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IMPROVING AUTOMATION DELIVERY PROJECT QUALITY WITH QUALITY GATE PROJECT MODEL

Master of Science Thesis

Prof. Jouni Kivistö-Rahnasto and Assistant Prof. Teemu Laine have been appointed as the examiners at the Council Meeting of the Faculty of Natural Sciences on March 9th, 2016.

ABSTRACT

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In Valmet Automation, a strong need for improvement of project quality and reduction of quality costs has been acknowledged. As a solution, in this study a new quality gate model for automation delivery projects is created. With systematic quality checkpoints defined in the project execution model, the target is to improve the project as well as product quality in the project deliveries of the target company. The model presents a more standardized way of project execution with suitable Lean project management principles applied in the model.

The study is conducted with a constructive research approach. In the theoretical background, project management as well as the most common project success factors were discussed. Also, the relationship between time, cost and quality factors in projects are reviewed and the basics of Lean thinking presented as well as the principles of Lean project management.

Before constructing the actual model, an extensive interview study with more than 40 interviewees was conducted in order to understand the current state of project execution as well as the biggest problems related to project quality. An important part of the construction process was a pilot trial, as the model was tested in six different pilot projects. With the feedback gathered form the pilot trial the final version of the quality gate model was defined.

The quality gate model constructed in this study will be implemented globally to the project deliveries of Valmet Automation in the autumn 2016. According to the feedback gathered from the pilot trial, the model is seen well suitable for practice and is seen to have potential to improve the project quality in the target company. One of the biggest differences compared to the current project quality assurance model is the strong focus on the in-house phases of the project. In the model, Lean principles of project management are applied and most of the quality assurance activities are conducted before the on-site phase in order to recognize the defects earlier and minimize the quality costs generated. In addition, two entirely new quality checkpoints were added to the project quality assurance due to challenges observed during the current state analysis.

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Valmet Automaatiolla on tunnistettu voimakas tarve parantaa projektien laatua sekä vähentää laatukustannuksia. Ratkaisuna siihen, tässä työssä luodaan uusi laatuporttimalli automaatiotoimitusprojekteille. Systemaattisia laaduntarkistuspisteitä sisältävän projektin toteutusmallin avulla tavoitteena on parantaa sekä projektin että tuotteen laatua kohde yrityksen toimitusprojekteissa. Uusi malli esittelee entistä standardisoidumman tavan toteuttaa projekteja, ja malliin on sovellettu myös sopivia Lean-projektinhallinnan periaatteita.

Tutkimus suoritettiin konstruktiivisen tutkimusmenettelyn avulla. Työn teoriaosassa käsitellään projektinhallintaa sekä yleisimpiä projektin onnistumistekijöitä. Työssä tarkastellaan myös aika-, kustannus- ja laatutekijöiden välistä suhdetta sekä Lean filosofian ja projektinhallinnan perusperiaatteita.

Ennen varsinaisen mallin rakentamista suoritettiin laaja haastattelututkimus liittyen projektitoimitusten nykytilaan sekä projektien laatuongelmiin, johon osallistui yli 40 haastateltavaa. Tärkeä osa mallin kehitystä oli pilottijakso, jossa luotua projektimallia testattiin kuudessa eri pilottiprojektissa. Viimeistelty projektimalli luotiin pilottijaksosta kerätyn palautteen avulla.

Työssä luotu projektien laatuporttimalli tullaan ottamaan käyttöön globaalisti Valmet Automaation projektitoimituksissa syksyllä 2016. Pilottijakson palautteen perusteella malli soveltuu hyvin käytäntöön ja sillä nähdään olevan potentiaalia parantaa projektien laatua kohdeyrityksessä. Yksi suurimpia eroja nykyiseen projektien laadunvarmistukseen verrattuna on se, että uudessa projektimallissa keskitytään voimakkaasti projektin in-house –vaiheisiin. Mallissa on sovellettu Lean-projektinhallunnan periaatteita, ja suurin osa laadunvarmistuksesta on tehty ennen työmaavaihetta, jotta mahdolliset virheet huomattaisiin aikaisemmin ja laatukustannusten synty saataisiin minimoitua. Lisäksi, mallissa on kaksi uutta laaduntarkistuspistettä, jotka lisättiin haastatteluissa havaittujen ongelmien perusteella.

PREFACE

Honestly, this thesis project has been the most meaningful and rewarding assignment in the short working history of mine - and not at all such a troubled road as the stories about master's thesis projects tell.

Surprisingly, no major difficulties were faced during this otherwise challenging thesis project, which is mostly due to my great thesis supervisor from Valmet, Jussi Näveri, who always had time, guidance and answers when needed and when I was in doubt. So, special thanks for him!

Also, I want to thank Valmet Automation for such an interesting and challenging master's thesis subject and all the employees who shared their time, ideas and opinions during the research. I would also like to thank my advisors Jouni Kivistö-Rahnasto and Teemu Laine.

My dear friends, the past six years have been simply the best! I thank you for the cheers, but for most, the happy moments.

Most of all, I want to thank my dear mother and father. For your love and support, through the years.

In Tampere, Finland, 24.5.2016

Henriikka Hujanen

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TERMS AND ABBREVIATIONS

DCS	Distributed Control System
DNA	Dynamic Network of Applications
FAT	Factory Acceptance Test
HW	Hardware
iFAT	Internal Factory Acceptance Test

AUT Procedures	Process Automation Systems Procedures, the working methods/process definitions used in Valmet Automation project department
QCS	Quality Control System
SW	Software

1. INTRODUCTION

1.1 Background of the study

As a long-experienced project house, Valmet Automation is confronting a strong pressure to increase productivity and efficiency of operations. Competition in the field is tough and ever more cost effective ways to operate are demanded to stay competitive and to win deals. But on the other hand, customer requirements are also getting stricter and the level of customer satisfaction must be ensured in order to keep the current and to gain new customers. At present, the on-time and on-budget delivery is not satisfactory as the expectations towards the product to fulfill the requirements, and quality standards are getting higher and more complicated. Also, customer requirements towards, for instance, the documentation, approvals, and applied standards are increasing and the project quality through the project lifecycle must be ensured.

But not only due to the increasing requirements of the clients, the improvement of project and product quality are necessary also in order to reduce quality costs and so make the business more profitable. A strong contributor in conducting this development project is the continuous need for reducing the extra costs emerging during the projects. On the whole, there is a strong need to improve the quality and reduce quality costs in delivery projects. As a solution, a quality gate model for automation delivery projects is created in this study, with which the delivery project quality will be improved.

According to Valmet corporate, quality is one of the company's cornerstones of success and high quality in Valmet's products, processes and services is an essential element of all the activities. (Quality Policy, 2014). As part of quality development, Valmet Corporation has decided to implement Lean thinking in its businesses and Lean way-to-operate is also being implemented to AUT operations. Lean principles are traditionally used to improve the quality, cost effectiveness and performance in manufacturing environment, and the methods have been discovered to provide significant benefits and competitive edge. In this study, the suitable Lean principles are applied in project environment in order to improve the project and product quality, as well as achieve cost efficiency with reducing the quality costs generated in projects.

The quality of the delivery project consists of the quality of the end product and quality of the project operations. Major segment of quality costs arise from the problems in project management level and implementation of the project. Therefore, the quality of the project managerial activities have also a significant impact on quality costs beside poor product quality. Hence, also the quality of project implementation and management is included in this study and taken into consideration in the quality gate model. In addition, customer satisfaction does not depend only on the product quality, but also strongly on the project quality, and so the aspect of project implementation is very important.

In a wider context, the research topic is interesting as the importance of project business is increasing in organizations and project management is one of the growing disciplines. Also, the perspective on quality has changed significantly during recent decades, and at present the costs related to quality are also seen as a potential opportunity of profit maximization in organization. Combining the two, successful project management and project quality in order to maximize cost effectiveness has potential for notable performance improvement.

1.2 Objectives and limitations

The objective of this thesis is to create a quality gate model for Valmet Automation's delivery projects. A new more standardized project execution model is created with the aim to improve the project as well as the product quality and ensure the right quality level in every phase through the project lifecycle. Hence, the delivery must satisfy the customer's needs as well as possible and also fulfill the financial objectives of the business. The main financial objective is to reduce the quality costs in projects, and so to maintain satisfactory gross margin levels throughout the projects, from the sales phase to the end of the delivery.

In this study, the focus is on Distributed Control System (DCS) deliveries, which is one of the major products of Valmet AUT. The project delivery begins already in the sales phase when the input for quotation is gathered and project specific requirements are set and agreed between the project parties. In this study, the project flow is discussed starting from the sales phase and more precise from the point, where a valid contract of the project is existing. Sales phase is not concerned in this study as a whole, because the gates for the sales phase are done in a separate development project. The project delivery is covered in this study until the point where the project is transferred to service organization and the responsibility of the project organization has ended.

At the moment, there is another development project ongoing at Valmet corporation level regarding also the project execution. A new Project Execution Model (PEM) is being developed at Valmet corporate level, concentrating more on the project follow-up and financial issues at the project portfolio level. The alignment of the quality gate model created in this study with the Valmet PEM model must be ensured, as the two models will be implemented at the same time with the same tool.

Also, another project ongoing at Valmet level, which must be considered in this study, is the implementation of Lean into the operations. Therefore a requirement for the model is set, to apply suitable Lean methods and practices in the new gate model. Suitable principles must be utilized to implement Lean way-to-operate also in the project operations, and in addition to make the operations more cost effective.

To have reasonable and realizable framing and time schedule in the thesis, the planning of implementation of the gate model has been excluded of the thesis scope.

1.3 Structure of the thesis

The structure of the thesis is organized so that the following chapter, chapter two, builds a theoretical background for the thesis. Literature is reviewed in order to build deeper understanding of the subject area discussed in the thesis and to build theoretical basis for the construction phase of the quality gate model. Chapter two includes the basics of project and project quality management, literature review over project success factors and discussion about time, cost and quality factors in projects and the trade-off decisions between them. Chapter two also includes an introduction to Lean thinking and the fundamentals of Lean. Also an understanding is built upon Lean project management and how Lean thinking can be considered in project management.

In chapter three, a description of the research target and the project process of Valmet Automation is given. The project flow of delivery projects is described and the chapter gives an understanding of automation project execution and the different phases of the project. In the same chapter is also described the current way of quality assurance in AUT projects. In chapter four the research methodology and the materials used in this thesis are described. The chapter contains a brief summary of the research strategy used and describes how information was gathered during the study. Also the different stages of the constructive research process are advised in the chapter.

Chapter five is a very important chapter of this thesis, as it presents the most significant results of the study. The structure of the chapter is based on the phases of the constructive research done in the thesis. In this chapter the recent state of project execution in Valmet AUT is presented and the observations made during the interviews are discussed. The construction created in this study, a quality gate model for automation project deliveries, is presented and also the most important results of the pilot trial are discussed.

In the next chapter, chapter six, the results are validated and discussed with related linkages to the theoretical background. The constructed model is evaluated mostly against the feedback gathered during the pilot trial. The final chapter, chapter seven, summarizes the results of the study and discusses how the thesis is fulfilling its objectives. Also the next steps and needs for further development in the target company are discussed, as well as the suggestions for further research.

2. THEORETICAL BACKGROUND

In this chapter, the understanding of the theoretical background related to the research topic is build. First the basics of project management are presented and a literature review about project success factors is conducted. Next, the relationship between the most important project success criteria, time, cost and quality is discussed. Also a short introduction to project quality management is presented as well as the basics of Lean thinking. Related to the application of Lean principles in the gate model, the biggest differences of traditional and Lean project management are also discussed.

2.1 Project management

A project is a temporary endeavor undertaken to create a unique product, service, or result. The temporary nature of projects indicates a definite beginning and end (PMBOK 2008, p. 5). A project is composed of unique set of processes, including coordinated and controlled activities, performed to achieve the project objectives (ISO 21500 2012, p. 13). Project management instead can be seen as the application of knowledge, skills, tools and techniques to project activities to meet the project requirements (PMBOK 2008, p. 6). According to Lock (2007, p. 1) the purpose of project management is to predict as many dangers and problems as possible, and to plan organize and control activities to complete projects successfully in spite of all the risks. Successful project management ensures the completion of the project in time, within budget, and to the project specifications (Babu & Suresh 1996, p. 1).

According to the international standard of project management, ISO 21500 (2012), organizations generally formulate strategy based on their vision, mission, policies and factors outside the organizational boundary, and projects are often the way to achieve strategic goals. The objective of a project is to produce measurable benefits that contribute to strategic goals, and project is managed through processes throughout its life cycle (ISO 21500 2012). For their temporary nature, projects are usually organized into phases which are collectively known as the project life cycle. To manage project efficiently through its life cycle, project management processes are needed to use as a whole, for individual phases or both. (ISO 21500 2012, p. 25)

The international standard for project management (ISO 21500 2012) has defined project management processes appropriate to projects in all organizations. Processes can be viewed from two different perspectives, as process groups for the management of the project or as subject groups for collecting the processes by subject. Processes are grouped into five categories (Process groups) (ISO 21500 2012, p. 29):

- Initiating process group
- Planning process group
- Implementing process group
- Controlling process group
- Closing process group

Management of projects starts with initiating the process group, containing processes used to start a project or a project phase, to define objectives, and to obtain authorization to start a project or a phase. The planning processes are required to establish the baselines of the project, against which the course of action required is defined and project performance can be controlled and measured. Implementing processes are used to carry out the project management activities and complete the work defined in the project plan according to project specifications. Controlling processes are used to measure, control and monitor the progress and performance of the project. Also preventive or corrective actions may be taken and changes to the plan made, in order to achieve project objectives. The management of project ends with the Closing process group, in which the processes are used to finalize all activities and formally close the project phase or project. (ISO 21500 2012, p. 29) (PMBOK 2008, p. 39)

As the objective of the process management processes is to manage projects efficiently and they have impact on the performance of projects (ISO 21500 2012, p. 7), the definition for project management success is not clear. According to Rolstadås (2014, p. 657) the formula of project management success has not even been found yet, and probably there is no single solution existing, as the success depends on several factors and can vary from project to project and organization to organization. Although the project management success is not easily defined, nor is the impact of project management on the project success, being still controversial and not so much researched study area (Rolstadås et al. 2014; Mir & Pinnington 2014).

Mir & Pinnington (2014, p. 203) state that there is an insufficient understanding of the relationship between project management performance and project success, partly being accounted for the subjective and objective nature of how project success is defined and perceived. According to Munns & Bjeirmi (1996, p. 84) the measures of project management success, such as budget and schedule, are conveniently used as a means of determining overall project success. Mostly resulting from the easily measurable nature of the project management objectives (Munns & Bjeirmi 1996, p. 84). Munns & Bjeirmi (1996, p. 84) emphasize the importance of improved appreciation of the project management role within the projects to avoid the confusion. The role of project management is to use the resources available effectively in order to accomplish a set goal, but project management will not stop a project from failing to succeed (Munns & Bjeirmi 1996, p. 86).

Of the same opinion is also Rolstadås et al. (2014, p. 640) who states that a project result can be successful even if the project was unsuccessfully managed, or the opposite. Also Mir & Pinnington (2014, p. 215) emphasizes more the impact of external factors on the project success than the project management, stating that the project management performance explains around

44,9% variance in project success. Mir & Pinnington (2014, p. 215) found certain project management variables having a significant influence on project success, the most influential being project management key performance indicators and project management staff, suggesting that project management performance measurement in an organization can have a significant impact on project success (Mir & Pinnington 2014, p. 215).

Even though project success or failure is not totally dependent on project management success or failure (Munns & Bjeirmi 1996, p. 86), the positive influence of project management on project success is strongly emphasized (Mir & Pinnington 2014; Munns & Bjeirmi 1996; Rolstadås et al. 2014). According to Munns & Bjeirmi (1996, p. 86) successful project management enhances the success of a project and Mir & Pinnington (2014, p. 209) state that the chances of project success can be significantly increased by managing project management performance. Rolstadås et al. (2014, p. 657) believe instead that the probability of project success can be increased by consciously selecting a suitable project management approach at the launch of each individual project, meaning that the success is dependent on the project management approach selected.

On the whole, there is no clear consensus about the impact of project management on the project success and the topic is not yet so much discussed. Instead, a much more debated theme is the project success in general, and as project quality is the key subject in this thesis, the understanding of the success factors is deepened next, and also other factors influencing to the project performance are discussed.

2.2 Success factors in projects

Project success factors can be seen as critical factors influencing strongly to the capability of the project to reach its objectives. To define and recognize the factors influencing the success of projects, it is necessary to evaluate the concept of project success first. Success may be measured against several different sets of objectives, but the focus in this study is set on the project objectives, excluding the business and social or environmental objectives. Three often discussed project success criteria can be distinguished among the project management literature: Cost, Time and Quality (Mishra et al. 2011, Lock 2007, Ruuska 1997, Dvir et al. 1998). These criteria can be fairly called as the basic criteria, since those three project objectives have been discussed in the literature at least since the 1970s. (Atkinson 1999, Cooke-Davies 2002). Cost, Time and Quality are also known as The Iron Triangle of project success criteria (Atkinson 1999, p. 338), and the relationship between these three factors is discussed more closely in the following chapter.

The triangle being still important criteria when discussing the project success, Ebbesen & Hope (2013) suggest that time, cost, and quality measure more the project efficiency, such as setting priorities during the course of the project. During 21st century more stakeholder focused project success criteria has been developed (Davis 2014, p. 194), customer being the most important stakeholder (Williams et al. 2015, p. 1836). According to Williams et al. (2015, p. 1836) the degree of customer satisfaction and also the quality of the customer relationship are seen more and more important metrics of project success, bringing also more people dimension and soft factors to the discussion about critical project success factors (Mishra et al. 2011, p. 356).

In the literature, a set of variable project success factors are presented, and it appears that there is no clear consensus about an agreed set of success factors (Muller & Jugdev 2012). As projects have different features, such as size, uniqueness and complexity, so are the consistent success factors missing. Most of the factors discussed before 21st century were concentrating strongly in identifying tools and techniques or general factors of the project success, but still less soft factors and people dimension have been researched (Mishra et al. 2011, p. 356). Mishra et al (2011) evaluated the critical project success factors based on a survey research in Indian project organization context. According to Mishra et al. (2011) the project manager is the most critical factor in project success, followed by the project team. Contrary to the most literature regarding the success factors, Mishra et al. (2011, p. 361) conducted a closer study about the project managerial factor and found out that the most significant features of the project manager are effective leadership, situational management and the ability of efficient management of resources. According to Mishra et al. (2011, p. 361) the emotional quotient of project manager as well as the state of commitment are recognized as critical success factors. Mortaheb et al. (2013, p. 436) also states that project manager characteristic is affecting to the project success especially, when measuring the client satisfaction of the project, but do not clarify the project manager features in detail.

Mishra et al. (2011) also identified interesting correlations between project manager's personal features and competence in work tasks. According to Mishra et al. (2011, p. 364) the age of project manager correlates highly with ability of effective conflict resolution and effective leadership. Also the experience of project manager was correlated to proper planning & scheduling, monitoring & controlling, proper communication and efficient management of resources. For the projects to be on time, Williams et al. (2015, p. 1846) consider project management performance as high importance factor. Project management performance, in all three phases of the project (planning, execution and delivery), has a strong impact especially on the customer relationship quality and customer satisfaction, execution performance being the most critical factor (Williams et al. 2015, p. 1846).

Dvir et al. (1998, p. 932) also states the importance of the managerial style of project manager in project success, especially in large Hardware projects. Dvir et al. (1998) investigated the success factors of projects, more closely large and small software and hardware projects among defense development. The study is relevant especially regarding this thesis, as automation project delivery consists of both hardware and software delivery. Over the course of the research, certain factors were found to have an impact on all types of projects and Dvir et al. (1998, p. 929) consider pre-project preparations and management policy as important success factors, regardless of the size and type of the project. Especially, in satisfying the customer, the preparation of detailed contract documents proved to be vital (Dvir et al. 1998, p. 927). For all projects, Dvir et al. (1998, p. 931) consider also the ability to apply lessons learned during previous phases of the project as an important factor. Also project milestones were found to be important to almost all types of projects (Dvir et al. 1998, p. 932) Project control is very important factor especially in large projects, and budget management and control has naturally greater impact on large rather than small projects (Dvir et al. 1998, p. 930). Also risk management and schedule control can be seen less critical for low scope and small projects, but extremely critical for high scope projects (Dvir et al. 1998, p. 932).

Williams et al. (2015, p. 1846) state that the greatest importance should be placed on execution activities like the creation of a reliable project schedule. Not only creating the schedule but also controlling and following a realistic project schedule are important in successful project (Mishra et al. 2011). Mishra et al. (2011, p. 360) emphasize the necessity of making a practical time chart, so that the project can be completed on-time and may be called as successful. Also White & Fortune (2002, p. 10) states the importance of a realistic project schedule, and according to Williams et al. (2015, p. 1847) it is also critical to communicate the reliable project schedule to customer, so that the client is being updated systematically.

Good project communication is a widely distinguished project success factor (Lock 2007), and according to Mishra et al. (2011, p. 362), especially the communication between the project team is seen critical. Mortaheb et al. (2013, p. 436) instead emphasizes the importance of regular client communication and involvement during the project. Dvir et al. (1998, p. 931) underlines the importance of good project communication in all types of projects, and according to Williams et al. (2015, p. 1843) communication impacts strongly especially to the quality of the customer relationship. Mishra et al. (2011, p. 365) states that the project success is strongly associated with project team management, especially in the form of information availability and proper communication, emphasizing the project manager’s characteristics and manners among communication.

