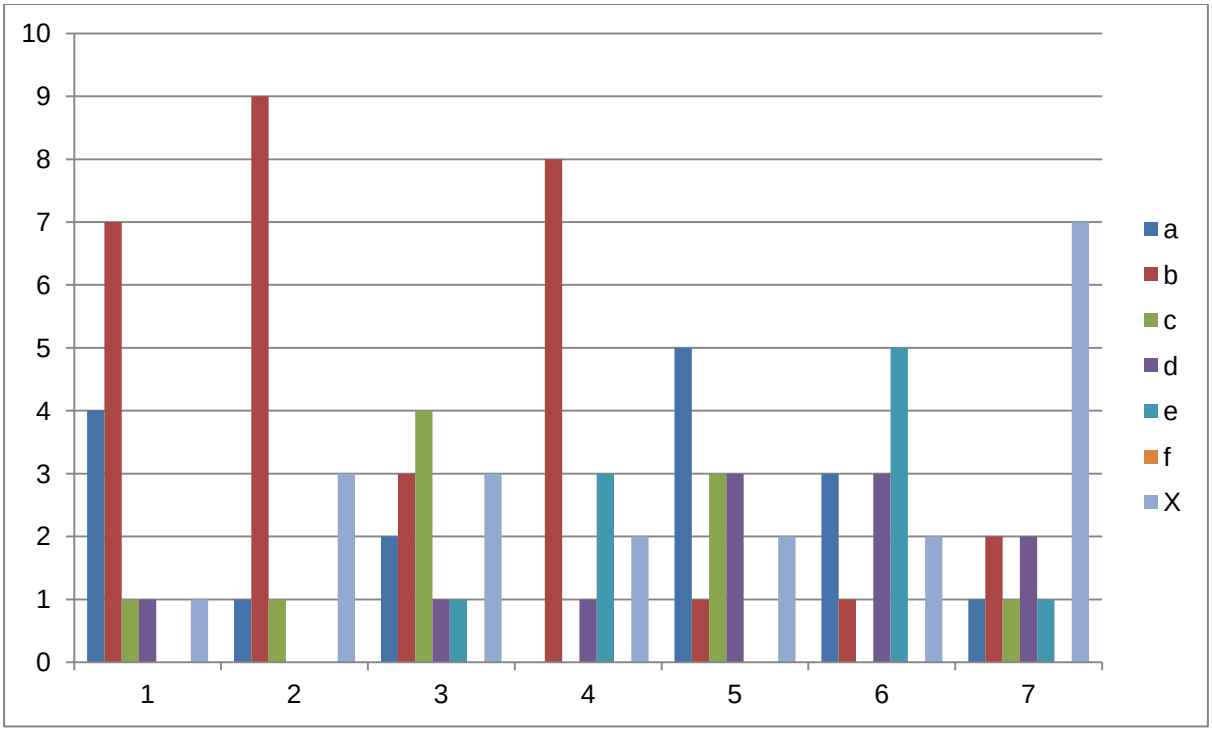

Figure 46 results from survey number one

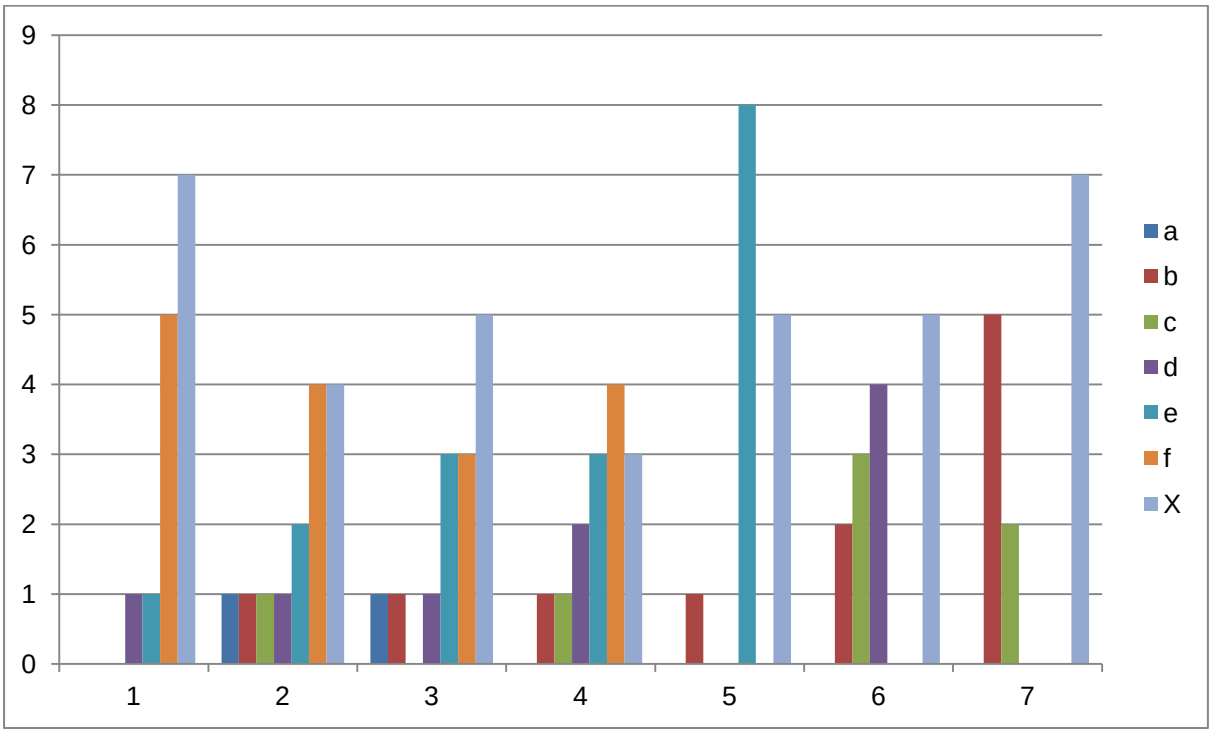