Also support from top management is recognized as a success factor of projects (Cooke-Davies 2002; Lock 2007; White & Fortune 2002) and Cooke-Davies (2002) emphasizes especially the cooperation of project management and line management, as well as the management processes. Also according to Mishra et al. (2011, p. 364) in decision making fully involved project managers seem to have also top management support with them. Also in correlation were the number of employee with the adequate funds and resources (Mishra et al. 2011, p. 364). Adequate resources was also mentioned as a success factor (White & Fortune 2002; Lock 2007) and bigger firms seemed to have more availability of right amount of right expertise owning resources and funds to support the project execution (Mishra et al. 2011, p. 364).

Table 2.1. presents the summary of the most common project success factors mentioned among the studies concerned in this thesis. As mentioned in the beginning of the chapter, there does not exist any consistent perception about the project success factors among the project management literature, and the criteria differs especially between the time periods from 1970’s to 21th century.

Table 2.1. *The summary of the most common project success factors.*

Factor / Author	Support from higher management	Good project communication	Adequate resources	Realistic schedule	Project manager
Cooke-Davies (2002)	x				
Dvir et al. (1998)		x			x
Lock (2007)	x	x	x		
Mishra et al. (2011)		x	x	x	x
Mortaheb et al. (2013)		x			x
White & Fortune (2002)	x		x	x	
Williams et al. (2015)		x		x	x
Total:	**3**	**5**	**3**	**3**	**4**

Even though the project manager and the competence of project management are somewhat discussed in project management literature, the discussion is very shallow and no detailed features of the project manager are mentioned. The discussion is strongly concentrated on certain areas of managerial skills that are seen also otherwise important success factors in projects, such as communication and communication skills of the project manager. Also most of the studies contained general statements about project managers competence having an effect on project success, but no more details on how or what kind of effect was at stake. Much less and almost no discussion exists about the leadership style of the project manager, Mishra et al. (2011) being the rare ones emphasizing the human factors and characteristics of project managers. The same conclusion was made by Turner & Müller (2005) who tried to identify if leadership skills are seen equally as a success factor among project management literature and general management literature. There is a strong contrast between the literature on project and general management regarding the success factors, because in general management literature the manager’s leadership style is seen widely as one of the most important success factor contributing strongly to the successful performance of an organization.

For instance, among change management, effective leadership is seen as a crucial and widely discussed factor for the change to be successfully introduced and sustained (Roger 2002). And especially when discussing about team leading, the leadership skills are seen having a very strong contribution to the motivation and performance of the team (Gemmil & Wilemon 1994; Houldsworth & Machin 2008). Of course, it may be that the managerial skills have no such a significant impact on project success, but it seems unconvincing, because that conclusion is in direct contrast with all general management literature. Hence, there is a need to further explore the human aspects and leadership skills related to project success.

2.3 Relationship between time, cost and quality

The three common shared project success measures, time, cost and quality, have all significant roles in automation delivery project also. Especially, since the target of the thesis is to create a model which will improve project quality and minimize quality costs, but still stick to the on-time delivery in projects, it is interesting to study the relationship between time, cost and quality factors and possible trade-off decisions between them. Almost all projects have certain demands with relation to their execution, most projects are undertaken with the expectation of financial benefits and all of the projects should be controlled against detailed cost budgets (Lock 2007, p. 19). The actual progress of the project has to match the progress planned, and all significant project phases must take place no later than their specified dates (Lock 2007, p. 20).

Suggested to be the most important factor, also the performance objectives of the project must be met, but the project quality characteristics depend on the nature of the project (Lock 2007, p. 20). In general, the most important definition of quality is customer satisfaction, how well the result meets the customer's needs (Juran 1999, p. 26). Juran (1999, pp. 26-27) divides the meaning of quality in two critical components: customer satisfaction and freedom of deficiencies, the latter meaning the freedom of errors that require rework or that result in customer dissatisfaction, field failures or customer claims, and so on. In this sense, quality is closely related to costs, and lower quality usually causes higher costs (Juran 1999, p. 27).

The project should be completed before due dates and within the budget given (Kim et al. 2012, p. 265). Yet a more important project target than minimizing the costs or time spent is reaching the minimum contentual and qualitative level of the result in the end of the project (Ruuska 2005, p. 187). The primary objective then being rather proportion of minimizing costs and time spent to the benefits gained (Ruuska 2005, p. 187), to find the optimum point between the three factors. According to Kim et al. (2012, p. 265) success is about balancing the three objectives, if any out of the three is overemphasized, burdens may then fall on the other two. Optimizing all three factors is not always possible, and decisions regarding putting more weight on some factor compared to others is sometimes demanded. What is interesting is, what are the impacts on the other two factors in situations where the trade-off decisions must be made?

2.3.1 Relationship between time and cost

Time-cost tradeoff problems have been discussed since the 1950s, when the Critical Path Method (CPM) for projects was introduced (Kim et al. 2012, p. 265). Time and money have usually direct and very important relationship in projects, and the time-cost trade-off often originates when activity time is attempted to be reduced with some extra direct costs (Lock 2007, p. 23). As project is often a changing entity, and the variance between the assumptions made regarding a project and actual outcomes might be significant, completing a project as scheduled often requires some rework or modification (Kim et al. 2012, p. 264). Due to fluctuating nature of projects, budgetary and scheduling pressures can be common results of sudden unexpected changes in human resources, technology, materials or technique. Changes and modifications may in turn increase the possibility of failure. (Kim et al. 2012, pp. 264-265)

A project is typically composed of a number of activities which must be executed in a particular order (Oladeinde & Momodu 2012, p. 215). Kim et al. (2012, p. 265) describe a typical technique for shortening overall project duration and reduce scheduling pressure, as to crash the time required to complete activities. The cost effect then consists of the increased amount of resources, such as labor or equipment, needed to be allocated due to shortened activities (Kim et al. 2012, p. 264). Thus crashing activities saves time, but increases the cost, for each activity normal time of completion and crash time of completion are determined, and also normal and crash costs are estimated (Babu & Suresh 1996, p. 321). In real situation, in order to make practical and cost effective project schedules, the possibility of rework and modifications when crashing activities, must be considered (Kim et al. 2012, p. 265). Hence, the real decision problem considered in the project management literature is to determine and choose the activities for crashing (Babu & Suresh 1996, p. 321). The selection about crashing activities must be properly made, in a cost effective manner, and the need for special care regarding non-conformance risk activities identified (Kim et al. 2012, p. 270).

The former theoretical approach of project management literature in time-cost trade-off problems may not necessarily illustrate the real project environment and scheduling problems very realistic. Time-cost analyses from the late 1950s mostly concentrated on shortening the overall project duration by crashing activities, the traditional models approximating the time-cost relationship as linear. But soon after, the studies in the area recognized the nonlinear nature of the time-cost relationship, assuming the linear model suitable only for individual activities. (Kim et al. 2012, p. 265). In its simplest form, the nonlinear model represents the linear relationship of the time and cost of one separate activity, as presented in figure 2.1. According to the model, the activity has a direct cost function and continuous time range, the minimum time to complete the activity being 15 weeks. (Moussourakis & Haksever 2004, p. 309) Otherwise, the cost of completing the activity varies linearly between the normal time and the crash time. (Kim et al. 2012, p. 265)

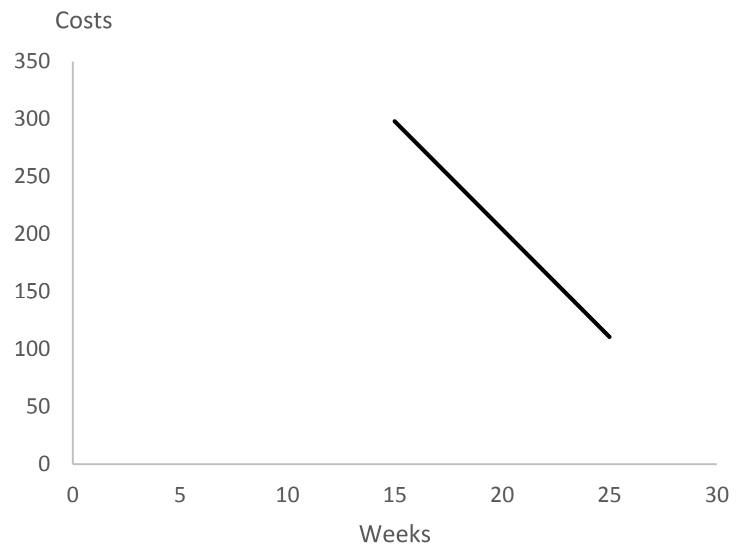

Figure 2.1. *Linear time-cost model for individual project activity. (Moussourakis & Haksever 2004, p. 309)*

Among project management literature, typical linear and nonlinear models are presented and designed as for tools to assist project managers in evaluating the tradeoffs between time and cost across the project. In many situations project managers need to evaluate alternative options for accomplishing project activities, in order to best achieve the project objectives. When the traditional discussion about the trade-off is concentrated in project manager's focus on minimizing project completion with minimal costs spent, the problem is that once the project is completed, the key issue, instead of time or cost, is quality (Kim et al. 2012, p. 265).

2.3.2 Relationship between time, cost and quality

Even though the relationship between time and cost has been studied with and without the consideration of their relationship with quality, at present project environment and especially considering this thesis, the trade-off problem cannot be discussed without the quality aspect included. Simply finishing the project by the given due date and within budget is not sufficient, as the project must also be delivered with acceptable quality (Kim et al. 2012, p. 265).

Quality considerations are not taken so explicitly into account among project management literature, when evaluating time-cost trade-off (Pollack-Johnson & Liberatore 2006, p. 534). Hence, the amount of existing models and procedures considering the project activity quality also is notably smaller, compared to the traditional time-cost –trade-off. In traditional analysis, the implicit assumption is made, that an equal level of quality is maintained throughout the analysis. Especially, the alternative time-cost pairs for separate activities are assumed to be of equal quality (Pollack-Johnson & Liberatore 2006, p. 534). The assumption of equal quality is too optimistic, while in actual project it is definite, that the level of quality is affected by the changes in time or cost factors.

Especially in projects where project activities are excessively crashed, quality becomes even more significant a factor in time-cost trade-off (Kim et al. 2012, p. 271). Also Babu & Suresh (1996) suggest that the project quality might be affected by project crashing, as crash completion of an activity may involve rework, modifications, overtime charges, specialized resources or faster wear and tear of equipment. According to Babu & Suresh (1996, p. 321), the overall quality is a function of quality levels accomplished at the individual activities. Babu & Suresh (1996) studied the trade-off between time, cost and quality, and constructed one of the first models including quality aspect in the trade-off.

Developed linear programming model studied the interrelationship of three functions by classifying the quality attained at each project activity with continuous scale from zero to one (Babu & Suresh 1996, p. 321). The overall project quality then being a function of quality levels attained at the separate project activities. Babu & Suresh (1996) created models with three different simple functions that optimizes one of the three factors by assigning desired levels on the other two. In figure 2.2. are presented the optimal project completion times according to Babu & Suresh (1996, p. 324), with cost and crashing average quality objective (OAVQ) being bound. Project costs presented on the horizontal axis and completion time on the vertical axis.

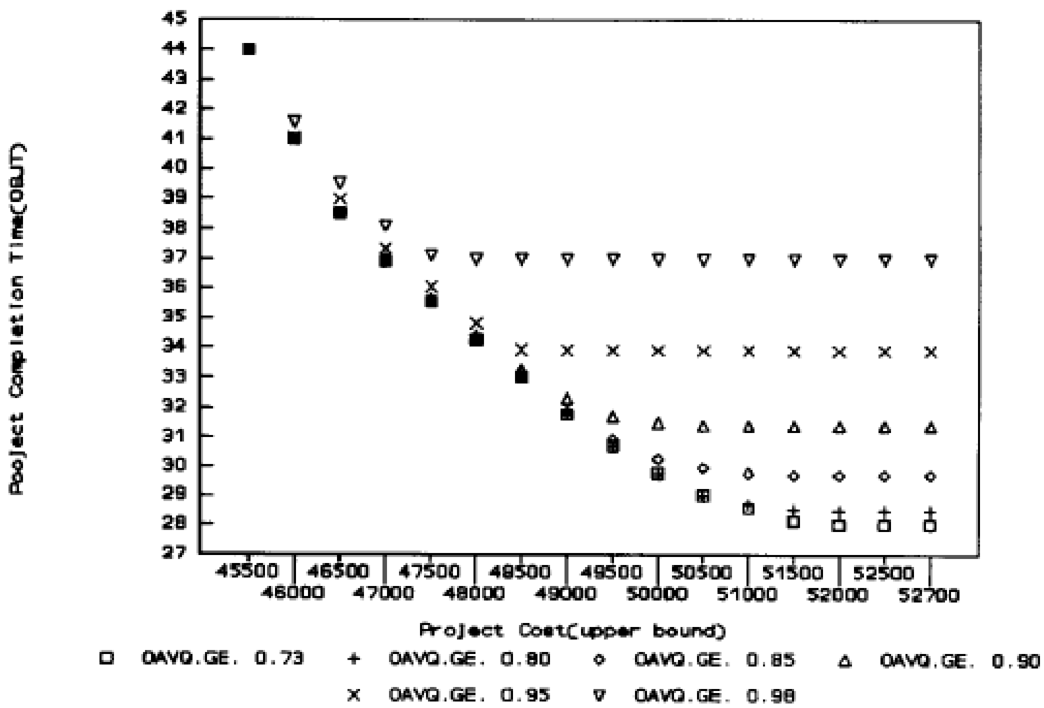

Figure 2.2. *Optimal project completion time when cost and OAVQ are bound according to Babu & Suresh (1996, p. 324)*

According to the figure 2.2., if the project budget value is low, the completion time is higher and is affected only marginally by the quality demand. As the budget value increases, the completion time reduces and depends much more on the quality requirement, the completion time being longer with high quality standards. (Babu & Suresh 1996, p. 324) The problem in linear programming model is that the assumption of linearity is not straight applicable in real project situations, where more complex relationships are existing. The assumption of continuous quality level in each activity may not be applied in practice, where quality deviations are possible or sometimes even to be considered, when project manager is evaluating different alternatives. Also, according to Liberatore & Pollack-Johnson (2009, p. 1324) the major limitation in the study made by Babu & Suresh (1996) is the assumption of quality being only dependent on time, and independent on cost for a given time.

Most of the models designed to help in the scheduling problems and decision making between time, cost and quality trade-off, are made from a very theoretical point of view. Using the calculation functions in actual project setting situation would presume a lot of extra work and a very detailed defining of the quality levels, estimated costs and durations of single activities. Therefore, the usability of the models is still quite far from the needs of actual project environment. Nonetheless, some of the studies have made useful conclusions about the consequences of certain tradeoff decisions that might be practicable in actual decision making situations, and are well related to the subject matter of this thesis as well. For instance, in a bit more recent study Liberatore & Pollack-Johnson (2009) studied the trade-off between time, cost and quality with mathematical programming model.

Liberatore & Pollack-Johnson (2009) discovered that the linearity assumption between quality and time was seen slightly problematic, and instead they discussed quality at the task level as nonlinear function of both, cost and time. The model created by Liberatore & Pollack-Johnson (2009, p. 1328) generates quality level curves to illustrate the trade-offs among time, cost and quality. Liberatore & Pollack-Johnson (2009, p. 1328) illustrated a summary of the time, cost, quality relationship with the iso-quality curves, which can be then used by project managers in decision making regarding project scheduling problems. The summary is presented in figure 2.4., where project activity quality is presented with nonlinear functions of time and cost, with the highest quality level lying uppermost. The critical path length on the horizontal axis illustrates the shortest possible completion time of the project. According to Liberatore & Pollack-Johnson (2009, p. 1328), in some cases it is not possible to achieve higher level of quality at a low critical path length. As described in the figure 2.3., for example critical path length of 18 is not realizable for quality level values of 71 or greater. Otherwise, there exists a time limit in projects, if the project is executed with less time than the minimum, the certain quality level cannot be reached.

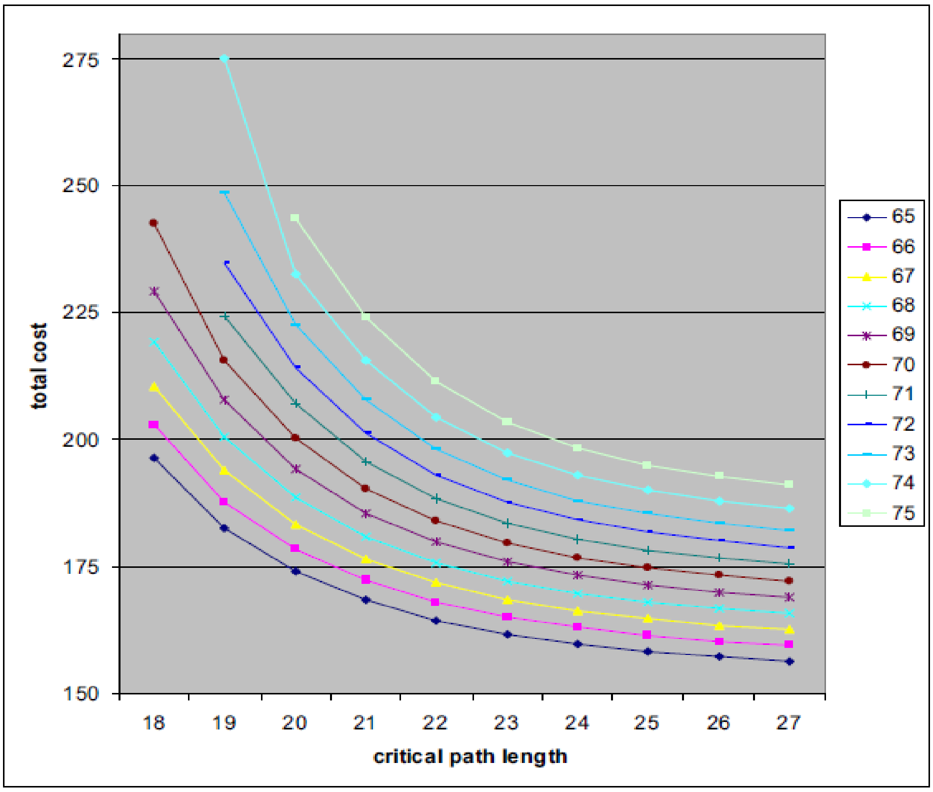

Figure 2.3. *The relationship between project total cost, critical path length and quality illustrated with iso-quality curves. (Liberatore & Pollack-Johnson 2009, p. 1328)*

Based on their model, Liberatore & Pollack-Johnson (2009, p. 1328) provides the insight that with certain quality levels, there appear to be budget threshold values that are not worth the crashing effort. For instance, for the quality level of 74 presented in figure 2.3., it will probably not be reasonable to try to complete the project in 19 days or less, because the cost increase from 20 to 19 days is much more than the cost of reducing the time from 21 to 20 days. Furthermore, another key notion made by Liberatore & Pollack-Johnson (2009, p. 1329) is that when considering the total quality of the project, the quality of each project activity is important and cannot be compromised without compromising the quality of the whole project. Liberatore & Pollack-Johnson (2009, p. 1329) came to conclusion that considerable increase in quality can occur with minimal impact on time and cost. And otherwise, time and cost could be notable improved with minimal effect on quality.

2.3.3 Relationship between quality and cost

Studying the trade-off without the time factor included, Abdelsalam & Gad (2008) also made interesting conclusions regarding the cost of quality in projects. Quality-cost trade-off is very relevant subject regarding this thesis also, as one of the targets of the Quality gate model is to reduce quality costs occurring in projects. Abdelsalam & Gad (2008) evaluated the cost of quality (CoQ) by using prevention-appraisal-failure (PAF) model, and determined the optimum value for CoQ, in other words the level of quality that minimizes the total cost of quality. According to Abdelsalam & Gad (2008, p. 502) quality and costs are very closely interrelated, and when seriously trying to improve quality, the costs associated with achieving quality must be taken into account since the objective in delivering a product with good quality is not only to meet the customer requirements, but also to achieve it with the lowest cost (Abdelsalam & Gad 2008, p. 502). In alignment is also Satanova & Sedliacikova (2015), who emphasize also the interlinkage between quality and costs. Satanova & Sedliacikova (2015, p. 5) states that costs of quality monitoring should be part of quality management system, and found out in a questionnaire survey study that significant amount of the enterprises interviewed do not consider management of quality and controlling the costs of quality as identical areas.

Abdelsalam & Gad (2008) evaluated the cost-quality relationship with the prevention-appraisal-failure model which is widely used model to determine the cost of quality. In the model, prevention costs are those resulting from quality activities done to avoid deviations and errors. Appraisal costs then consists all the costs associated with evaluating, measuring or auditing products to determine if they conform to their requirements. Failure costs instead are those losses associated with the production of non-conforming product. Failure costs include the costs associated with the defects found before delivering the product to the customer as well as those costs that occur when a non-conforming product reaches the customer. (Abdelsalam & Gad 2008, p. 503)

The prevention-appraisal-failure model according to Abdelsalam & Gads (2008, p. 503) is illustrated in figure 2.5. The PAF model presents the relationship between costs and the quality level from 0 defects to 100% defects. The Total cost of quality curve represents the sum of the other two curves, Prevention + appraisal and Failure costs curves. As presented in the figure 2.4., there exists an inverse relationship between prevention and appraisal effort and failure costs. According to the PAF model, the more the preventive plus appraisal costs are, the less failure costs occur. (Abdelsalam & Gad 2008, p. 503)

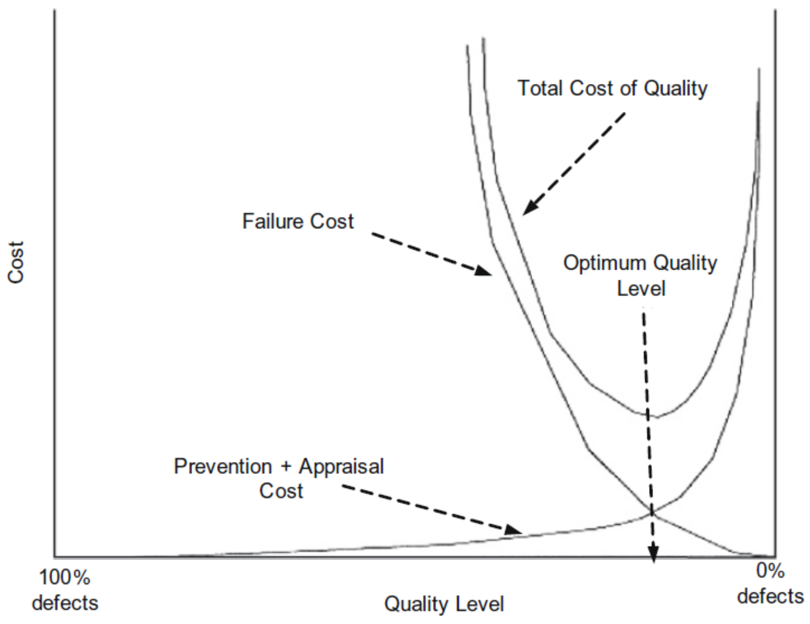

Figure 2.4. *The prevention-appraisal-failure (PAF) model (Abdelsalam & Gad 2008, p. 503)*

According to the PAF model the optimum conformance to quality level is at the point where the cost of failure equals to the cost of prevention plus appraisal cost. The optimum point of the costs, which is the location of the minimum point on the total quality cost curve, depends on the shapes of the two lower curves. (Abdelsalam & Gad 2008, pp. 503-511)

It has been suggested that it is the wrong objective to attempt to find the optimal trade-off point between quality and costs. Instead, project managers should put their effort to eliminating all defects and do things right the first time. (Abdelsalam & Gad 2008, p. 510) Also, the trade-off models have limitations as they don't include the hidden costs which are caused by poor quality. Those hidden costs, such as customer goodwill or future lost sales, can have a significant impact not only on the project success but also on the success of the business. The control of the trade-off and reasonable decision making between the three factors is difficult, especially as the sufficient quality level should be always attained. Maintaining the minimum level of quality even after the trade-off decisions sets requirements for the quality management of the project. In order to understand more about sustaining the right quality level at the project better, the principles of project quality management are presented in the following chapter.

2.4 Project quality management

ISO 9000 series of standards is widely accepted as the base for the project specific quality management. As project quality is described as meeting the customer's needs or performance objectives set in the start (Juran 1999, p. 26), project quality management instead is defined more as the processes and activities needed to achieve project quality (Chang & Ishii 2013, p. 928). According to the ISO 10006 standard (2004, p. 5) about guidelines for quality management in projects two aspects to the application of quality management in projects has been recognized; one concerning the project processes and one about project's product. Emphasizing top management responsibility in achieving project quality objectives, ISO 1006 standard (2004, p. 5) requires systematic approach in maintaining process and product quality in a project with a strong focus on understanding customer needs.

Apart from the ISO 1006 standard, a very common way among project management literature to display project quality management is with three separate processes: quality planning, quality assurance and quality control (PMBOK 2008; Chang & Ishii 2013; ISO 21500 2012). In figure 2.5. project quality management is divided into three processes, and as presented in the figure, each of the processes have clear inputs, tools and techniques specified to each phase as well as outputs. Each of the processes occurs at least once in every project and in one or more of the project phases. (PMBOK 2008, p. 189).

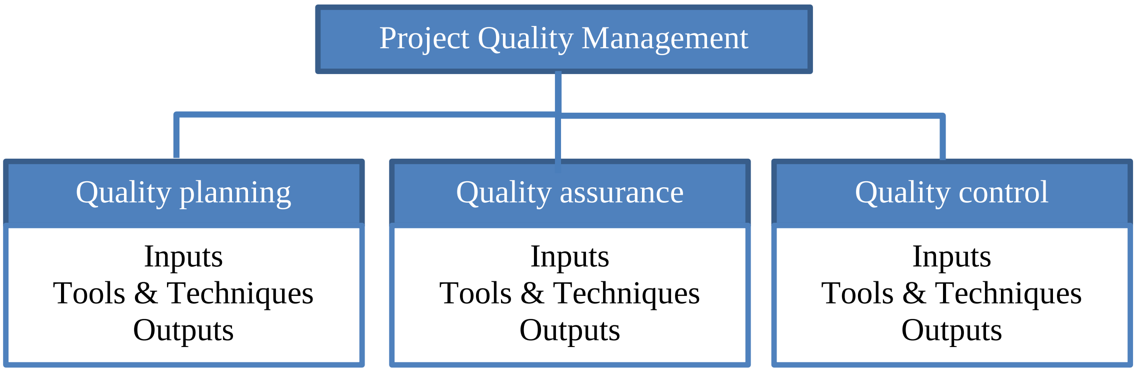

Figure 2.5. *Project Quality Management processes (PMBOK 2008, Chang & Ishii 2013, ISO 21500 2012)*

Project quality management begins with planning process which involves identifying relevant quality standards to the project (Rose 2005; Chang & Ishii 2013). Identifying standards and requirements and determining how to satisfy them is one of the key activities during project planning, and that is the foundation for quality being truly planned and build in, not inspected in (Rose 2005, p. 42). Rose (2005, p. 54) emphasizes the importance of customer and requirement prioritization to be completed in early stage, even before project plan, so that the project starts in the right direction. According to the ISO 21500 standard (2012) the planning process includes at least determining and agreeing the objectives and relevant standards with project sponsor and other stakeholders, defining relevant tools, procedures, techniques and resources to achieve the objectives, determining methodologies, techniques and resources to implement planned quality activities and as an primary output developing quality plan for the project.

The next process after quality planning is quality assurance which includes the planned and systematic activities, including processes, tools, procedures, techniques, and resources necessary to achieve the project objectives. Activities include the efforts made to determine if the project performance is meeting the requirements of quality objectives and standards. (Rose 2005; ISO 21500 2012) Assuring process includes ensuring the communication, understanding and acceptance of objectives and standards to be achieved by the project members, executing the quality plan as the project proceeds and ensuring the usage of established tools, procedures and techniques. Also quality audits are one primary mechanism to determine the performance of the quality process and activities made, and then recognize the need for recommended action. The primary input of the process is usually quality plan and output instead the change requests made after recognizing the need for change in the course of action. (ISO 21500 2012, p. 61)

The third process of Project quality management is quality control. Involving monitoring precise project results to see if they comply with quality objectives and relevant standards, quality control is performed to identify ways to eliminate unsatisfactory performance. Control is conducted to determine whether the objectives and requirements are met in the project, and the process should be carried out throughout the project life cycle. (Rose 2005; ISO 21500 2012) Quality control process is including detecting defects with the established tools, procedures and techniques and monitoring that the quality of deliverables is according to objectives, analyzing possible causes of defects, determining change requests and preventive actions and communicating the actions and requests to the appropriate project organization members. The primary inputs in controlling process are quality plan, deliverables and progress data, while the outputs are change requests, inspection reports, corrective actions and quality control measurements. (ISO 21500 2012, p. 61)

Rose (2005, p. 41) adds also an important fourth process to the general definition of project quality management, quality improvement. According to Rose (2005, p. 69) the loop from quality control back to planning and specifications is not the end of the quality course. Therefore, the fourth process, quality improvement, is added presenting a deliberate process that begins with data collection. Quality improvement uses objective measurement and data to create beneficial change in organization. This improvement process is necessary for many reasons and is strongly associated with customer satisfaction and competitiveness, hence having an effect on the whole business survival. (Rose 2005, pp. 69-70)

Making processes and performance better continuously is critical, as well as understanding the customer needs and requirements in the very beginning of the project (PMBOK 2008; Rose 2005). Also the ISO 1006 standard for quality management in projects (2004) which is based on the ISO 9000 Quality management standard mentions customer focus and continual improvement as two of the eight quality management principles which should be applied to the processes of project quality management:

1. Customer focus
2. Leadership
3. Involvement of people
4. Process approach
5. System approach to management
6. Continual improvement

7. Factual approach to decision making
8. Mutually beneficial supplier relationships

Within the framework of the standard (ISO 1006, 2004) customer orientation is seen as crucial principle to take into account in project quality management, as organizations are dependent on their customers and project success on customer satisfaction. Relative to project quality management, customer requirements should be taken into consideration in every process and possible trade-off situation between time, cost or quality. If conflicts arise between requirements of the customer and other interested parties, excluding statutory requirements, customer requests should be taken precedence. The second principle considers leadership as a strong contributor for project quality, starting from the creation of a culture for quality in organizations. As for project and project quality management it is important to appoint a project manager as early as possible, so that establishment, implementation and maintenance of project's quality management system is ensured. (ISO 1006 2012, p. 17)

Additionally, also people involvement should be considered in processes as people are, at all levels, the essence of an organization. The competent personnel assigned for the project should be provided well-defined responsibility and authority for their participation as well as appropriate tools, techniques and methods. Also cross cultural management should be addressed in the case of multi-national, multi-cultural or international projects as well as joint ventures. In alignment with ISO 9000 standard, process approach is seen crucial also in ISO 1006 (2004), enabling more efficient achievement of results if project activities and related resources are managed as a process. Project processes should be identified and documented, so that experience gained in developing and using the processes can be applied in new projects. In order to accomplish that, certain subjects regarding project processes must be identified, such as inputs, outputs and objectives of the processes, process owners and their authority and responsibility and the interrelations and interactions among the processes. (ISO 1006 2012, p. 19)

Identifying and understanding processes is important, but so is also managing them as a system contributes to the effectiveness in achieving organization's objectives. Defined as one of the project quality management principles in ISO 1006 standard (2004), a systematic approach to management enables the coordination and compatibility of an organization's planned processes and a clear definition of their interfaces. To align project processes with the originating organization's overall system, it is necessary to define and link the processes to manage them as a system. (ISO 1006 2012, p. 19)

According to the standard (ISO 1006, 2012), the sixth principle, continual improvement, is based on the "Plan-Do-Check-Act" (PDCA) concept, and should be a permanent objective of the organization as well as present in every project quality management process. It is necessary for project organizations to continually seeking to improve the efficiency of the processes and learn from the experience. Therefore, the information gained during the project should be systematically collected and analyzed, for use in a continual improvement process. Also opportunities for improvement are important to identify, and to perform that internal and external quality audits can be conducted, with the consideration of the time and resources needed. (ISO 1006 2012, p. 21)

When regarding the management of project quality and the processes related, the decision making should be factual and based on analysis of data and information. The seventh principle, factual approach to decision making, emphasizes the importance of performance and progress evaluations in effective decision making, and the ISO 1006 standard (2012) gives an example about analyzing the information from project closure reports of previous projects to use to support the improvement of current and future projects. The eighth principle involves also suppliers into project quality management and emphasizes the beneficial relationship between the organization and the supplier. The cooperation with the supplier when defining strategies is important especially in the case of products with long lead times, and the requirements towards suppliers' processes and product specifications should be developed jointly among the organization and the supplier. (ISO 1006 2012, p. 21)

2.5 Lean thinking

Valmet Corporation is implementing Lean thinking strongly to all business lines and operations and Lean ways to operate are taking root in Valmet Automation as well. The aim in this research is not to create a quality gate model by following Lean principles, but more to choose those concepts and methods from Lean thinking that truly benefits the goals of this study and fit beneficially to project environment. The target is to get familiar with Lean philosophy and find suitable and value adding factors to utilize in the quality gate model.

The market is getting even more competitive and companies are constantly demanding more profitable solutions. Therefore, Lean approaches such as efficient application of resources, cost reduction and excellence in processes, are making it essential to consider Lean philosophy in this development project also. Lean concept is one of the most widespread management concepts in the world, and there is no unambiguous definition of Lean. Liker (2006) demonstrates one well noted approach to Lean philosophy in his book The Toyota Way. Liker (2006, p. 14) describes those Lean principles that will help companies to improve their processes: Eliminating the dissipation of time and resources, building quality into workplace systems, finding affordable but reliable alternatives for expensive new technology, improving the core processes and building a culture of learning to realize the continuous improvement process in an organization. At least some of those approaches provide a reasonable value basis to use in this project development study also. Next, a short introduction to general Lean philosophy is conducted, the main focus kept in concepts that can be useful from quality development and project point of view.

The roots of Lean philosophy are in Japanese car production industry, especially in Toyota's culture and way of working. The concept of Lean was born in the end of 1980 century, when a broad international research International Motor Vehicle Program (IMVP) was organized by

Massachusetts Institute of Technology. The auto industries of North America and Europe were stuck with outdated mass production systems and techniques, simply lagging the development and losing market share for the pioneering Japanese companies. Unable to learn from their Japanese competitors, Western companies were concentrating on very wrong issues and an idea about undertaking a closer study of the new Japanese techniques came up. Those techniques were started to name as Lean production and a major research project launched with MIT and motor vehicle manufacturers around the world to find out about competitiveness differences and reasons behind them. The source of competitive advantage resulted from the Lean production model developed by Toyota during the years, giving the Japanese companies copying the model a huge lead in productivity and quality compared to their competitors. (Womack et al. 1990, pp. 3-4)

Lean way of production and work is still tried to be embraced by manufacturers around the world and often the philosophy is seen as a set of Lean-tools (Liker 2004, p. 10). That kind of thinking is a huge barrier and an annoyingly often occurring phenomenon, preventing companies to improve their performance with Lean. Liker (2004, p. 10) states that Lean must be seen as an organization wide cultural change and a new way of thinking, the most powerful requirement being the commitment of management to continuously invest in their employees and promote continuous improvement. While there is not existing any unambiguous explanation or definition of Lean and in literature the authors seem to have divergent opinions about the characteristics associated with Lean concept, for organization planning to implement the concept it is therefore essential to identify the variations and make active choices to discover the most suitable components and concepts (Hines et al. 2004). Hines et al. (2004) provide a very extensive literature review about the evolution of Lean thinking, based on more than 250 articles discussing Lean.

Hines at al. (2004, p. 15) emphasize that for applying the right tools, it is crucial to understand Lean completely, from strategic level to Lean production at the operational level. In this study it is more reasonable to concentrate on the strategic level and thoughts that can be transplanted into project business. Big part of Lean literature concentrates on Lean production and Lean tools for waste elimination and other productivity improvement techniques. From this thesis point of view the specialties of Lean production are of minor importance, and the concepts suitable for project development are collected to this literature review. The basic principles of Lean thinking are studied via commonly known definition provided by one of the basic works of Lean, The Toyota Way (Liker 2004).

Liker (2004, p. 6) presents the fundamentals of Lean philosophy with Toyota way's model with the management principles divided into categories. The 14 Lean principles, that are important for the management to embrace, are divided into four categories in the 4P model shown in the figure 2.6. The Ps coming from: Problem solving, People & Partners, Process and Philosophy. The first category, Philosophy is about the principle, that management decisions should be based on a Long-term philosophy, even at the expense of short term goals (Liker 2004, p. 37). All the activities in a company should be evaluated by the value they are producing for the customer, society and economy. Responsibility and self-confidence are especially valued, and one should always maintain and develop one's skills to make more additional value. (Liker 2004, p. 37)

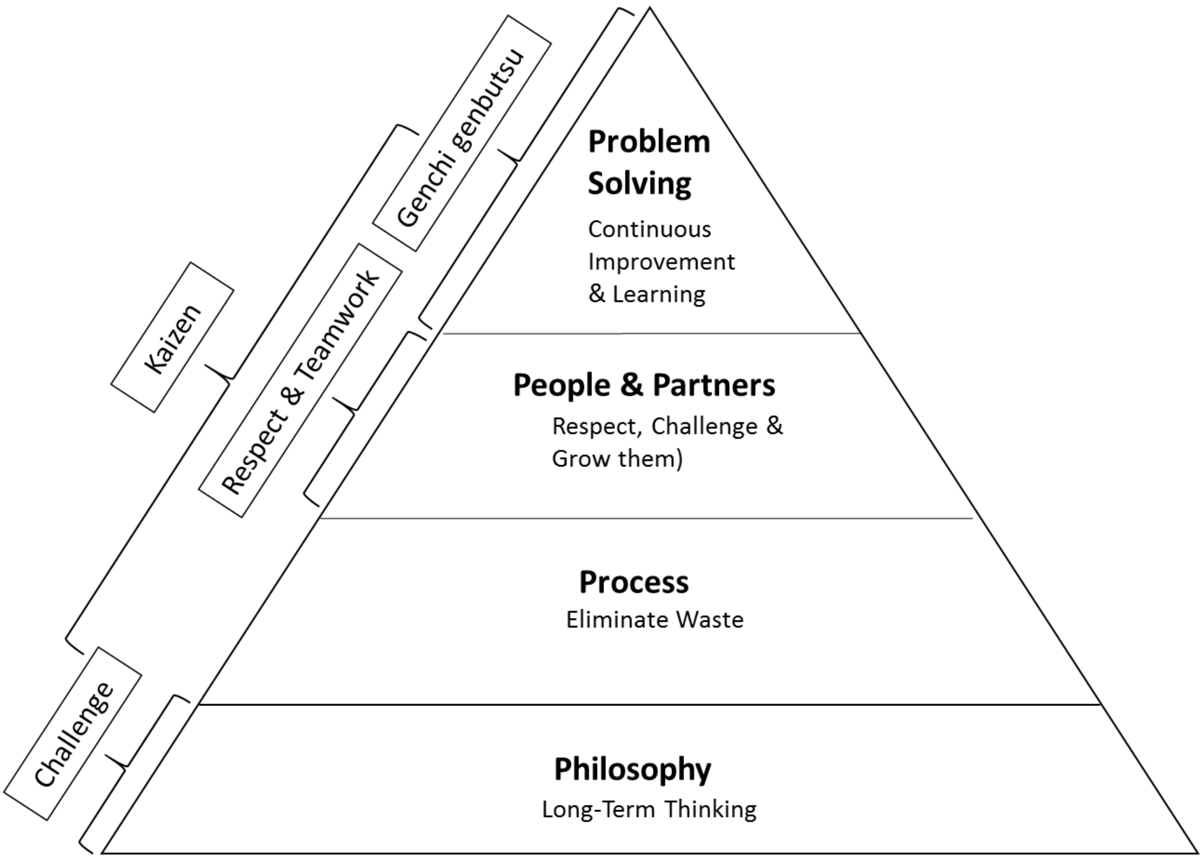

Figure 2.6. *Toyota Way's 4P model with four categories for the 14 management principles. Liker (2004)*

The second category, Process, includes the statement, that following the right process, the right results can be achieved. According to Liker (2004, p. 13) the majority of companies are focusing only on this process level, leading to situation where the philosophy and culture is not adapted and the company fails to become a Lean organization. The principles in the Process category are pursuing more the optimization, concentrating more on the technical side of Lean. According to the principle number two, it is important to create a process flow to reveal the problems and get rid of waste, the useless and unnecessary work (Liker 2004, p. 37). The pull system should be used to avoid the overproduction (principle 3) and the inventory of finished and incomplete products kept in minimum by reacting fast to daily changes and stocking up the inventory often. Principle number four states that the workload should be balanced, so that the overload of the workforce and the equipment is minimized. The working culture should be created so, that a stop is made, when a problem is noticed (principle 5). Problems should be handled quickly after occurring and the quality level of the product should be closely guided by the customers’ demands. It is also important to have standardized tasks to enable the continuous improvement, commit employees and gather best practices (principle 6). To promote continuous improvement and reveal the problems a Visual Control should be applied to work (principle 7). Simple visual systems and indicators can be used to inform the employee immediately if the standard circumstances are diverging, helping to maintain the process flow. Also related to remaining the effective flow, only reliable and thoroughly tested technology should be used to serve people and processes according to Toyota way principle 8. (Liker 2004, pp. 38-39)

According to Liker (2004, p. 39) the third category of Toyota Way principles is People & Partners, focusing on respecting, challenging and growing them. The aim is to produce added value to the organization by developing people and partners, holding the people as the most valuable asset. The organization should grow talented leaders, who understand the work thoroughly and act as role models and most competent teachers of the philosophy (principle 9). All the individuals in the organization should know and comply with the philosophy well to get the best results (principle 10). People should be empowered and the organizational culture stable and strong, so that the company values and visions spread and obeyed. Also partners and suppliers should be respected by giving them challenges and helping them to grow and develop (principle 11). (Liker 2004, pp. 39-40)

The fourth category, Problem Solving, is essential to internalize if organization is willing to change into learning organization. Problems should be always solved, and the best way to do it is finding one’s way close to the source of the problem (principle 12). The information related to the problem should be gathered on the spot, and even the high level managers and directors should get into the place to understand the situation thoroughly. Principle 13 states that the decisions should be made slowly, considering and weighing the options, while the implementation after should be made rapidly. Consensus in decision making is important and eases the implementation process. According to the last principle, learning organization should be made by tireless evaluation and continuous improvement. After achieving stable processes, continuous improvement should be used to figure out the origin of inefficiency and waste elimination. (Liker 2004, p. 40)

Liker (2004, p. 41) emphasizes the importance of finding the principles suitable for each organization rather than copying the Toyota way production and tools. The improvement of performance is possible in the short run when implementing Lean tools and following few Toyota way principles. But getting a competitive edge and maintaining it requires understanding and compliance of all the key principles. (Liker 2004, p. 41) The second requirement being probably the most challenging part for organizations, and the most common reason for the failure of the Lean implementation in the long run. Without getting into much details on how organization should put the change into practice, Liker discusses more about the cultural and philosophical part of the Lean concept. Only the principle number two is more about the tools, the rest principles explaining more about the management approach and mindset required in order to succeed in the change.