Figure 47 results from survey nr 2

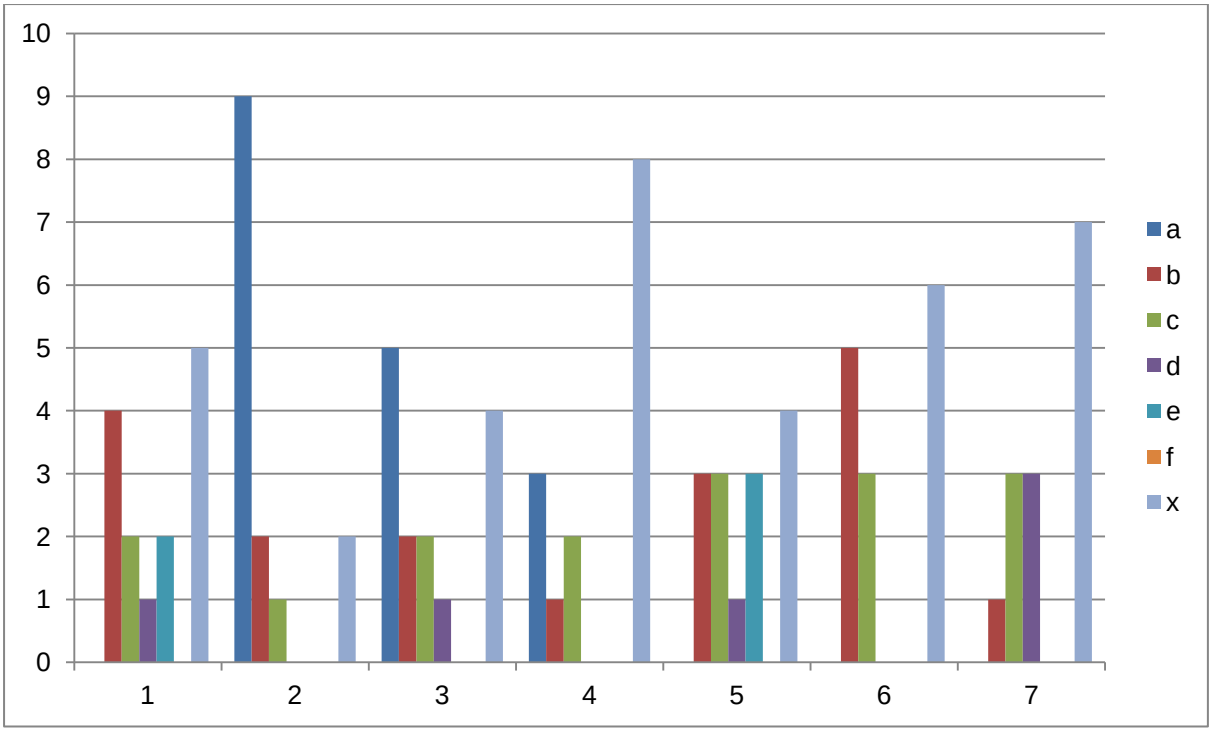