A bit more closer to practice approach is discussed by Womack & Jones (2003), who present five Lean principles and the concept of "waste", in their famous book Lean thinking – Banish waste and create wealth in your organization. The similar approach with the same five main principles is also adopted among Valmet and chosen as the future way-to-operate. The five Lean principles are illustrated in the figure 2.7. as they are presented also in the Valmet Lean training material. The first principle being the identification of value, and according to Womack & Jones (2003, p. 16) the critical starting point for Lean thinking is value. Value can be only defined by the ultimate customer, and it is meaningful only when expressed in terms of a specific product or service delivered to customer at the right time at an appropriate price and with fulfillment of the customer's needs (Womack & Jones 2003, p. 16). Value is created by the producer, and to precisely define the value, rethinking is required (Womack & Jones 2003, p. 16), while producers tend to often define value as the product they are already making. Instead, the focus should be more on a question: "What need does the product meet?" (Modig & Åhlström 2013, p. 24).

Figure 2.7. *The fundamentals of Lean thinking: five main principles. (Valmet Lean 2015)*

After attaining an understanding of the value, all the steps required to deliver the value to the customer must be identified. The *value stream* includes all the specific activities in all processes, and to create a value stream, all the steps in the delivery chain must be defined and described. (Womack & Jones 2003, p. 19) For example in a project delivery, the end product or solution delivered to customer can be called as flow unit, and the activities in the value stream are defined from the flow unit's perspective (Modig & Åhlström 2013, p. 24). There can be specified three types of activities in the value stream:

- *Value-adding activities:* Those activities that unambiguously add value to the flow unit. Value is added when the flow unit is being processed or moved forward. In automation delivery project for instance when the system is shipped over to customer's site.
- *Type one Muda (waste):* Those activities that create no value but are unavoidable with current production assets and technology. In a project for example conducting the quality check for the system over again on customer's site.
- *Type two Muda (waste):* Those activities that create no value and should be immediately avoided. In a delivery project that can be for example delivering a system that does not meet the customer requirements. (Modig & Åhlström 2013; Womack & Jones 2003)

The concept of *Muda*, meaning waste in Japanese, originates from the derivation of Lean thinking at Toyota, from strong pressure to do things effectively with scarce resources. Modig & Åhlström (2013, p. 73) define seven types of waste without any value adding feature:

- *Waste of overproduction:* The production process should always produce only what the customer needs.
- *Waste of waiting:* All unnecessary waiting should be avoided, and the production should be organized in a way that no machine or worker have to wait for no reason.
- *Waste of transportation:* Transporting material and products should be avoided.
- *Waste of processing itself:* Extra work on a part or a product, that customer does not require, should be avoided, including the unnecessary use of expensive or too precise tools for example.
- *Waste of inventory:* Inventory that is capital tied up in the process should be avoided.
- *Waste of movement:* Unnecessary movement of things, information, or workers should be avoided.
- *Waste of making defective products:* Only fault-free products should be made in every step of the process.

For example, Womack & Jones (2003) strongly advise to avoid and remove all the waste from processes, and it does sound fascinating and efficient for sure. But for instance in project environment, when many issues are not only dependent on the project organization but also from the customer or the supplier, it is harder to minimize for example waiting time for information, when the delivery time depends upon the customer. Also, in many circumstances various types of controls are necessary, especially regarding project quality assurance. Mandatory review-approval chains must be conducted to assure the quality of documents for example and the approvals might be demanded even in the project contract. Even though those chains might create unnecessary waiting time to the processes. One could assume the Lean principles a bit more suitable for stable manufacturing environment rather than project environment, where there is much more changing factors present and the process is not that foreseeable.

However, after identifying the value stream, according to the third principle of Lean, a continuous flow to the process must be created. Flow can be described as a progressive achievement of tasks along the value stream, so that the product proceeds into the hands of customer with no stoppages, scrap or backflows. (Womack & Jones 2003, p. 348) In a project environment it is clearer that the focus is on the end product itself and that the product is made with just-in-time principle. In a manufacturing environment it is more about abandoning the traditional batch-and-queue principle and trying to create the flow for single products.

The fourth Lean principle of pull can be defined so that nothing should be done by the upstream supplier until the downstream customer communicates a need. (Womack & Jones 2003, p. 24) In other words, the customer must be let to pull the product from the producer, rather than pushing products onto the customer. When speaking of projects, it is quite obvious that nothing starts before the project is ordered by the customer. But there is more to think about on how to maintain the customer pull throughout the project and create a system of cascading production and delivery instructions from downstream to upstream.

The fifth and the final principle is perfection, defined by Womack & Jones (2003) as "complete elimination of muda so that all activities along a value stream create value." The purpose of the fifth principle is to make Lean a never-ending process which will continue until perfect value is created with no waste (Womack & Jones 2003, pp. 25-26). As there will always be activities that are considered as waste, the process must be started again and again making the effort of improvement continuous.

In reality, cutting of all the extra costs of operation can be also dangerous regarding customer satisfaction. Hence, the customer requires a reliable product delivered with supportive project delivery, and recently for example the sustainability of operations has been a growing trend required by the customer. Relative to those demands, a delivery with no waste and extra costs can be at least difficult to combine. Clearly, most of the Lean principles are aimed for the manufacturing environment, and as said before, applying Lean thinking in the traditional environment is already extensively researched, but the intention of the next chapter is to deepen the understanding of Lean in project environment as well.

2.6 Lean project management

As the suitable Lean thinking principles are applied in the quality gate model constructed in this thesis, it is reasonable to clarify the major differences between normal project management and Lean project management. The major differences are studied to build an understanding about how Lean thinking can be applied into project environment and what possible benefits that might bring from the project management and quality point of view. Lean project management concept was developed when first the Lean manufacturing was taken to construction industry and later on was applied to project environment (Karim & Nekoufar 2011, p. 2). Hence, Lean project management is much less discussed concept compared to Lean manufacturing or Lean construction, but it has already shown significant benefits especially among difficult and complex project areas (Gabriel 1997, p. 209).

According to Ballard & Howell (2003, p. 1), projects, in other words temporary production systems, are called Lean projects when those production systems are structured to deliver the product while minimizing the waste and maximizing the value. As Lean thinking is based on values, also in Lean project management the value is defined by the end customer, and can be seen as any action or process that the customer would be willing to pay. Hence, all that expenditure of resources for any other goal then the creation of value for the customer can be considered as wasteful also in projects. (Reusch & Reusch 2013, p. 457)

In addition to delivering more value with less waste, another major principle in Lean project management is the pursuit of quality. As the focus in Lean thinking is on the end customer, increasing quality beside eliminating the costs is crucial, because quality is critical to satisfy the customer. (Kliem 2015, p. 15) As mentioned in previous chapters (2.2 & 2.3), customer satisfaction is seen as the primary objective also among general project management and as the most important project success measure. Although Lean project management and general project management share the same objectives, there is still remarkable differences between the concepts, and some of those are presented next, the summary table being presented in the end of this chapter.

As in traditional project management the temporary and unique nature of a project is emphasized, one of the Leanest approaches especially in large scale projects is project standardization (Karim & Nekoufar 2011, p. 2). Kliem (2015, p. 17) emphasizes strongly the benefits of project standardization, and from a Lean perspective standardization applies to processes, operations, procedures, tools and techniques enabling the improvement of performance. According to Kliem (2015) "Uniqueness is fine, however, when delivering a product or service standardization is critical." Of the same opinion is also Karim & Nekoufar (2011) who states that project standardization has a strong impact on the cost and time reduction of a project, amongst other things.

Karim & Nekoufar (2011, p. 5) identified six different elements of project standardization, which are illustrated in figure 2.8. According to Karim & Nekoufar (2011, p. 3) the standardization of projects starts from standard design, which results in minimizing waste of material as well as time and maximizing the project value. Also Kliem (2015, p. 17) emphasizes the effect of standardization of design on reducing waste. The more a component is based upon a common standard, the less time and labor are required to make a change (Kliem 2015, p. 18). Also document and construction, especially off-site manufacturing, are seen important parts of project standardization. Karim & Nekoufar (2011, p. 4) emphasizes the need for new approaches, processes and techniques suitable for multi-project context, in which many projects are increasingly undertaken, and that sets new requirements for project management standardization. Multi-project management integrates projects and strategic planning, and in order to approach standard projects, companies should consider the standardization as a strategic plan (Karim & Nekoufar 2011, p. 4). Also value analysis presents a basis for project standardization as functional value evaluation focuses on identifying the value of the function as well as correlates this value with the significance of the function.

Figure 2.8. *The different elements of project standardization. (Karim & Nekoufar 2011, p. 5)*

Karim & Nekoufar (2011) emphasize also the advantages of project standardization from the customer point of view, because high level of unification in standard project enables the client to predict the project costs and time better in the start of the project. After all, Lean underlines standardization and modularization to allow adding, deleting or rearranging components with as little disruption as possible in response to changing conditions (Kliem 2015, p. 24). According to Ballard (2008, p. 11) the improvement of performance requires learning from experiments and breakdowns, which are in other words intended and unintended deviations from standard. Otherwise, processes can be improved through acting on the root causes of breakdowns and by reducing variation through experiments.

Another major difference between traditional project management and Lean project management is the timing of assuring the quality in project. According to Kliem (2015, p. 9) under Lean, the basic idea is to pursue quality at the source. As quality is critical to satisfy the customer, among Lean the best way to deliver quality to the customer is to address it at the source, for example during design or development phases (Kliem 2015, p. 9). Among traditional project management instead, quality is often controlled through inspections and other quality controls, which are conducted after the product has reached certain state of completion. Traditional ways of dealing with quality as checking if the product fulfills its requirements or late quality inspections are not Lean ways of working, as inspecting the product just before delivery to customer is wasteful (Kliem 2015, p. 9). According to Kliem (2015) inspection just before the delivery can slow down the cycle time, block the value stream and requires often overheads such as labor or spare parts, which can lead to passing the additional costs on to the customer. Not addressing quality at its source can result also in returns or dissatisfaction of the customer (Kliem 2015, p. 9).

In addition to the principle of pursuing quality at its source, also the attempt of minimizing waste has a strong foothold in Lean philosophy, and among project management, there exists many methods and forms to realize the principle. According to Forbes & Ahmed (2011, p. 462) one approach in Lean project management, especially concerning design, is to systematically delay decisions until the last responsible moment. Identified as Set-based design, deferring decisions is done in order to allow more time for weighing and analyzing the options and so ensure that work is done only once. Whereas in traditional project management practice, selecting options and conducting the work as soon as possible is a common way to operate. (Kliem 2015, p. 121) Making, for example, design related decisions and executing design tasks immediately can lead to rework and also interruptions if decision is taken on a tight schedule and needs to be corrected later. Set-based strategy suggests to analyze thoroughly the options and hold up the decision contrary to rushing into one resolution, allowing interdependent specialists to proceed within the limits of the set of options under consideration. (Kliem 2015, p. 121)

More human aspect considering difference between Lean and traditional project management is the involvement of project organization. Traditionally the different project participants take part at various stages during the project, for instance the designer is involved in the early phases and usually a construction manager may take part around mid-design or later (Alarcón et al. 2013, p. 250). This can result in situation where projects have organizations that resemble silos, with each function organized vertically and separated from each other. Instead, in Lean project management the early involvement of project key participants is used to generate a higher level of integration and communication of the parties in the project initial phases. (Alarcón et al. 2013, p. 250) According to Alarcón et al. (2013, p. 250) the early involvement of project key participants has a strong impact on how the project is conceived. Also Kliem (2015, p. 179) emphasizes the importance of getting people involved especially when increasing the ownership and reducing the resistance for change. In addition, when considering the best way of eliminating waste and satisfying the customer, processes will likely to be improved best by the people who know them, especially if they have an understanding of the process as a whole. (Kliem 2015, p. 179)

In addition to involving project organization in an early phase, it is also common in Lean approach to project management that the customer is also tightly involved to the project delivery (Gabriel 1997, p. 209). Related to involving key personnel in projects, one feature very much accentuated among Lean project management is communication. Communication is also mentioned in traditional project management literature, but discussed from a slightly different point of view. The biggest differences on the discussion between the two project management approaches are the communication related to customer and the communication manners. Traditional project management emphasizes the importance of planning and managing project communications, and recognizing different stakeholders' needs for communication in certain phases of the project (ISO 21500 2012; Lock 2007; PMBOK 2008). Whereas in Lean project management, the offset is not so much in recognizing the customer's needs for communication, but more in soliciting the customer involvement in every phase of the project, and persistently engage and inform the customer (Kliem 2015, p. 90).

As mentioned in chapter 2.2., in traditional project management good project communication is seen as a success factor. In Lean approach the emphasis is on enhancing the communication constantly, even if it needs persistency towards the customer (Kliem 2015, p. 90). For instance project meetings are not held only when needed, but instead regular meetings are organized and the customer is informed about the cost and progress of the project (Gabriel 1997, p. 209). Another Lean project management specialty is that all formal communication between the customer and the project team in both directions is conducted always via project manager. Using always only the mechanisms the project manager has set up, communicating via one channel aims to the reduction of unnecessary controls and decision-making processes, which can occur if multiple members of the project or client organization are permitted to communicate and state requirements with work in progress (Gabriel 1997, p. 207). Enhancing and controlling the communication is seen as a way to eliminate all forms of waste in addition to ensure the customer satisfaction (Kliem 2015, p. 82).

Also the usage of visual signals differentiate Lean and traditional project management approaches, as visualizing is a Lean way to communicate information and improve performance (Kliem 2015, p. 19). In Lean project management visual signals are used to coordinate and adapt to situations, and for example dashboards can visually display reports of progress, potential risks, trends and statuses (Kliem 2015, p. 79). According to Kliem (2015, p. 19), through visualization information is communicated to various levels of organization, so that needed decisions or actions can be taken quickly. Effective decision making is done in order to ensure the continuous flow of the value stream, which is in turn based upon pull (Kliem 2015, p. 19).

Structuring work through pull scheduling is another basic characteristic of Lean project management (Ballard & Howell 2003, p. 127). The idea in pull technique is at simplest to make only what is pulled by the customer (Reusch & Reusch 2013, p. 547). As mentioned in chapter 2.1., in traditional project management the operating system is based on project activities, which are often planned in the beginning of a project. According to Lock (2007, p. 1) the purpose of project management is to plan, organize and control activities, and the traditional approach has somewhat forecasting offset for managing the project processes. In Lean project management instead the work and activities are structured from a completion date backwards (Ballard & Howell 2003, p. 127), the movement of resources starting from the end of a process (Kliem 2015, p. 57). Hence, the tasks and activities are defined and sequenced so that their completion releases work, and only work releasing tasks are those not producing waste. According to pull technique, for instance the phase schedules are based on milestones and targets from the master schedule, in order to produce a plan which maximizes the value generation (Ballard & Howell 2003, pp. 127-128).

Another key factor characterizing Lean project delivery is the type of contract used and pursued. As in traditional project management transactional contracts are favored (Alarcón et al. 2013, p. 251), which usually governs the change of goods and services and include penalties for nonperformance or under performance in a project (Forbes & Ahmed 2011, pp. 168-169). According to Forbes & Ahmed (2011, pp. 168-169) it is typical for traditional contracts to discourage cooperation and innovation, rewarding some of the parties for optimizing their performance at the expense of others. The contracts working well in situations where there is a single outcome expected and the deliverables are easily defined (Forbes & Ahmed 2011, pp. 168-169). In Lean project management approach favored relational contract differentiates from transactional since the foundation of the relational contract is in mutual benefits (Alarcón et al. 2013, p. 251). Relational contract apportions responsibilities and benefits fairly and transparently between the contract members, based on partnership and trust (Forbes & Ahmed (2011, pp. 168-169). Typical for relational contracts, the team interests have equal or even greater weight than legal agreements (Forbes & Ahmed (2011, p. 171). With common goals, tight cooperation and shared responsibility, risks and rewards more innovative solutions become possible, as the focus of the parties is freed up on work issues instead of contractual issues (Forbes & Ahmed 2011 & Alarcón et al. 2013). The atmosphere of goodwill and cooperation requires sharing of knowledge and ideas between the parties as well as high level of trust (Forbes & Ahmed (2011, p. 171).

In a real project environment, some of the Lean project management methods may sound quite surreal, while these days for instance contractual issues are impossible to base only on trust between the parties. The financial pressures of the project organization as well as the client may be high and no risks are taken willingly only based on trust. Also the contractual form is not always even questionable when doing business, while some organizations and business fields may have very strict requirements and ready-made forms for the contract. Some of the features in Lean project management remind more like an ideal way of delivering projects, and may be considered more as a target level to show the direction of project operations development. For example, in project standardization the reason for projects' temporary and unique nature is easily forgotten, and the project delivery is recommended to be fitted in one mould. Hence, only those steps towards more standardized project model should be taken that are truly value adding regarding the project objectives. The above presented differences are summarized in the table 2.2.

Lean project management	Traditional project management
• Project standardization	• Unique and temporary features of the project
• Pursue quality at its source	• Quality inspections and control
• Activities are performed at the last responsible moment (Set-based design)	• Activities are performed as soon as possible
• Early involvement of project organization	• Project participants involved in different phases
• Solicit and maintain customer involvement	• Customer involvement depends on the customer
• Pull technique & Flow centered operating system	• Forecasting & activity based operating system
• Relational contracts	• Transactional contracts

***Table 2.2.**. The summary about the biggest differences between Lean project management and traditional project management.*

Altogether, the approach of avoiding unnecessary work and maximizing the customer satisfaction as well as the profit of the project may have very efficient applications on project environment. According to Gabriel (1997, p. 209) the Lean approach to project management has worked very successfully in especially difficult and complex project areas. Gabriel (1997, p. 209) states that the advantage of reducing risk to the client can be reached with the right balance of quality, performance and value for money. Also a higher level of commitment and motivation from the project team can be achieved, leading to the satisfaction of the whole client organization (Gabriel 1997, p. 209). However, the benefits of Lean project management are not much discussed among the literature and empirical studies about the profits gained are still missing. The reasons for failing the application of Lean project management are only somewhat discussed, the main reasons according to Kliem (2015, p. 97) being the lack of sufficient training on the processes, insufficient discipline and patience by stakeholders, the view of project management processes as administrative and the lack of sponsorship or support of senior management.

3. DESCRIPTION OF THE RESEARCH TARGET

3.1 Valmet AUT

The quality gate model created in this thesis project is done for Valmet Automation (AUT) which is one of the four business lines of the Finnish company Valmet Corporation. Valmet is presently one of the leading global developers and suppliers of technologies, services and automation for the pulp, paper and energy industries and the company has over 200 years of industrial history. (Valmet 2015) Valmet's history begins from the 1750s when a small shipyard was operating in Helsinki, under ownership of the Finnish state. The shipyard was a part of the state metal factories, later known as Valmet. Several companies were forming part of the Valmet Corporation during 1800 and 1900 century and the product portfolio was diverse. At the beginning of the year 1951the Finnish state metal factories (Valtion Metallitehtaat) was renamed as Valmet Oy, and the manufacturing of paper machines had started in Jyväskylä. Valmet was focusing more and more on paper technology during the 1980s and 1990s and in July 1999 Valmet Corporation and Rauma Corporation were merged into a new company, Metso Corporation. 14 years later, in the end of 2013, Metso's Pulp, Paper and Power business was demerged and transferred to the new company, Valmet Corporation, while the Mining and Construction and Automation business remained part of Metso. Automation became part of Valmet in January 2015 as Metso Corporation sold its Process Automation Business to Valmet Corporation. (Valmet history 2015)

Valmet Corporation has over 130 locations in 33 different countries around the world and more than 12,000 employees altogether. The other three business lines apart from Automation are Pulp and Energy, Services and Paper. Valmet's net sales in 2014 were about 2,800 million euros in which Valmet Automation (AUT) forms around 11% with its 297 million euros net sales. (Valmet 2015) Automation business line has around 1,600 employees and it operates in 30 different countries. AUT serves its customers in four main industries: pulp and paper and other process industries, power generation, marine and oil & gas. Valmet's automation solutions are designed to improve customers' production performance and cost, energy and material efficiency. The main products in AUT are Distributed Control Systems (DCS), Quality Management Systems (QCS), Analyzers and measurements, Vision systems and performance and service solutions. In this work the main focus is on DCS products and project deliveries. (Valmet AUT 2015)

The biggest market area for AUT is ERMEA region (Europe, Russia, Middle East and Africa) and most of the employees are situated in Nordic area with Tampere being the headquarters of Valmet Automation. Also the biggest supply center is situated in Tampere. Valmet Automation has delivered more than 4,500 automation systems, 40,000 analyzers and measurements, and over 1,000 power plants worldwide utilizes Valmet's process automation. (Valmet AUT 2015)

At the moment AUT has more than 700 active projects in 50 different countries, 150 of them being service projects. Project size varies from 100,000 euros up to 10 million euros and typical project life time differs between 6 months up to 24 months. (Project business 2015)

Valmet Automation is divided into three different business lines: Control & Measurement Systems (CMS), Energy & Process Systems (EPS) and Services. The product lines are divided into Dynamic Network Systems (DNA), Quality Control Systems (QCS) and Analyzers and Measurements. Product lines are supported by other functions such as Finance and Business Control, Human Resources, Business Development, Marketing and Communications and two operational functions Operations and R&D. Operations unit is responsible for the project execution, project management and development of project related processes. (Flow a 2015) This study is conducted for the Valmet Automation Operations unit.

3.2 Project execution in Valmet AUT

A quantitatively large number of projects is being executed in Valmet AUT, several hundred automation delivery projects yearly. The variety in project sizes is wide with most of the projects being relatively small. The variety in project size and scope sets certain challenges for quality assurance in projects and the quality gate model being created. The model should be well scalable and realizable in all types of projects with minor changes alternatives.

Operational functions, containing project managers, engineers, initialization engineers and other resources needed in projects, are responsible for project execution in Valmet Automation. Projects are divided into three different categories based on their different characteristics (Project business 2015):

- Small size project
  - Typical sales volume small
  - Simple project flow (delivery-commission-invoicing), not expected add-on sales
  - Few members in the project organization, moderate in-house scope
  - Includes hardware and engineering
  - Typically Service projects

- Medium size project
  - Typical sales volume medium
  - Final acceptance by performance guarantees or Pilot products deliveries
  - Significant project purchases or bigger engineering team

- Large size project
  - Typical sales volume large or High priority project
  - Complex project delivery: Multi countries project team or large project purchases

The decision about project category is made by regional Operation responsible and it is made during the Transfer from Sales phase. Projects are guided to meet the requirements and objectives set in the beginning of the project. Large projects have often also performance guarantees which the system has to fulfill with a threat of a fine. (AUT Procedures 2015)

Automation project in Valmet can be divided into 9 different phases, from the project department point of view:

1. Sales
2. Definition
3. Design
4. Manufacturing
5. Factory acceptance tests
6. Shipping
7. Installation
8. Commissioning
9. Customer service

The project begins in the sales phase, where also the project manager is often involved. In this thesis the sales phase is only partly included in the scope of the quality gate model. After the sales phase the responsibility of the project is transferred from sales organization to project organization, and the transfer from sales meeting is being held between project representatives and sales manager. After the project has started and the initial opening meetings have been held, the customer delivers basic information for the project.

Next, the definitions are made according to the data received from the customer. Definition information contains necessary standardization and model solutions needed in design phase, and is important in order to agree common technical standards with the customer and make sure that both parties have the same understanding. Definitions are reviewed with customer, and after customer acceptance the design phase can be initiated.

Design phase contains the detailed design of the software and hardware, and the design is implemented according to the definitions, basic data, instructions and implementation plan. After the hardware design is finished, the manufacturing phase begins, which is conducted by the logistics function. In the end of manufacturing phase the system is initialized and integrated by logistics before the handover back to the projects organization. Depending on the project, the project engineers are conducting some internal testing for the system before the implementation phase ends to Factory acceptance tests (FAT). The fifth project phase, FAT, is usually the first time when the customer sees the whole system and is involved in testing the system according to beforehand planned testing procedures.

After getting the customer acceptance from FAT, the system is being checked one more time in system audit and then packed and shipped to customer's site by logistics function. The on-site phase begins with the installation of the automation system, which can be conducted also by a subcontractor, and then continues with generally longer lasting commissioning phase. During commissioning the automation system is being tested so that processes including automation are completed and ready for the start-up. A trial run can be conducted during commissioning, the trial usually including the test period of certain time, when no major problems caused by the automation system are allowed. Before the last project phase, the system is handed over to customer and the responsibility of the project is shifted over to service function which takes care of the warranty-period and customer service.

3.3 Quality assurance in AUT projects

The variety of project sizes in Valmet AUT is wide and the customer requirements considering quality assurance can vary depending on the project. Quality management in Valmet AUT is based on ISO 9001 management system and the quality assurance in projects consists of the processes and instructions of the Quality management system. Quality control is divided to different parts of the project and the aim is to ensure properly documented and highly reliable system and software functions before start-up. Quality assurance is an ongoing process during the project and has several different stages in different phases of the project. QA activities are integrated into the tasks and operations of the project delivery. This means that the project organization also has the responsibility for the quality activities in the project. Department managers and quality manager are responsible for development of quality assurance and procedures related.

Valmet AUT's Quality Management System sets the framework for quality assurance in projects. The primary component in project quality is a workflow application for delivery projects, which builds the internal quality assurance plan of the project activities. The application includes the project phases, reviews, approvals and templates for plans and tests. The content of the application may vary depending on the project specific requirements and usually excludes the quality assurance of procurement. Considerably large and demanding projects, which often last for more than a year, have a project specific quality manager, who is responsible for the quality assurance during the project as well as providing a project specific quality plan.

The quality plan provides the project guidelines with identified actions and key milestones during the project lifecycle. The key milestones are mandatory hold points, where often customer acceptance for defined phases is required. With defined quality assurance milestones, the quality plan includes project phases, reviews, approvals, templates and tests related to project quality assurance. The present quality assurance milestones are presented in figure 3.1. in the automation project delivery flow chart. Through the project, 10 quality assurance milestones are located in different phases, most of them concentrating strongly on the on-site phase. Six out of ten milestones are positioned in the phase after shipping the system to customer's site. The Quality assurance milestones presented in figure 3.1. are the following: 1. Transfer from Sales to Projects, 2. Definition acceptance, 3. System take over from manufacturing, 4.

FAT acceptance, 5. Installation acceptance, 6. System audit & diagnostics, 7. Test run, 8. Take over, 9. Final customer acceptance and Transfer to service.

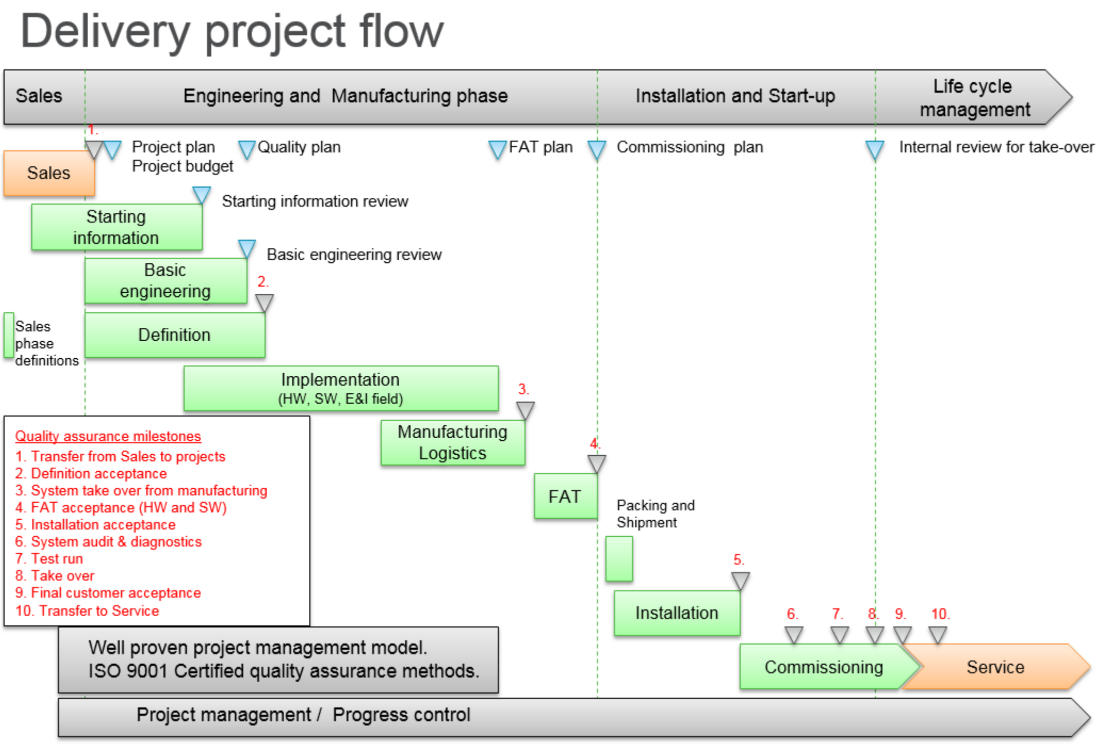

Figure 3.1. *Automation delivery project flow and quality assurance milestones.*

From the customer point of view, the most important elements of quality assurance during the project are engineering input data, approvals of definition material, typical loops, factory acceptance test (FAT) and engineering changes. Most of the phases including customer acceptance prior to move on in the project. Also relative to system delivery, the main validation period is factory acceptance tests, when all the hardware and software is tested against customer accepted test procedures. Factory acceptance tests are a major milestone during the project, because that is the first time customer sees his system as a while, when coming to follow the tests to the supply center test area. Also FAT is the last chance to test the system before the on-site phase which is important to minimize the changes and modifications done during the on-site phase. The variations or corrections in design and implementation identified during FAT will be discussed according to Valmet Change Procedures, change control being one very important quality assurance method during the project.

(AUT Procedures 2015)

4. RESEARCH METHODOLOGY AND MATERIALS

The objective of this study is to create a quality gate model for automation delivery projects, which is done in order to improve the quality of the delivery projects in the target company. As the purpose of the study is to create a new project delivery model, which will be later on implemented into practice, a constructive research method is used. In this chapter, the research strategy and the materials are described. Also the structure of the construction process is presented, with the five different phases of the research study.

4.1 Research strategy and methods

The research done in this thesis is conducted with a constructive research approach. Constructive research is used when a real practical problem needs to be defined and solved or to improve performance or an existing system (Oyegoke 2011, p. 576-578). The problems are solved with developing a construction which is something new differing from anything which existed before (Kasanen et al. 1993). The aim in constructive research is to produce a new-found solution which will be implemented to confirm its workability and suitability (Oyegoke 2011, p. 576). Constructive research approach is well suitable for the research done in this thesis, because the intention is to create a new model in order to improve the quality in projects. As Kasanen et al. (1993, p. 244) describes, constructions refers to entities which produce solutions to explicit problems. In this case, a real practical problem regarding project quality was already existing in the target company, and the construction of a new gate model was chosen as a solution for the problem.

Oyegoke (2011, p. 573) argues that the constructive research approach is applicable especially in the project management field of science because of the applied and practical nature of the research done in this field. The six different phases of the constructive research support the main condition of validity of the construction, the model created must be clearly working and solving the problems in question (Kasanen et al. 1993, p. 10). The process is a step by step procedure with different research phases (Kasanen et al. 1993, p. 3):

1) Find a relevant problem with research potential.
2) Build a general and comprehensive understanding about the topic.
3) Innovate and construct a solution.
4) Demonstrate that the new construction works.
5) Show the theoretical connections and the research contribution of the construct.
6) Observe the scope of applicability of the construction.

According to Kasanen et al. (1993, p. 3), the core element of constructive research is the innovation phase because the researcher must be able to produce a new solution to the problem. If not, there is obviously no point in proceeding in the study (Kasanen et al. 1993, p. 3). In order to construct a new solution, an understanding about the topic must be created. In this study the theoretical understanding was built with a literature review about phenomena concerning the topic and practical experience about the current state was gained through multiple methods presented in the next chapter. Multiple methods in data gathering were used to ensure the findings were right and corroborate the observations made.

As the objective of the constructive research is to create a model suitable for practice, according to Kasanen et al. (1993, p. 3), to pass as a constructive research, the novelty and actual working of the construction must be demonstrated. In order to do so, a pilot trial was conducted for the model created in this study, and according to Oyegoke (2011, p. 585) a pilot case study is the most appropriate method to test and improve a construct. In addition, an essential part of constructive research is to tie the solution with accumulated theoretical knowledge (Kasanen et al. 1993, p. 3), and both theoretical connection and experience from practice inform a better design of a construction (Oyegoke 2011, p. 579). In this case, as the research question and practical problem originates straight from a need of the target organization, the theoretical connections of the model do not have such a significant role in validation of the model as the connections to the practical problem.

In this study, also a phase regarding the requirements and limitations set to the construction is added to the research process because the definition of requirements is a significant factor influencing to the construction as well as suitability of the model into practice. The main phases of this study are presented in the figure 4.1. and described in more detail in the next sub-chapters. The actual research done in this study begins from the current state analysis and building of the theoretical background, as the practical problem was already existing and defined in the target company. The arrows on the left and right side in the figure illustrate the validation of the model, the evaluation of the theoretical connections of the model as well as the suitability and connection to the practical problem behind the study.

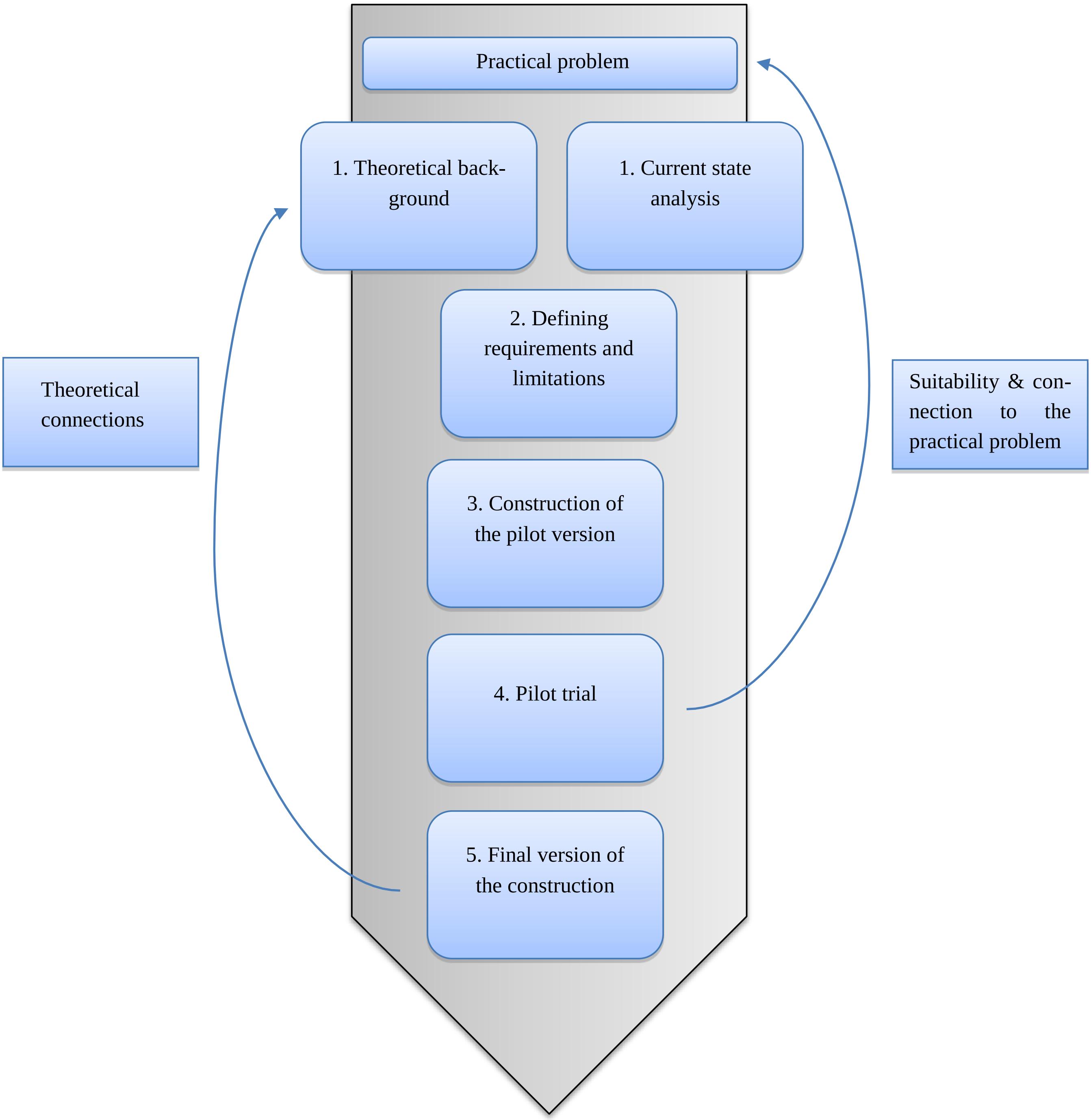

Figure 4.1. *The constructive research process conducted in this study with five different phases.*

4.2 Subtasks of the research

4.2.1 Current state analysis

The second step of constructive research method is to build an understanding about the topic and the phenomena occurring among the researched subject (Kasanen et al. 1993, p. 3). In this study there were multiple methods used to build a sufficient understanding to start the creation of the construction. A literature review was conducted to build an understanding about the theoretical background of the subject. Theory was studied especially about the project management and project success factors, time, cost and quality trade-off, Lean thinking and Lean project management. The understanding of Lean principles applied especially at the target organization was deepened with a one-day training course, Management Lean Training, held at Valmet premises. The present state of the project operations and quality assurance at the target organization was studied also with multiple methods, the interview study being the main method. Multiple methods were used to ensure the validity of the observations made during the present state analysis. Making same observations from multiple resources increased the reliability of the findings.

Qualitative interviews were used as a main data acquisition method to gather information, generate a picture of the present situation and understand and analyze the biggest challenges in project quality at the moment. Interviews were started right after the beginning of the thesis project, in October 2015. In the very beginning of the study project the main objectives of the interviews were to build an understanding of automation project flow, get to know the different products in Valmet AUT and understand the role of different functions in project delivery. Interviews were conducted as semi-structured interviews, as there were a list of themes and certain questions which were covered in every interview (Saunders 2009, p. 320). Also additional questions were included depending on the flow of the conversation and the organizational context of the interviewee. The course of the interviews were not defined beforehand, so that the interviewee could talk freely about the topic area, but the idea of the aspects to be explored during each interview were clear.

After attaining a basic understanding of the industry and the research target, the focus of the interviews was on the research problem. To get deeper understanding and identify the targets of the development, people from different functions and levels were interviewed. The interviews were conducted one by one, the interview time being more than one hour in each interview. Two of the interviews were conducted by Skype and the rest were face-to-face interviews. All the interviews were documented by taking notes and 10 of the interviews also recorded. Altogether more than 40 persons were interviewed and a worksheet was gathered about the similarities occurred in the answers of the interviewees. To form a picture about the general opinion about the biggest problems in projects, 15 of the most common answered reasons for project quality problems were gathered in the worksheet. Tabulation of the answers enabled to get numerical data and recognize those phenomena which were seen having the major impact on the project quality.

Interviews also had a significant role in developing the first version of the construction, while the demo version was created in an early stage. The construction was remodeled after the feedback gathered in the interviews and then presented again to a new person, who commented the construction and the changes made to it, again from a new viewpoint. The experiences and opinions from the interviewees were used to iterate the construction to meet the requirements of the target organization better. During and after the pilot trial of the construction, interviews were also the main method to gather feedback and evaluate the construction.

The understanding of the needs for the gate model and current state of project execution was deepen also as three projects were chosen as a deep dive projects. These deep dive projects were explored closer to get the understanding of whole end to end process and how the gate model could be implemented in that. Possible problems related to the project delivery were also discussed during the case studies. Closer introduction to projects was made by interviewing the key personnel in projects: project manager, lead engineer and also product line, going through the project material and documents as well as following closely some of the project phases, such as customer FAT at Tampere Supply Center.

Project quality costs

Information about extra costs occurred during projects, and especially quality costs related to projects, was gathered from the project closing forms. When the project is completed the project manager fills in a project closing form which is the financial closing of the project. In the form is stated the margin improvement percentage (actual margin – sales margin), margin change in euros and the share of add-on sales. Project manager is also asked to comment shortly to the form about major margin percentage changes and explain the increase or decrease of the margin. The changes in gross margin are mostly results of add-on sales or unexpected costs occurred during the project. Most of those unexpected costs can be seen as project quality costs, because they were not originally budgeted and usually results of rework or product quality issues.

The comments of the margin change, improvement percentage of the margin and margin growth in euros were gathered in an excel worksheet with the project information such as project manager, project number and project name. Comments were divided in two columns, positive comments and negative comments, to ease the analyzing process of the information. The margin change worksheet contained information of around 150 different service and capital projects from Nordics business area. The worksheet is used to analyze the most common reasons for the margin change in projects from the project manager’s point of view.

4.2.2 Setting of requirements and limitations

The business type, other development projects and wishes of the target company set various limitations and requirements for the quality gate model constructed in this thesis, and the following requirements are to be taken into account since the early phases of the study. The scale of the project sizes in the target company is very wide, as the biggest projects are more than ten times bigger by financial scale than the smallest delivery projects. Also the delivery time can vary from months to more than two years. Therefore, the scalability of the gate model must be high. The model must be conceivable to execute in small as well as in bigger projects, and that sets tight requirements to create alternatives to scale the model to be suitable. Also, none of the projects are exactly similar, and the execution type and even the phases of the project depend also from the customer requirements. Thus, the gate model must be general enough, to fit into different projects, and the gate requirements must be suitable for various kinds of DCS deliveries. However, the requirements cannot be too general, so that the object of the model, quality assurance of the project and the end product, suffers.

In the scope of this study are mostly those project delivery phases which concern the project organization. In addition, the final part of the sales phase is also included, starting from the point where a valid contract has been made. Part of the sales phase is also included while the success of the phase has significant impact on the execution of the project. The scope of the model ends to the point where the project has been delivered to customer and the responsibility is shifted to the service organization. Hence, the focus is being kept on the project implementation phase, when the project organization has the responsibility over the project.

In the quality gate model created in this study the focus is on Distributed Control System (DCS) project deliveries. The gate model is designed especially for DCS deliveries, including the product quality assurance of DCS systems. Also the main focus of the recent state analysis is kept on the DCS deliveries and quality problems occurred in those. Even so, the development project ongoing at the same time, Valmet Project Execution Model (PEM) must be taken into account during the construction of the DCS gate model. The quality gate model created in this thesis must be aligned with the PEM model so that they are easily merged before the implementation of the models.

The target company also required to involve Lean thinking and Lean principles into the development of the gate model. Some of the suitable Lean methods were required to apply in the model, in order to bring Lean thinking into project operations of the target company as part of the ongoing Lean implementation project.

4.2.3 Constructing the pilot version of Quality gate model

The construction of the quality gate model was based mostly on the problems observed concerning the recent state of the project execution. After defining the problems causing quality issues during projects and the root causes of those, the focus was set on the time period before the problems arise, to define needed actions to be done to avoid the difficulties. The construction of the solution proceeded very fast, because the meaning was to build the first demo version in the early phase to enable a pilot trial of the model in the given time schedule for the research.