Figure 48 results from survey number 3

APL

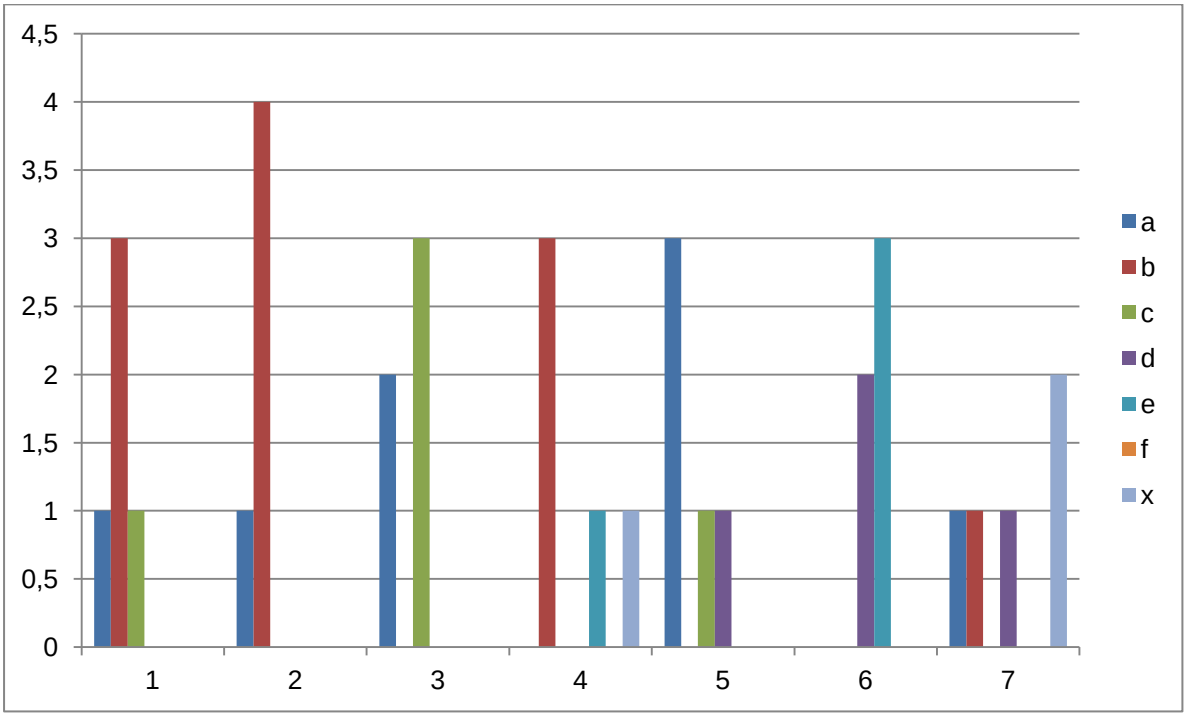

Figure 49 results from survey number one, only APL