The first step in the beginning of the construction process was to define the different project phases and to illustrate the project flow. The construction of the actual gate model started as a post-it notes exercise, where the project flow was described on a3 paper and the post-it notes presented possible gates or milestones and were attached to important phases of the project flow. In the first phase of the construction, more than ten gates were existing on the paper model, and the amount was reduced later on as the construction developed. The paper model with the post-it notes was presented in the early stage to some of the interviewees to get opinions and improvement ideas. In the end of November the model was converted into electronic format and the iteration of the model continued via interviews and discussions with different parties

Alongside of constructing the gate model, also benchmarking was done inside and outside the Valmet Corporation to find out, how the gate model concept is conducted in other organizations. Inside Valmet Corporation, other two business lines, Paper and Pulp & Energy (P&E) were benchmarked. Two meetings were arranged in December with the key personnel working with project execution models in Valmet P&E and Valmet Paper. In the benchmark meetings the present Valmet AUT Quality gate project was presented and ideas shared, how quality can be assured during the project and how processes should support that. Valmet Paper had recently implemented also a project gate model for the project execution, so experiences of the implementation phase were also shared.

Benchmarking was also done outside Valmet, towards a Finnish company that develops and manufactures products and services for environmental and industrial applications. The company was chosen as a benchmark enterprise because of their global project type business and far developed quality assurance system with quality gate model also in use in project execution. The objectives of the benchmark were to explore the company’s gate model for projects and to draw new ideas and concepts that can be applied to the Valmet AUT quality gate model as well. Also, it was important to hear about the feedback and experiences the company had about their gate model and the implementation phase of the model.

As the quality gates started to stabilize their places in certain phases of the project flow, also the definition of the gate content started. The content for the gate checklists was gathered little by little, based on the interviews and other company material. The pilot version of the quality gates was defined in the end of December, and the checklists were also finalized for the pilot trial. In this phase also a first check was made to ensure the alignment of the quality gate model with the other gate development project ongoing.

4.2.4 Pilot study of the gate model

In order to evaluate the first suggestion of the construction, a pilot study was conducted as a part of the development process. In the study, 6 pilot projects were chosen, in which the quality gates would be operated in practice. Quality gates were piloted to different phases of the projects to get information about usability and suitability of the gates in practice, and thus further develop the construction according to the feedback gathered. Feedback and experiences from the pilot projects were seen crucial in creating practical and suitable model for improving quality in delivery projects. Big variety in Valmet AUT project sizes, scopes and customer demands set special requirements for the scalability of the gate model. The model must be suitable and fit to all projects, regardless of their size or scope, and so the required level of convertibility is high. The objectives of the pilot trial of the construction were to gather feedback about the suitability and usability of the model, and how well the scalability confronts with different size projects. Also feedback about the possible impacts of the model to the project quality were gathered.

The pilot projects were chosen during December 2015. Altogether, six projects were found, in which the time schedule of the project suited for the trial. Five of the projects in the pilot were fairly large capital projects, and one project was smaller and faster service project. In most of the automation projects, the duration is longer than one year, so only limited amount of gates were possible to test in one project. Pilot projects were also chosen by their characteristics, while the objective was to find as different projects as possible to get diverse experience. One of the projects contained a wide mix of different Valmet AUT products, also IQ paper quality control systems, and helped to get experience of the gate usability in many product deliveries. Second pilot project was basic DCS delivery and third project was special standards containing DCS delivery with big amount of field design. The fourth project in the pilot was a service project with smaller scope and faster schedule. The last two pilot projects were DCS deliveries, which were chosen few weeks later, and were included to the pilot to get experience also from the on-site phase gates. Before making the final decision about the pilot projects, also the project managers were interviewed and questioned about their interest to be part of the pilot process.

After choosing the pilot projects, project managers were interviewed about the situation and history of the projects, in order to understand possible special requirements or risks related. The pilot trials continued from the beginning of the January until the end of March 2016. There were altogether 16 meetings held with the project managers during the pilot phase. First meetings considered planning the gate execution, then the gates were reviewed with project managers in suitable phases of the project and feedback meetings were held in the end of March.

4.2.5 Suggesting a final Valmet AUT Quality gate model

The final suggestion about the construction was made according to the feedback gathered during the pilot trial. Insights and opinions from the key personnel, in this case mostly project managers, were collected regarding the usability and suitability of the model as well as the tool with which the pilot trial was conducted. The feedback from the pilot projects was gathered along the pilot trial in gate review meetings, and requisite changes were made to the gate model according to the suggestions.

At the final stage of the construction process, the detailed gate requirements were defined and finalized as well as the gate practices with review-meetings. Also a final check for the gate model was made regarding the synchronization to the other gate model which is being developed at Valmet. The development project of Valmet Project Execution (PEM) model was still ongoing, but the quality gate model was compared to the PEM-model of the moment to ensure the alignment of the two models.

5. RESULTS

The construction of the Valmet AUT quality gate model was a multiphase process, and in this chapter the most significant results are presented. Results are discussed in order based on the phases of the constructive research done in this thesis, under five sub-chapters. First the results of the current state analysis are presented and the problems regarding delivery project quality are then discussed based on the interviews. After that, the requirements and limitations are assessed and the first version of the quality gate model is described. Also, the results of the pilot trial of the construction are presented and accordingly the final version of the constructed gate model.

5.1 Current state analysis

The current state of the project execution and related quality problems were observed through an interview study, and the results were used as a base for the construction of the model. Via interviews, the problems related to project quality were discussed and analyzed to find the root causes affecting to the generation of quality costs during projects. First, the understanding was built upon how project quality is understood in the organization at the moment. The insights of different interviewees about project quality were fairly similar. Most of them mentioning customer satisfaction as one of the main elements:

"-Project quality consists of controlling the costs, delivering on time and customer satisfaction." –Director, Project operations

"Project quality means that we deliver what we promised and the customer demands are satisfied. In addition, also the internal project cycle has been effective." – Director, Project operations

"Project quality means that the end customer is satisfied and the project has been executed according to the plan." –Director, Product line

"The whole project should aim to the final quality objective: deliver what have been promised to the customer, in promised time with agreed expenses." –Director, Product line

"Project is delivered with right quality if the customer feedback is good." –Project manager

"When regarding internal project quality, the project must fulfil the contract requirements, stay in budget and the project is delivered according to our procedures and quality management system, with right quality assurance done according to the procedures. The right documentation must be found." –Manager, Engineering

”The most important criteria of project quality is the customer’s feeling and image and customer satisfaction. The prime measure of quality is customer feedback.” – Director, Project Department

”Regarding the project quality, most important is to deliver what the customer has ordered, in the promised time and within the contract requirements. Also, the product needs to be technically functioning and fulfil the requirements.” –Project manager

”A successful project is economic, has high customer satisfaction and has met the qualitative and time objectives set.” –Manager, Sourcing

According to the interviews, project quality is understood as a complete success of the project, meaning that the project must be executed on time with tight cost control and high degree of customer satisfaction. Surprisingly, none of the interviewees mentioned quality control or assurance as a major element of project quality. Instead, the elements of project quality resemble very much the criteria of project success discussed in the beginning of chapter 2.2. Therefore, the observations made in the interviews about project quality problems are concerning very closely the same factors which are seen to have major impact on the project success.

In general, the biggest challenges in project operations were seen to relate to the strong pressure to make the operations more effective. According to the interviews, rationalizing the operations, high workloads and rush can easily lead to taking shortcuts, which is especially seen in the beginning of the project where critical steps are taken. Shortcuts can occur, such as ignoring instructions, passing on incomplete documents, leaving quality assurance inspections undone and so on. It requires time and courage to stop and consider if the project is ready to proceed or is there a big risk related to the progress.

Despite of the currently existing quality assurance instructions, the rules are not always followed and dispersion occurs especially in global projects. Also, the current quality assurance of the projects concentrates strongly on the on-site phase, and quality defects are noticed in late phases. Usually, the expense for a defect increases significantly, if the error is not recognized before the on-site phases. In the current model, some of the quality assurance checks are skipped and hence the documentation related might be missing. The importance of right documentation is significant also because it is a way to cover one’s back as well. As high level of cost effectiveness is required and the contract requirements are strict, documentation is also needed for leaving evidence of conducted actions, approvals and checks. Accordingly, a common way to put the quality checkpoints into practice is missing, and as there is not existing too standardized way to execute projects, the establishment of good practices is difficult. In the next sub-chapters the most significant observations regarding project quality problems are presented based on the interviews done during current state analysis.

5.1.1 Communication

Communication was a very much emphasized factor of project success among the literature in the study (chapter 2.2.) and surprisingly often the root cause of quality problems occurred during projects in Valmet AUT turned out to be poor or missing communication, mostly between project team members or with the customer as well. Additionally, communication was one of the five most mentioned reasons for the quality problems in projects among the interviewees. Communication problems came up especially regarding international projects, with project team members coming from more than one country. The poor quality of project communication was mentioned by many of the interviewees in leading roles in the company, quality meaning the way of how and the timing when information is communicated in the project. Communication was seen as a phenomenon related very closely to organizational culture, and therefore difficult to be discussed or improved. Sometimes, communication rules were considered to be lacking, as in some of the projects a common understanding about which issues to communicate and how to do so during the project was clearly missing. Missing agreement of communication style sometimes culminated to situations where communication was decreased or almost nothing but the very essential information was communicated among the project team. Also continuous rush and pressure were seen to reduce the amount of communication in the project.

Communication was considered as insufficient especially in situations where a problem was faced in the project or a deadline was getting closer and it seemed that the work was not going to be finished on time. Quite often, in situations where the delay of a work task could be predicted in an early phase, for some reason, it was not communicated further. The warning about the delay was given not until the deadline, when it was already late to react or do corrective actions. The late communication was partly due to professional pride and perseverance, as the persons responsible for the belated work task tried to catch up with the schedule persistently until the last possible point, and the delay was not communicated until it was certainly unavoidable. Many of the interviewees wished for more proactive communication about the delays, so that the possible problem or delay would be communicated immediately, as there is one in view. Hence, other project team members can prepare to the impacts which the delay might have to their work, so the possible risk can be noticed in time as well as the actions planned.

On the contrary, as communication was reduced in a rush or when the project was facing difficulties, the importance of communication in the exact situations was seen critical. Same kind of hold-up or shortage in communication was seen also when unfinished or faulty work tasks were passed forward in the project, for example incomplete design drawings. In a tight schedule, sometimes the tasks are left uncompleted before proceeding in the project, and the biggest problem was seen related to the information availability about the incompleteness or flaws. As there were unfinished matters, they were not always communicated forward properly, and also flaws or mistakes were easily left uncommented, even though it would ease the work of the next person significantly, if he or she would not have to start with recognizing the missing parts or defects.

According to the interviews, one of the biggest risks causing quality issues, delays in the schedule, and extra costs in the project was the change of resources in the middle of the project, for example during detail engineering phase. The change of resources has a significant impact on the success of a project, and especially important is the way how the displacement is done and the communication is operated. If the flow of information is effective, and the new person has all the right and sufficient information available at the right moment, the risk can be significantly reduced. In many cases though, it is hard for the new person to get a clear picture about the project, its history and course of previous phases, risks related and the next steps and tasks that needed to be done. All that time used for familiarization for example means extra hours and costs, and the risk for quality defects increases as the person changes in design.

Especially important in the project were seen the communication habits of the project manager, which often defined the communication style in the whole project. Project manager was seen to have the biggest impact on the communication issues, and an interesting observation was, that the shortages of project communication were emphasized much more among other employee groups than project managers themselves. The characteristics and personal way to communicate of the project manager have strong impact on the communication relationship with the customer. Regularly, communication through face to face meetings was seen important, but in the case of a passive customer, the quality of communication was seen to depend too much on the activity of the project manager.

5.1.2 Basic data

On the basis of the interviews, certain factors were clearly considered having the biggest impact on the success and also quality problems of a project. The most answered factor among the interviewees influencing strongly to the quality of the project as well as the schedule and the financial outcome of the project was obtaining the basic data. Project basic data concerns all the technical information and specifications which is needed in order to start the detail engineering of the delivered system, hardware as well as software of the system. Almost two thirds of the interviewees mentioned the availability and quality of basic data as a critical problem related to the project success and quality. As basic data is the cornerstone of the implementation phase, a lot of difficulties to the project schedule and the start of the detailed engineering was causing the fact that the basic data received from the customer was late in most of the projects. The dates for documentation exchange with the customer are typically agreed in the beginning of the project, but rarely written down in the contract. Though, the data sent by the customer is received often late compared to the schedule, causing a delay to the start of detail engineering and schedule pressure for the next phases of the project. Project schedules are almost invariably very tight, and the pressure to start detail engineering is strong, even if not all of the information is yet received. Starting the design phase with insufficient technical information from the customer often leads to rework later on, as the information is revised. Also the quality of the design can suffer from new revisions and changes done along the design phase.

Even more than the late timing of basic data, especially the poor quality of the data was seen as a critical difficulty. Even if the data is received almost on time, the quality of the initial data can be insufficient and not detailed enough to start the detail engineering, causing lot of extra work on solving and clearing out the missing parts of information. Extra work and waiting time is required as there might be several technical inquiries sent to the customer in order to specify the information. Because of the time pressure, usually the engineering phase must be started as soon as there is some information available from the customer. The bigger issue then is, by whom and how the quality of the information received so far is checked. Even if the engineering must be started in an early phase, it is very important to check the quality of the data available, so that there is no unnecessary risks taken regarding rework for example. At the moment it is not so clear, whose responsibility it is to give the permission to start the engineering. It can lead to situations, where engineering is started with poor quality basic data and lot of guesses and interpretations are done by engineers, which usually lead to rework in later phases. Sometimes rework and fixes are required still in the testing phases, and of course, that results in extra costs and sometimes even delays in the schedule.

The problem with the quality and timing of the basic data is difficult, as it depends also lot on the project manager and the way, how assertive and persistently he communicates with the customer on the issue. At the same time the project manager needs to require strictly the customer to stay in the appointed information schedule but also remain good relationship with the customer, which usually requires certain amount of flexibility. Especially among the employees other than project managers, the personal assertiveness of the project manager towards the customer is seen critical. According to some of the interviewees the role of the project manager in the problem is crucial, as the customer is not pressurized tight enough to stay in the given dates and lot of overdue is forgiven to the customer, meaning that the project has to catch up with the schedule with extra resources or overtime with no compensation.

Problems regarding basic data quality and availability are not related only to the information received from the customer but also to the data transferred between functions. For example from the logistic point of view the basic information received from project for procurement or cabinet deliveries can be very insufficient and cause lot of extra work and risks related to purchasing. The problem in the internal information exchange stands out particularly in global projects. The early timing of the information is crucial especially regarding long lead time items, which should be purchased in an early phase for the whole system to stay in the delivery time.

5.1.3 FAT testing

The third most often mentioned problem related to quality in projects was the shortage of Factory Acceptance Testing. FAT tests were considered having major impact especially on the product quality, and more than half of the interviewees found that there should be more testing done before shipping the system to customer's site. Thoroughly and properly done FAT testing was seen to have a major impact also on the success of the on-site phase. If the tests are managed to do properly according to plans and test results with open items are well documented, it is likely to have fewer problems and surprises during the on-site phase, and installation and commissioning will go more fluent. According to the interviews, a significant factor having a strong impact on the success of the FAT tests is the definition phase and how well the definitions are made. Properly and thoroughly done definitions take time, but they were seen to have a great impact on the quality of FAT and also to the later phases of the project.

When FAT testing is done poorly, only partly compared to the plans or not documented properly with all open items, it is likely to expect problems with the system during installation and commissioning. Complications during on-site phase often cause extra costs or delays in the implementation schedule because of unexpected and unplanned rework and repair done on-site. And usually, the later the changes are made or problems fixed, the more expensive it gets. According to the interviews the reasons for poorly done FAT testing vary between projects. The most common reason for difficulties during FAT is the time period before customer testing. Usually the problems occurred during FAT are results of insufficiently done internal testing.

In the project flow, there is a significant phase before FAT testing, as the system is handed over from logistics back to the project. In the handover significant amount of information is transferred from logistics function to project about the stage of the system. The handover should be a clear phase after the integration and initialization of the system, with the information about the system stage and readiness shifting to the project. After the handover the project is supposed to do internal testing before the customer FAT. Yet, in many cases the integration schedule of logistics function stretches because of delayed or insufficient integration information, belated hardware deliveries or other problems, and there is almost no time left for the project to do internal testing. Also, even if internal testing is done, the key issue is to make sure that there is test reports according to the tests available, to prove what tests has been done to the system and how.

The trade-off situation with time, cost and quality factors discussed in the chapter 2.3. is strongly present in the discussion about the importance of internal testing. As the schedule can be very tight, with no extra time available, and also the budget of the project is already pushed a decision related to the testing can be difficult compromise. The testing requires resources, money and time which are in short, but also testing can improve the quality of the system significantly, reducing the amount of problems faced during the on-site phase.

5.1.4 Sales support and transfer from sales

Another very often mentioned factor related to project quality problems was insufficient sales support by project during the sales phase. Sales support from operations was considered crucial related to the project quality by more than half of the interviewees. The content and quality of the contract was mentioned as a very common reason for quality costs emerging during the project. Quality costs are can be partly made in the sales phase by poor sales proposal, as the project costs and schedule are estimated wrong, or some of the costs are left out of the sales budget. Also, extra costs during the project will most probably occur if the agreement is imprecise and defined poorly. Especially the criteria for the customer acceptance must be carefully defined and sometimes there might be promised something in the sales contract that can be hard for the project to fulfil, for example high performance guarantees can be very difficult to reach. The quality and realism of the contract and sales budget have such a significant impact on the financial success of a project that among the project managers it is seen hard to avoid a financial failure in a project if the sales budget is done unrealistic. Even suggestions concerning an inspection practice were mentioned, meaning that the contracts would be checked by project organization before the acceptance. All in all, the support from project organization in the sales phase was very much emphasized among every function, and the practice was seen crucial in every probable sales case.

Usually the support is given by the project manager and support practice is profitable also because of the early introduction of the project manager and customer, especially in a case of a new project manager. Moreover, according to few experiences involving engineering function already in the sales phase was seen as a profitable practice, but not yet established to common use. However, the involvement of the project manager as well as engineering function or product lines in the sales phase depends quite much on the activity of the sales responsible.

Additionally, another important activity related to the project quality in the beginning of the project is the transfer of the project from sales to project organization. The transfer also depending much of the activity of the sales responsible, it is seen very important factor influencing also to the quality of a project. In the transfer from sales phase the information about the content of the contract, scope, schedule and budget of the project should be transferred to the project organization, usually to project manager. The phase is truly important for the project manager to understand risks related to the project, customer requirements and the solution as a whole, which is to be delivered to the customer. For example, significant amount of quality costs can be generated if some special directives or standards required by customer are realized during the project implementation, because usually the fulfilment of the requirements demands extra resources.

Usually, the transfer is a face to face meeting between the sales responsible and the project manager with a checklist existing about the issues needed to be discussed. The coverage of the material is especially important and the meeting should be well documented with no open items left. However, this is not always fulfilled and the project team needs to start the delivery with insufficient information. According to the people interviewed, the instructions about the transfer are decent, but not always respected, and the problem is more common in global projects. Especially the project scope was mentioned among the interviewees as crucial information to transfer, which should be well communicated to the whole project team.

5.1.5 Quality costs

One of main reasons why this study is conducted is the objective to reduce quality costs in the target organization. Also, according to Lean thinking and principles, quality costs are often generated because of waste existing in the processes (chapter 2.5). For example the costs of design rework in automation projects are relatively high in some of the cases, causing the gross margin budgeted in the sales phase to drop down during the project. Rework can be consequence of many reasons, one of the most common being the delay of basic data according to the interviews. The delay of basic data causes waiting, one of the eight Lean wastes, as the resources are already booked for engineering phase, but the input data is still missing and the design work cannot be started.

Even though quality costs in projects are difficult to identify at the moment, there is no doubt that they exist. There is certainly a price that can be calculated for the rework, wrong purchasing orders, product defects and engineering flaws, and those costs form the most of the project quality costs in Valmet AUT at the moment. Information about quality costs related to projects and especially the reasons behind those were gathered from the project closing forms. When the project is completed the project manager fills in a project closing form which is the financial closing of the project. The form includes the comments of the project manager about the margin change of the project. The reasons for margin change to decrease or increase during projects were studied based on the comments, and the most common explanations and reasons were identified and are presented next.

Decrease of the margin:

Among the project managers the most common factor affecting negatively to the improvement of the gross margin was higher actual engineering costs than budgeted. One of the reasons mentioned many times for exceeding the budget was wrong estimation made in the sales phase about the working hours needed in the project. Most often the working hours were budgeted too optimistically in the sales phase and the amount of hours needed increased significantly during the project causing the gross margin decrease. Especially hours budgeted for hardware engineering and basic engineering deviated notable from actual hours.

Another often mentioned reason for margin decrease was mistakes made in the sales budget when some of the costs were completely missing from the original budget. Such a costs were for example traveling costs, logistic hours, and training costs not mentioned in the budget made by sales. According to the work sheet, another reason for exceeding engineering costs was unsuccessful change management during the project. The customer didn't agree with the changes or +/- list and could not be invoiced for the changes made during the project.

Refit projects were also seen much more challenging than new product deliveries and complicated product replacement was mentioned as a reason for extra costs in engineering during the project. Other reasons mentioned causing margin dropdown were closely related to resources of the project such as: changing resources in the middle of project, especially in engineering, lack of resources that caused the extension of the engineering work or inexperienced resources in engineering. Other mentioned reasons were poor basic data, difficulties in assembling Info system and exceeding installation costs due to lengthened on-site time because the work could not be completed in one time but required several periods and visits on-site.