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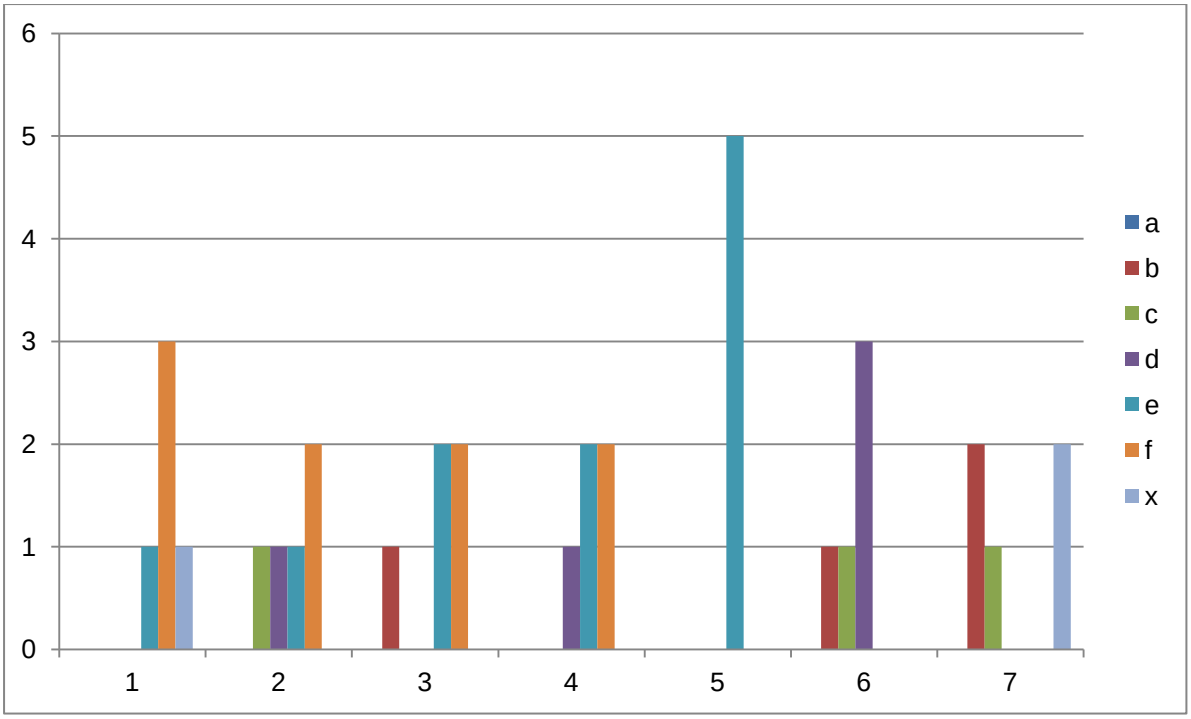

Figure 50 results from survey number 2, only APL

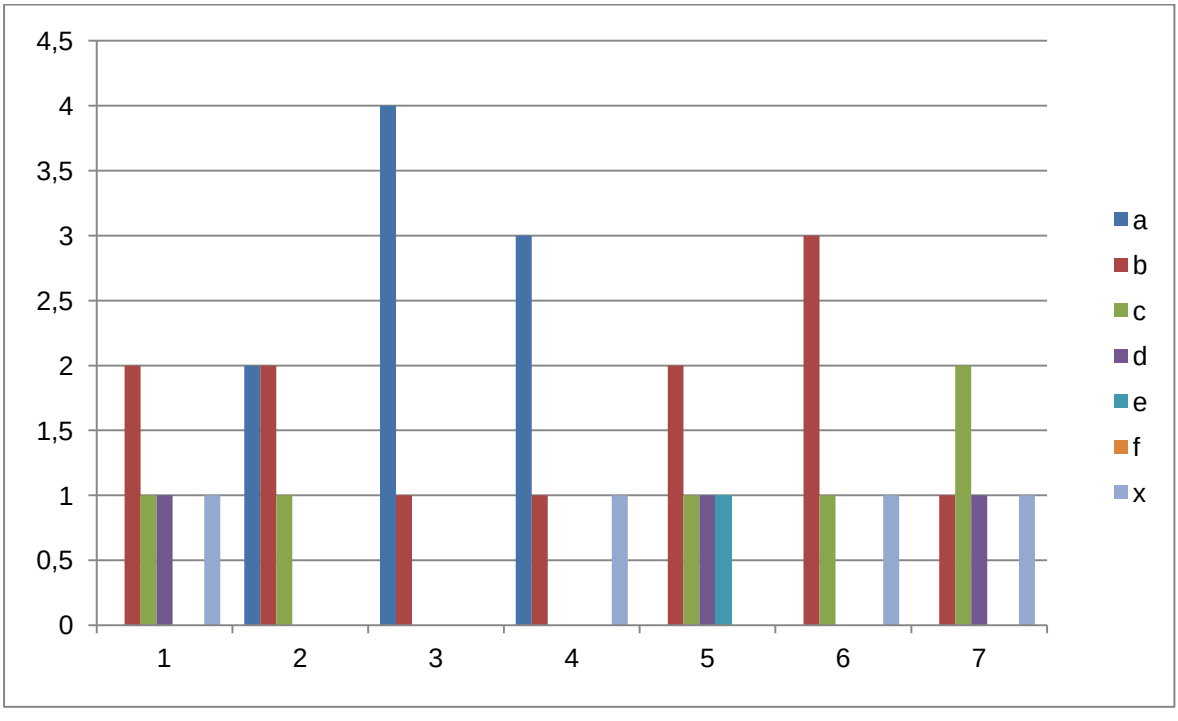

Figure 51 results from survey number 3, only APL

Appendix 3

	Characteristics	Definition
2	Unambiguous	" An SRS is unambiguous if, and only if, every requirement stated therein has only one interpretation"
3	Complete	"An SRS is complete if, and only if, it includes the following elements:" All significant requirements should be included. This includes all types of requirements whether they relate to functional description, design constraints or external interfaces. Definition of the responses of inputs, both valid and invalid inputs. Definition of measures and terms also full labels and referenses to all figures, tables and diagrams.
5	Ranked for importance and/or stability	"An SRS is ranked for importance and/or stability if each requirement in it has an identifier to indicate either the importance or stability of that particular requirement."
6	Verifiable	"An SRS is verifiable if, and only if, every requirement stated therein is verifiable. A requirement is verifiable if, and only if, there exists some finite cost-effective process with which a person or machine can check that the software product meets the requirement"
7	modifiable	"An SRS is modifiable if, and only if, its structure and style are such that any changes to the requirements can be made easily, completely, and consistently while retaining the structure and style."

- **Number 2** will be overviewed in the documents and a reandomly selected part of the Specification will be examined to look if there is requirements which has an unclear interpretation
- **Number 3**, if there is references to tables and figures, this is done to see how much time is spent on the document. And if there is a definition of measurments and terms.
- **Number 5**, does the requirements have a rank of importance or stability in the document.
- **Number 6**, is there a statement of how it can be tested or verified.
- **Number 7**. An overview of the document will be made to see if there is a usage of traceability and if there is a consistent method of handling traceability

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	P1	P2	P3	P4	P5	P6	P7
2	Yes	No FD	Yes	Yes	No	Yes	no
3	Yes	-	Yes	Yes	No	No	Yes
5	No	-	No	No	No	No	No
6	Yes	-	Yes	Yes	No	-	No
7	Yes	-	yes	yes	Yes	yes	no
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