Success factors in projects / margin increase:

In the project closing form, also the positive improvements of the margin were commented by the project managers. One of the often mentioned reasons for the project success was good planning from the beginning of the project. It was stated that even less hours than budgeted was needed because of in advanced made successful planning. Also effective project execution was mentioned as a reason, which was due to high competence project team or committed personnel in the project.

Another often mentioned reason for margin improvement was well done sales, meaning that the estimation of working hours and the budget was done right already in the sales phase. Also reuse of previous projects was seen as a success factor. In some of the projects the resources and methods from previous projects were usable in new delivery and saved working hours. With familiar customer the reuse could be done also in engineering, saving working hours.

Good relationship and cooperation with the customer was also mentioned in positive comments, making project delivery easier and more cost effective. Excellent change order management was also seen as affecting the margin improvement, when the scope changes and +/- list were accepted by the customer and could be invoiced. Change management was seem to succeed mostly because of accurate follow up and record keeping of the changes during the whole project.

Other factors mentioned in the comments were doing things right at the first time, so that there was no need for extra or rework, savings made in travel expenses, or effective commissioning on-site. Also long time used to definitions was seem to be good practice and made the FAT tests much easier and faster, as noticed also in the interview study.

5.2 Setting of the requirements and limitations

As the scale of project sizes in the target organization is wide and the delivery scopes, schedules, and contents may significantly vary between projects, the quality gate model has to be well scalable and easily modified. To respond to the variation in the project deliveries, the scalability was seen to be best conducted so that the locations of the gates were planned in the beginning of the project, to be in line with the project schedule. As the same phases are present almost in every project, it was seen reasonable to remain the amount of the gates, and enable the scalability by shifting the locations of the gates case-specific.

The number of gates was seen reasonable to be reduced only in projects where certain gate related phases were completely missing. In those cases, the project manager makes the decision about which gates are to be included in the project delivery. The reasons must be documented and presented later on to the Head of Project Department. Instead, the scalability is enabled for example with the gate-review practice, as in big projects the practice is heavier with most of the project team members present at the gate meetings. Whereas in smaller projects or low risk projects the practice can be kept light and easy, the gate reviews mostly being held only by the project manager. Also referred in chapter 2.2. about Project success factors, Dvir et al. (1998, p. 932) mentioned project milestones to be found important in almost all types of projects, regardless of the size and therefore the scalability is enabled mostly with the modifications to the gate practices.

One project manager may have several projects ongoing at the same time and therefore, the quality gate model is designed to be easy to use with fast completed checklists. In the checklists some of the requirements are defined as critical, and those compose the minimum requirements in smaller projects. As there is no possibility to extend the work scope of the project managers, the checklists contain only items which has to be done in order to deliver successful project and non-value adding requirements were left out of the checklists. Nevertheless, in order to fulfill the requirement of the quality assurance of the project, the gate requirements are not too general.

One of the requirements considering the design of the quality gate model was to take into account the Valmet Project execution model (PEM). The gate model constructed in this thesis is aligned with Valmet PEM so that the gate naming and positioning are made consistent. Some of the checkpoints in the quality gate model are named as milestones instead of gates. Milestones are clearly Valmet AUT internal checkpoints, to ensure the quality of the automation system or the project delivery. With some of the checkpoints named as milestones, the quality gate model created has the same coding in the gate numbers and the same basic idea in the gate contents as the Valmet PEM. Synchronizing is done in order to ease the implementation phase of both models.

5.3 Pilot version of the Quality gate model

According to the interviews and the recent state analysis, the uppermost objectives for the quality gate model created in this thesis are to standardize project delivery, clarify the roles and responsibilities in projects, create common code for project documentation and make sure that right things are done at the right time in the project. All the actions are done in order to pursue better quality of the end product as well as better project quality with less quality costs generated during the project. Compared to the previous quality assurance model used in Valmet AUT, the presented model consists of some of the same checkpoints as the previous one, but the naming, focus and content of the checkpoints have been redesigned. A significant finding is that there are two entirely new quality checkpoints added to the model, of a kind which did not exist before. Also one checkpoint to the sales phase is added and the previous documentation milestones in the beginning of the project are rounded up as a new checkpoint.

The gate model constructed in this study presents the project flow of a DCS project delivery in a new way, which is illustrated in the appendix 1. In the project flow, the main phases are described and the locations of the checkpoints are presented, starting from the end of the sales phase and ending to the start of the warranty period, as the project is handed over to customer service organization. Also, four different project phases are presented: sales phase, engineering and manufacturing phase, on-site phase and service phase.

Gates and milestones are positioned at places in the project delivery flow, where critical information is transferred, there has been problems observed, insufficient procedures acknowledged or a need noticed for more precise working method or instruction to ensure the quality of the next phase. Gate model guides the work to be done before next gate and altogether nine gates and three milestones are presented in the quality gate model. Gates and milestones are checkpoints, defining when results must be achieved in the project and reviews or decisions must be done. The purpose of the checkpoints is to make sure that the project has all the prerequisites in order to proceed successfully. Those review points in the end of each phase require a number of criteria to be met before the project can progress to the next phase.

Gate criteria is composed of gate specific checklists. Checklists consist of activities or documents that need to be done or delivered no later than at the gate review moment. Some of the checklist requirements are defined as critical activities or documents that have to be controlled and accomplished at the gates because of their importance to the success of project execution. With the gate specific checklists the next pending actions can be recognized in an early phase, and also the capability of meeting the upcoming requirements can be evaluated in advance and corrective actions or notifications made.

In every gate or milestone, there is a “Go”, “No go” or “Go with option” decision made. Hence, a gate review can lead to three different results, depending on how well the gate criteria is met at the decision moment. The gate decisions are made on the basis of facts and information available at the time. If the gate criteria is well met at the decision moment and the project proceeds normally a “Go” decision is made at the gate review and the project will continue. A “Go” decision indicating that there is no remarkable risks related to the project or remarks that must be taken into account and the project can continue. In case of some of the gate criteria is missing at the gate review moment, but the project has the ability to continue with the defined options, a “Go with option” decision can be made. The continuation requiring that no critical gate criteria is missing. In case of a “Go with option” decision, the missing actions are carefully noted and action plan is required with responsible persons and due dates. If the gate criteria is not satisfied at the decision moment and one or more critical gate criteria is missing, a “No go” decision is made and the project is put on hold until the criteria have been met. A detailed action plan is required and the project needs monitoring.

Additionally, the same decisions are made in the project milestones, which are also checkpoints to ensure the project is proceeding with the right quality. Milestones are scheduled events between the gates, indicating that a major deliverable of a project is to be completed. The decision made in a milestone is checked at the following gate review, and it is one of the critical activities that has to be done to pass the gate. Furthermore, there is an identified decision maker defined for every gate and milestone decision, depending on the gate. In milestone decisions the decision maker is the project manager. Also, in gate checklists the responsible persons and confirmed roles are defined. Every decision and deviations must be also documented and communicated to the project organization.

The specific due dates for gates and milestones are scheduled in the beginning of the project, based on the internal project main schedule. Project manager is responsible for the scheduling of the gate dates and for that gate decisions are made on time. As one of the intentions of the quality gate model is to shift the project operations into more proactive manner, it is important to time the gates right, for example just before an important transfer of information is done in the project. Especially important regarding the quality of the project is to have the right deliverables available at the right time. Hence, a gate can be divided into three main elements: inputs - in other words deliverables, criteria and outputs. The gate inputs consist of the checklist requirements, or the documents and activities that the project manager or the project team has to deliver to the decision point. Whereas the criteria contains those metrics or instructions on which the project is judged with the information available in order to determine a result of the gate decision. The gate outputs instead are the results of the gate review. As an output the decision about the continuation of the project is made, including the possible action plan to be carried out before the next gate.

Regarding the follow-up of the project progress, the status information is made visible with gate indicators presented in the figure 5.1. A gate indicator symbolizes the status of the project and indicates how severe open issues there were or is at the time of initial gate decision. The statuses of different gates are shown in the scheduled order in the project follow-up tool and each gate has its own indicator. Green indicates that the project is proceeding as planned and no specific actions are needed. Yellow gate color means that there are some requirements missing at the gate, but with no severe impacts. The pending actions must be planned and the project needs monitoring. Red color indicates such missing requirements that have critical impacts on the project and the project needs to be put on hold until the gate requirements can be fulfilled.

Figure 5.1. *Gate indicators which visualize the gate status.*

5.4 Results of the pilot trial of the quality gate model

The pilot version of the quality gate model was tested altogether in six different pilot projects. Due to the long duration of the automation delivery projects, only limited amount of gates were able to be tested in one project. Even so, valuable feedback and experience was gathered about the usability and suitability of the gate model with hands on experience.

Execution of the gates with the gate specific checklists was seen as a suitable way to make sure that the project has the right requisites to proceed forward. Clear stated requirements were seen beneficial especially regarding the project follow-up, helping the project manager to have a grip and control over the project. During the pilot trial, it was noticed that the model is already quite suitable for practice and no major changes had to be made after the pilot trial. One of the pilot projects was a service project with smaller scope and shorter schedule than normally in projects, and a significant observation regarding the scalability of the model was done during the pilot trial of the project. According to the project manager, the amount of the checkpoints was suitable for the project, requiring though that the gate practice is kept light enough. Also three other project managers found that the gate practice is light and easy if the right things have been done in the project, meaning that the project activities have been conducted as planned and according to the procedures. Whereas, if the project management and quality assurance activities have been neglected, executing the gate model requires much more time and effort.

Although one of the projects was much smaller than other pilot projects, it included the same project phases as mid-size and large projects, and the same product quality assurance was required throughout the project. It was even discovered during the pilot that reducing the amount of the gates would jeopardize the effectiveness of the quality assurance needed in the project. Some of the phases in the small project were conducted with more simply manner than in more complex projects, and still the gate checklists were seen to fit, especially if regarding only the critical requirements of the checklists. Also, unlike normally in projects, the FAT testing phase was scheduled later and planned to be executed on customer’s site. With the gate model, this was conducted so that the places of the gates were switched to match the project schedule. Hence, the gate model was found to be easily adjusted also to somewhat abnormal scheduling of project phases.

Otherwise, the locations of the gates and milestones were seen suitable for normal project delivery, and the checkpoints were seen to be located in reasonable places just before problematic handovers or other important milestones during the project. The benefits of the gate model were seen to relate especially in making the project execution more systematic, with checking that right things have been done in right order, and turning the methods of project managers more consistent, which was seen as a positive change.

One significant question came up during the pilot trial, which was decided to be discussed outside of the scope of this thesis. The question is, how the gate model is implemented in large, complicated projects which contain deliveries of several different products. One of the pilot projects of this study was a large many product delivery, in which there were several different project fields progressing in different time schedules. The question about the gate implementation and practice in different sections of the project was faced during the pilot trial. The conclusion was, that most of the requirements of the checklists must be discussed several times with different project field at a time as they become topical. Gate practice must be divided after the project sections, so that a “Go” decision can be made regarding those sections which have the requisites to proceed further, even though some of the project fields can be still in a previous phase. Still, the gate practice must be held light enough, to avoid excessive administrative work, and the complex subject decided to be discussed further in a separate steering group outside of the scope of this thesis.

5.5 Suggestion of Valmet AUT delivery project Quality gates

The fifth phase of the constructive research done in this study is the suggestion of the final quality gate model. The final version of the quality gate model was constructed according to the feedback gathered during the pilot trial and in this chapter the final version of the model is presented in more detail. Contrary to the former quality assurance milestones, in the new quality gate model most of the gates are concentrating on the in-house phases of the project, with two entirely new checkpoints added to the model. Especially the focus of the product quality assurance is more on the in-house stages, in order to recognize defects and deviances earlier, and hence reduce the amount of waste regarding rework and late changes. The project quality and product quality assurance activities are not separated in the gates because quality is perceived as natural component of everyday work and tasks conducted in a project. Next, the gates are explained more in detail, based on the primary purposes and the checklist contents of the gates, starting from the first gate of the sales phase.

Gate 0 – Set up the project: The first gate is situated in the sales phase, ensuring a solid foundation for the project. The basic idea of the gate is to check with minimum criteria that a stable basis for the project is existing, before investing the resources to the project. In the gate zero the most important issue to be considered is the sales contract, which shall be valid and signed by the customer before further arrangements regarding the project is done. Valid contract is required in order to avoid situations where preliminary work is done and resources fixed but the project is later canceled and the made working hours lost.

At the gate zero, the sales process is in the final phase and heading towards the handover to the project organization. One or more key resources have been identified, requiring at least the recognition of the project manager for the project. Furthermore, the project category has been identified in this phase, meaning that a possible high priority project is recognized and the required preparation, such as risk analysis, is done. Another important issue to be concerned in this early phase of the project delivery is the recognition of possible pilot project. If the delivery consists of new technology, products or process areas, certain demands and practices is set for the project. In addition, particular demands and technical requirements can be appointed to the project also because of the customer requirements and standards agreed, which should be recognized latest in the gate zero by sales organization. The recognition of relevant standards and requirements is very important as it is the base for project quality management planning (chapter 2.4.), and the identification and determination how to satisfy the requirements is one of the key activities of quality planning.

In addition, the recognition and definition of the technical requirements and standards agreed with the customer is important especially in relation to the project finance and cost effectiveness. Directives and related standards agreed for example can cause heavy documentation requirements or special technical solutions for the project, and requirements should be taken into account in an early phase to minimize the cost impacts.

Milestone 0 – Transfer from sales: The first project milestone is located to the handover point where the project responsibility and information is transferred from the sales organization to the project team. The transfer consists of a checklist about the issues to be considered in the transfer from sales meeting between the project manager and the sales representative. The objective of the milestone is to ensure that the key information is transferred and the project organization has sufficient knowledge about the project to start the delivery process successfully. The successful transfer of key information, such as contract terms, customer requirements, technical requirements and risks related to project, is crucial in order to start the project efficiently and to minimize risks and rework done later in the project. With recognizing the special requirements agreed with the customer, the focus can be set on the right things from the beginning of the project. Especially important for the sales responsible is to pass on the information about the project scope and the solution sold for the customer to the project responsible. As the project quality is dependent on the customer satisfaction, it is crucial for the project team to understand clearly the customer requirements and the solution which is to be delivered to the customer. Sometimes there can be also unwritten customer expectations or requirements, and to communicate that information properly from sales to the project, a face to face meeting is a must between the sales responsible and the project manager.

According to the interviews done for the project personnel, transfer from sales phase was seen very important regarding the whole project quality and success, but not enough focus was always put on the transfer. With a mandatory milestone located in the phase, the intention is to emphasize the importance of the phase and also make the face to face meeting with minimum criteria to be discussed as an established manner in every project. The acceptable completion of the milestone is approved by the project manager, leaving him the possibility to reject the completion of the milestone if the information received from the sales is insufficient.

Gate 1 – Project started: As the beginning of the project is a determining phase having a strong impact on the success of the whole project, the first gate is located in the beginning of the implementation phase to ensure the project has a stable start and the right requisites to proceed successfully. The gate is partly a new checkpoint compared to the previous quality assurance model, while it replaces previous requirements of single activities and documents in the beginning of the project, such as project plan, budget and quality plan. In the Project started –gate the completion of the previous milestone is verified and several activities related to the project start and planning have been aggregated together. At this point, the project organization has been appointed and the resources allocated to carry out basic engineering. The main intention of the gate is to ensure that the project organization has the sufficient information to proceed in the project and the project plan and schedule have been issued as well as communicated internally and with the customer. Risks related to the project should be identified latest at this point and proposals for action made. Also the long lead time items are important to recognize at an early stage to avoid delays in the hardware time of deliveries.

In the beginning of the project, communication and information availability are very important for the project to start on the right track. Therefore, to pass the gate several kick-off meetings is required to be hold with different stakeholders to ensure the sufficient exchange of information. The whole project team must be aware of the project scope, customer requirements and risks related to the project. Additionally, one very important issue to discuss and agree with customer is the change management during the engineering phase. As mentioned in the previous chapter 5.1., change management was seen as one of the difficult areas in project execution among the interviewees, and therefore it has been set as one of the critical gate criteria to be taken into account in every project, regardless of the project type or size.

Gate 2 – Start detail engineering: Receiving the technical information and specifications late and with inaccurate quality was seen to cause major problems in project quality and progress (chapter 5.1.). Therefore, a gate is located to the beginning of the detail engineering phase to clarify the point where the basic data received from the customer is frozen. At this gate, a decision is made either to proceed to detail engineering phase or put the project on hold due to insufficient basic data for example. In the gate criteria, the critical requisites are defined, and the main intention of this gate is to ensure that the project proceeds only if the sufficient preconditions are fulfilled. The availability of certain gate criteria is crucial in order to ensure a financially successful project with right quality and on time delivery.

With the gate decision at this point, the focus on the freezing point of basic data is increased. Clarifying the point is crucial in order to avoid rework and to start the change management process in the project. After the basic data is frozen, the changes made by customer, for example to the hardware requirements, are handled through change management procedure and can be invoiced. But not only for financial reasons, the gate is important also regarding the quality of the design. The risk of quality defects in design increases as there is late changes done and the management of revisions becomes more difficult.

In the gate criteria, a validation for the basic data quality level is required, to ensure that the data received from the customer is sufficient. At this point, also the definitions are made and a customer acceptance for them is required in order to ensure a consensus between the customer and the supplier. Also resources for the next phase must be available and the possible standard requirements for engineering recognized.

The idea behind the gate number two relates strongly to Lean project management principles, as one of the basic ideas in Lean approach was to eliminate waste, in this case mainly rework, and especially eliminate waste by making the decisions as late as possible. As mentioned in chapter 2.6., one Lean approach in project management, especially concerning design, is to delay decisions until the last responsible moment. This is done mainly in order to ensure that the work is done only once. The method is pursued also in the gate number two, as it is rather preferred to wait a little longer for the accurate basic data than start the design with insufficient information and make corrections later.

Milestone 1 – Ready for manufacturing: Again, the idea of making decisions later and doing things only once is present at the second milestone, Ready for manufacturing. The milestone is a new addition to project quality assurance and is located to the point, where the cabin manufacturing drawings are about to be sent to the subcontractor. The intention of the milestone is to clarify the practice of freezing and sending the drawings in order to assure the quality of the hardware and keep the delivery times of the cabins. One problem observed during the recent state analysis was the belated schedules in logistics' delivery times, as the cabin deliveries were often late causing time pressure for the next important testing phases of the project. Several different revisions of the cabin drawings made it difficult for the subcontractor to keep up with the tight schedules and to respond to the quality requirements at the same time. Reducing the amount of revisions has also a straight impact on the manufacturing costs, as the rework of the subcontractor is minimized and so the cost per cabin decreases.

Hence, the objective of this milestone is to finish and inspect the drawings and send only one and finished version to the subcontractor, instead of sending several different revisions. From the product quality assurance point of view, reducing the amount of revisions is important, as the possibility of quality defects decreases and a significant point is that only quality inspected drawings are sent to the subcontractor.

Also, another method familiar from the Lean project management approach is applied in this milestone. Instead of controlling quality through inspections and controls, which are conducted after the product has reached certain state of completion, in Lean approach quality is pursued at the source (chapter 2.6.). A whole new review practice is included to the criteria of the milestone, which intention is to assure the quality of the design already before the manufacturing phase. The intention is to find as many design defects as possible before the manufacturing phase, because if the defects are noticed only in the inspection done for the ready cabinets, mistakes are much more difficult and expensive to fix at that phase. Finding the defects before freezing the cabin drawings is more cost effective but also eases the work of the subcontractor, as there is more finalized and quality inspected drawings sent for manufacturing.

Milestone 2 – Ready for iFAT: The third milestone in the gate model is situated to the point where the project is handed over from the logistics function back to project organization. The handover before internal testing phase is very important regarding the project and system quality, as a significant amount of information is transferred and yet, according to interviews, the phase is often conducted with unclear procedures and information. The main intention of the Ready for iFAT milestone is to ensure that sufficient amount of information at the handover is transferred and the project is enabled to do internal testing before the customer FAT.

Regarding the success of customer FAT, insufficient internal testing was seen as the major reason causing problems and delays in cFAT. As more than half of the interviewees found that more testing should be done before shipping the system to customer's site, the milestone is set to the critical phase to make the handover procedure clearer and set more focus to internal testing phase. One of the targets of the milestone is also to increase the preparedness for customer FAT, as the probability of avoiding complications in cFAT increases with properly done iFAT.

From the quality assurance point of view, internal testing has significant importance and the milestone is also important because of the hardware quality assurance conducted at this phase. Before internal testing, the hardware must be quality inspected and the major quality assurance documents regarding the hardware manufacturing are gathered. Emphasizing the early testing approach, which was seen to have major impacts to the on-site phase also, in the milestone criteria is also included the testing required to be done for the software of the system. Before the project is prepared to start the internal testing, also the electrical safety of the iFAT and cFAT must be planned and ensured.

Gate 3 - Ready for cFAT: The next phase with major importance to the quality of the system as well as to the customer relationship is the customer FAT. With a gate located just before the FAT phase, the intention is to increase the focus and the stage of preparation on the FAT test period before the customer comes over to start the testing. The objective is to ensure the preparedness of the project for the tests and for the customer to come over to Valmet's premises. As the shortage of the FAT testing was the third most often mentioned reason for project quality problems among the interviewees, a strong focus must be set on the enabling thoroughly and properly done FAT testing. Additionally, in order to minimize complications, changes and rework done on-site, thoroughly done testing is a key factor in reducing waste of that kind.

But not only for quality assurance of the system, the point has also a significant importance regarding the customer relationship. Customer FAT is usually the first point where the customer sees the bought system for the first time. Therefore, the preparedness is crucial in order to pursue the customer relationship and to present a professional way of working. Accordingly, the gate requirements include activities to ensure the testing is planned in cooperation with the customer, the right equipment, tools, procedures and resources for testing are available and ready to start the tests. Also, the internal test report is checked and the preparations for the on-site phase have been started.

Gate 4 – Ready for delivery: The last gate of the in-house phase is Ready for delivery -gate which intention is to ensure the project has the right requisites to send the system over to customer's site and pre-check the readiness of the site. Delivery of the automation system is a significant phase in the project, especially regarding the project finance and schedule, as the shipping day is often defined in the contract. From the quality assurance point of view, it is important to ensure the project has the right documentation available and the system is ready to be shipped. Especially important is to ensure the documentation of the customer FAT, and the gate requirements include the test reports and the test acceptance from the customer.

In addition, at this point the site readiness to receive the delivery must be checked and a written confirmation received from the customer. The time between the delivery and installation may vary by project, and sometimes the system must be stored on-site for a while. In that case, it is important to ensure proper circumstances for storing. Also the availability of the site resources must be checked, including possible country specific worktime limitations, to ensure continuous working flow and minimize waiting time. At this point, also the on-site plan must be updated and the site HSE plan conducted to ensure safe working conditions for the on-site phase.

Regarding the improvement of processes, a new requirement and working method has been added to the gate as one of the gate criteria is internal feedback. Before the delivery, internal feedback should be shared for the project team and other functions working with the projects. Feedback is required after the in-house phase because in most of the projects the duration of the on-site phase is more than six months. Also the project personnel can change after in-house phase, so it is important to give the feedback right after the in-house phase in finished and the stages of the project execution so far are still in one's mind.

Gate 5 – Ready for installation: After the system is shipped to customer's site, the installation readiness must be prepared and assured. The intention of the gate number five, ready for installation, is to ensure that the project has all the requisites to start the installation of the system successfully. To assure that installation is done with right quality, on time and according to customer expectations, the readiness of the site must be checked before and needed communication ensured by conducting a kick-off meeting with the customer and the project on-site team.

The readiness check of the site is important in order to avoid for example waiting time on-site, as the resources are sent over but the work cannot start before the customer's part of site preparations is done. Also the availability of needed installation resources must be checked in advance in order to avoid waiting time. Before starting any task on-site, the occupational safety of the site personnel must be confirmed. Therefore, HSE trainings must be conducted and a safety check to the site carried out in order to avoid accidents, absences and hence waiting time.

Again, one very important issue regarding system quality as well as project finance is to agree the change management process with the customer. Change management is agreed again in the beginning of the on-site phase because the project personnel might change after the in-house phase. The process and templates about managing the changes during the on-site phase must be agreed before starting any work on-site. It is done to keep track of the changes made to the system with defined process to ensure the quality assurance and to invoice the extra work form the customer. In addition, before proceeding to installation the delivered system must be checked, so that the delivery has been done according to delivery terms and all the parts are delivered to the site.

Gate 6 – Ready for commissioning*:* At the gate number six, the decision about the start of commissioning is made. At this point, it is important to ensure that the installation is done properly and the intention of the gate is to ensure the project requisites are sufficient to conduct the commissioning successfully and acceptable. The target of commissioning activities are usually to assure that the two next phases, Take over and Final acceptance will be made according to the contract and schedule. Therefore, commissioning phase should be also conducted successfully and on time, and well done installation is also a strong contributor in that. The installation must be inspected and accepted by the customer before starting the commissioning and also a kick-off meeting must be held to ensure sufficient transfer of information, especially if the project personnel has changed after installation. At this point also the change requests made after FAT must be made, which will contribute strongly to the customer acceptance which is required at the next gate. The decision of starting commissioning is noteworthy as it usually means the start-up of the machines and production on the site.

Gate 7 – Take over: The gate number seven is short and simple by its criteria, as there are only few requirements in the gate checklist, but for the project finance the phase is usually crucial. The most important issue at this stage of the project is to ensure that the customer has accepted the Take over of the project, so that the responsibility can be shifted to the customer. Importantly, the Take over of the system must be documented correctly to proceed to the final phase of the project. The gate could be also an internal milestone with certain document requirements, but it is presented as a separate gate because of the alignment with the Valmet Project Execution model. In addition, the phase is a significant milestone when considering the invoicing of the project.

Gate 8 - Close the project: The last gate is located in the end of the project, as the project responsibility has just been transferred to the service organization. The intention of the gate is to ensure a clear closing for the project with all the assignments conducted, documents supplied and importantly, to enable continuous improvement and project learning. Clear ending of the project is important as the responsibility is shifted between project and service organization, and the importance of communication at this point is high, especially regarding possible open items left. Effective closing contributes also to efficient use of resources, as the project personnel is released for the next projects as soon as the closing is done. Still, as the resources are often scarce, a clear closing procedure is needed so that the project documentation and closing tasks are properly taken care of, before the project personnel are torn to new projects.

Before being able to close the project, also production and performance guarantees must be fulfilled and approved by the customer, and the delivery must be accepted according to the contract terms. Furthermore, what comes to the project quality as well as the product quality assurance, the process of continuous improvement is crucial. Continuous improvement is also mentioned as one of the project quality management principles (chapter 2.4.), and continuous performance improvement is one of the main Lean principles (chapter 2.5.). Learning from the previous projects and gathering information about achievements as well as failures is important to improve the project operations and take the quality assurance in projects further. To gather information, feedback must be collected and documented for analyzing and making decisions.

The gate criteria includes a requirement for an internal lessons learned meeting, which is held to share feedback for the project team and to analyze the project execution. The feedback must be documented and shared to the internal database, to enable data analysis later and hence the project learning. To improve the performance, also customer satisfaction survey must be done in order to pass the gate. Customer satisfaction survey is set as a critical gate requirement because according to the interviews, the satisfaction of the customer is the most important criteria of the project quality (chapter 5.1.) and the project success according to the literature review. Established practice to collect the feedback must be conducted in order to improve processes.

6. DISCUSSION OF RESULTS

The main intention of the quality gate model constructed in this thesis is to improve quality in automation delivery projects. In this chapter the benefits of the gate model to the project quality are discussed and the results are assessed in order to determine whether they respond to the objectives. Altogether, the validation of the gate model is discussed and also the connections to the theoretical background are presented, especially regarding the application of Lean principles in the model.

6.1 Validation of the gate model

According to the interviews project quality is understood as complete success of the project, meaning that the customer expectations are met and the project is executed in promised time schedule and with agreed expenses. It was also recognized that the quality costs are not generated only because of insufficient product quality. Instead, the project quality and successful management of the project have significant impacts on the quality costs formed in a project. Therefore, in the quality gate model constructed in this thesis, all the project activities which are estimated to have an impact on the financial result, duration or degree of customer satisfaction of the project are acknowledged.

According to Kasanen et al. (1993, p. 10), the main condition of validity for a construction is clearly that they work and solve the problems in question. In addition, the theoretical connections of the construction should be appointed (Kasanen et al. 1993, p. 3). In this constructive research a new gate model was created to improve the quality of projects in target company and the model will be implemented in the autumn 2016. Therefore, the model must be suitable for practice and have beneficial impacts on the project quality. As in this thesis the practical problem behind the study originates from a need of the target company, the main validation method is to test the model in practice, and the validation for the quality gate model was done in six pilot projects, during which the experiences and feedback was gathered form the project managers.

According to the interviews done after the pilot trial, the model was found well suitable for practice. The content of the gate checklists was found relevant and according to the project managers there where right things asked at the right phases of the project. All of the five project managers were of the opinion that the gate model brings a more systematic way to conduct projects and will improve the project quality if it will be properly implemented to the project operations of Valmet AUT. The biggest improvements were seen to relate to the streamlining of project execution so that the projects would be executed with more equal quality in the future as well as to the improvement of project documentation.

Also the improvement to the project communication was mentioned, especially in a case where a new person joins the project team and the history of the project, current state and next steps are easier to clarify for the new project team member. The importance of communication increases in replacement situations, as changing resources in the middle of project was mentioned as a reason for project quality costs (chapter 5.1.). With accurate and extensive information available at the right time the replacement can be done faster and more cost effective way. Also related to the improvement of the communication, the checklists of the gates were found as a good way to communicate the detailed project situation for the team, as they can also be sent by e-mail to those team members who were not able to attend the gate meeting.

One factor strongly emphasized by two of the project managers was the potential positive impact of the implementation of the gate model on the project follow-up. The tool for clear status follow-up was seen needed especially in cases when the project manager has multiple different projects ongoing at the same time. The ability for more accurate follow-up was highlighted also in situations when the project is not going so well or there is a risk related to the project. With the help of gate model the risk can be identified earlier or the defect caught. The preventive feature of the gate model is particularly important regarding the improvement of project quality and product quality.

An interesting finding related to the suitability of the model for practice and different size projects was that the gate practice with checklists was considered light and fast also in smaller projects if the project was on track and the project activities had been taken care of properly during the project. Whereas the gate model and practices are causing significantly more work in projects where there has been shortages in documentation and the normal project activities have not been done according to procedures. Hence, the gate model also guides the project execution towards more systematic way because otherwise the gate practice is much more difficult and time-consuming to conduct for the project manager. So, conducting the project with sufficient quality standards is also rewarding and efficient for the project manager.

Otherwise, the quality gate model was found suitable to be implemented in practice and also several potential positive impacts to the project quality were recognized. In addition, the enthusiasm of some of the project managers to use the model on their own initiative in their other projects as well indicates that the model has beneficial impact on the project quality. Still, the pilot trial raised few questions about the use and suitability of the model, such as how the gate model is used in multi-product projects with several different project fields with different time schedules. The question was decided to be discussed outside of this thesis in a separate steering group, as the matter is important and needs to be solved at a management level.

Part of the validation process of the model was also a workshop, in which the gate model was discussed among project management, logistics and engineering persons in charge. Regarding this thesis, the main outcome of the workshop was that the gate model itself was found well suitable for implementation into practice, but there is still decisions to be discussed and made regarding the practical realization of the model, including the IT solutions, training and gate practices globally. Also, the gate model implementation into many product deliveries is a major question to be discussed with the right interest groups later on.

Regarding the target organization, this study has revealed some shortages as well as weaknesses in the project operations of the company, but also a solution suggestion has been made. Some of the findings regarding project quality and quality problems are significant, especially regarding the success of delivery projects, and corrective actions should be considered in the foreseeable future. Although the decision to take actions regarding the project quality in the target organization was already made prior to this study, the gate model was chosen as a method to improve project quality. Also the decision of implementing the model was made earlier and the quality gate model constructed in this study will be implemented in synchronization with the Valmet PEM model to Valmet AUT global operations during the autumn 2016. Putting the gate model into practice signifies a remarkable change in the operations of the target organization.

According to Kasanen at al. (1993), constructions considered technically adequate may not necessarily work in practice, mostly due to poor focus on implementation during the construction phase. In this study, valuable information and feedback regarding the implementation of the model was gathered during the pilot trial. This feedback should be carefully taken into account while planning and executing the implementation. According to Oyegoke (2011, p. 590) the possible problems regarding implementation can be tackled with involving approach during the construction phase of the solution. While designing and implementing the solution, the organization should be involved to the process, instead of importing a solution to the organization after the overall development phase (Oyegoke 2011, p. 590).

In this study, the involving approach was attempted to be carried out throughout the research process, starting from the problem definition phase, where employees from different functions were involved via interview study. The intention of the extensively conducted interviews was to strengthen the commitment of the organization to the upcoming changes as well as to ensure the actions taken are focused on the right problems.

6.2 Project quality and quality costs

One of the biggest difference of the new model compared to the current project quality assurance model is the more preventive approach to quality assurance. In the new quality gate model the quality assurance is focused more on the in-house phases of the project. Earlier focus is set to notice the deviation as soon as possible and make the preventive actions in an early phase, because usually the later the corrections are made, the more expensive they are. Also, two entirely new quality checkpoints were added to the project quality assurance, and all of them are positioned to the in-house phase of the project. The early focus on the quality and execution of the quality assurance activities as soon as possible are very much emphasized also in the Lean project management approach (chapter 2.6.). Hence, with the new quality gate model the perspective of the quality assurance is shifted towards more proactive approach. For example reviews are made already in the design phase, rather than concentrating only on the quality inspections when something is already done. That is done to avoid situations where quality deviations are discovered after the implementation of the system and minimize the amount of faults in as early phase as possible.

A successful example regarding the previous discussion was discovered during the pilot trial of the model as in one of the pilot projects, a “No Go” decision was made. The project manager conducted a “No Go” decision at the second milestone Ready for manufacturing which is a new addition to the project delivery quality assurance. The decision to put the project on hold was made due to insufficient quality of the hardware drawings. After the decision was made to put the project on hold, the responsible persons and schedule for corrective actions were put down to the checklist and the drawings were sent few days later after they were corrected. The second milestone is, but has proven its importance and likely prevented probable quality costs for the pilot project. As mentioned in chapter 2.5., also according to the Lean principles, the working culture should be created so, that a clear stop is made, when a deviation is noticed, and the problems should be handled quickly. According to the feedback from the pilot project in question, similar working method seem to suit well also for the target organization.

Another new addition to the quality checkpoints is the third milestone, Ready for iFAT. The milestone is new clear checkpoint in the transfer point between logistics and the project and although the target is to ensure successful internal testing phase, the main purpose is actually to support the successful customer FAT. Probably the biggest contributor in the readiness of customer FAT is well done internal testing phase, and if the implementation of the new working method is successful, it might have significant impacts to the success of customer FAT. If the internal testing is conducted and documented well, there is even potential to reduce the time spent in customer FAT, as usually customers do not require the same tests to be done again if there is a valid test report proving the accomplishment of the tests.

Another benefit of the new quality gate model compared to the current one is that the criteria for the project to proceed in a certain phase of the project is made clearer with the gates and milestones. With clear hold points and unambiguous criteria for the checkpoints the decision making is more reasonable. The decision to proceed or put the project on hold is based on facts, instead of speculative estimations, which is especially important while the decision are often made under considerable pressure. Also recognized as one of the project quality management principles (chapter 2.4.), factual approach to decision making is important because at the gate the project manager must be provided a realistic evaluation of the performance and progress of the project.

The observations made in the recent state analysis of this study respond surprisingly well to the findings of the literature review about the Project success factors (chapter 2.2.). First, an interesting observation done is that the perception of project quality among the interviewees of the target company responded very closely to the common known project success criteria. Otherwise, both the project success criteria and perception of project quality compose of three major factors: customer satisfaction, on-time delivery and economic result of the project. As the result of the project success factors literature review good project communication was seen as the most important factor impacting to the success of the project. Whereas according to the interview study project communication was seen as one of the most important factors influencing to the project quality and so to the success of the project delivery. In addition, where Mishra et al. (2011, p. 362) emphasize the criticality of the good communication between the project team, it was exactly the internal communication between the project team members, which was seen difficult and insufficient in the target organization, especially in situations where the project is facing complications or problems.

According to the interviews, insufficient communication was highlighted as a major problem regarding project quality. One of the benefits of the model is that it increases the communicational activity in project and ensures that the possible problems observed in the gate are communicated to the project team and responsible persons. Milestones or gates are positioned in places where critical information is transferred, for example to the point where the project is handed over from logistics back to the project organization. The purpose of the systematic gate review meetings and checklists is to ensure that information is changed in critical phases of the project and at least a minimum amount of project communication is ensured between the project team. With checklist requirements, the intention is to ensure that right information and documents are available at the right time in the project.

The real value of the gate model regarding project communication came up in one of the pilot projects, as a “No Go” decision was made in the review meeting. The shortage of communication may not have such a significant impacts if the project is proceeding well, but if a complication is phased and a delay in the project schedule is probable, the impact of inadequate communication is severe. In the pilot project the complication was handled effectively with a review meeting and action plan with responsible person and due date defined and documented to the gate checklist, which was then informed to project team members.

Probably, the real value and importance of the gate model to the project delivery is best seen in situations where there is problems or complications faced in the project, as with gate model they will be noticed systematically and on time. Also, the process requires to react to the deviations so that they cannot be left unnoticed. Therefore, the deviations do not have much time to escalate as the gate practice requires actions to be made. As mentioned in chapter 2.3. about the time, cost, quality trade-off, the total quality of a project is dependent of the quality of each project activity, and therefore the systematical way to ensure the quality at each step through the project lifecycle is crucial. In case of a trade-off decision must be made at a gate, at least the possible effects of the crashed activity are pondered. As it is reality, that trade-off decision between time, cost and quality factors must be made in projects, the gate model at least ensures that there is right information available for the time. Also, the impacts of the decision to the next phases of the project can be easier evaluated as the course of more standardized project execution is easier to predict.

6.3 Applying Lean principles in the gate model

As mentioned in chapter 2.5, it is most important in successful Lean implementation to find the Lean principles suitable for each organization rather than copying the Lean way production and tools exactly. In the beginning of this thesis it was decided to build an understanding about the Lean concept and then choose the suitable principles and methods to be applied in the quality gate model constructed. Several Lean principles especially regarding Lean project management were found to be suitable and profitable regarding the objectives of the gate model.

In Lean philosophy, the focus is on the customer and customer satisfaction, and value can only be identified through the ultimate customer. The same kind of thinking was observed in the target organization, as the main criterion for project quality was considered to be customer satisfaction (chapter 5.1.). Therefore, many of the Lean basic principles were easy to adapt as the basic philosophy of the gate model. One of the major thoughts behind the gate principles is the pursue of quality at its source (chapter 2.6.), meaning that the quality assurance during the project is made as soon as possible on the earliest possible phase. Hence, the defects can be recognized earlier and fixed with fewer costs.

Aiming also to the reduction of quality costs, another Lean principle applied in the gate model is the idea of avoiding waste by doing things right at the first time. Wastes such as rework, waiting, overproduction and defective products are produced as activities are performed too early without evaluating the conditions to proceed in the project. According to Lean project management principles (chapter 2.6.) the decision should be made at the last possible moment. In the gate model clear instructions and criteria is given for each gate in order to proceed in the project only with the sufficient requisites. That is done to ensure that the progress to next phase is done only if there is no risk of doing things twice or the risk has been assessed and approved.

Related to the progress only with right requisites, an important Lean principle applied in the gate model is to make a clear stop if the requisites are insufficient and there is a problem noticed (chapter 2.5.). A decision is made at each gate about to proceed in the project or to put the project on hold if a critical shortage is noticed or a problem faced. The decision to put the project on hold must be made in order to avoid the risk to escalate later in the project. Also, with the systematic way of defining the gate requirements and activities needed to be completed in certain phases of the project, the gate model determines a standard way of the project execution.

Project standardization is one of the most emphasized Lean project management principles (chapter 2.6.), which is stated to have strong impacts on the cost and time reduction of the project (Karim & Nekoufar 2011). The gate model defining a more standardized way of project processes, procedures and methods, the improvement of performance is easier. In addition to continuous improvement, the more standardized way of delivering projects is also beneficial for the target company because of the more unified documentation. As the greatest importance should be set on customer satisfaction, the standardization of project delivery has advantages also from the customer point of view (chapter 2.6.). For the customer, it is easier to predict the possible result if the projects are more of uniform quality, also predicting the project schedule and costs is easier with more standardized project model. In achieving the trust and goodwill of the customer, the equal level of quality in projects is important and increases also the amount of good reference projects.

To increase the information availability, a visual way to follow-up the project status is integrated to the quality gate model. In Lean project management visual signals are used to coordinate and communicate information in order to improve the performance (chapter 2.6.). Therefore, the status of the project is communicated with three different colors, green, yellow and red to see the current state of the progress and situation of the project. The colors of the previous gates are also in the view to notice the project history and possible problems that has been passed. The benefits of the visual management are the effectiveness of the communication, minimization of information breaks and the communication to several levels of organization easily and fast.

The visual follow-up of the gates enables the whole project team to see the project status at once, and another specialty of Lean project management is the early involvement of the project team (chapter 2.6.) which is also pursued in the quality gate model. The project team members are invited to the regular gate review meetings starting from the early beginning of the project to ensure the sufficient information flow and to commit the project team better.

As Lean has been studied quite extensively among traditional manufacturing environment and one of the main issues raised up has been the effective flow of production, in the project environment instead the flow might have a slightly different meaning. According to the literature review, project communication is seen as one of the main success factors of projects (chapter 2.2.) and when considering the trade-off situations, the project manager must have the right information available at the decision point to make successful decisions (chapter 2.3.). Also, in the current state analysis of this study the importance of the communication was highlighted, and the situations were emphasized where important information should be transferred (chapter 5.1.). As a conclusion, the major importance seem to lie in the availability of the right information at the right time in the project. The availability of the information is crucial for the flow of the project process because the key information of a certain phase releases new work or starts a new phase in a project.

Hence, the traditional flow described in Lean principles could be applied into project environment so that instead of illustrating the work tasks or product progress in the process, the information flow would be described. As the importance of communication is so much emphasized, probably a great potential to make the operations more effective lies in the flow of information. As the new project flow would describe the project process, phases and especially the key transfer points from information point of view, communication and effective transfer of information could be taken into closer investigation more easily.

7. CONCLUSIONS

In this chapter, the main results are summed up and conclusions presented. The objectives of this thesis were well achieved and the chapter presents an evaluation of the whole research done. First the research is shortly summarized and the main results revised. The whole research is evaluated against the objectives, limitations and requirements set in the beginning, and also the possible generalization of the study is discussed. Additionally, the recommendations for further study are advised and the recommended next steps for the target company. In the last chapter, a potential further implication of the gate model is presented.

7.1 Meeting the objectives

The objective of this study was to construct a quality gate model for automation delivery projects. The quality gate model will be used as a method to improve the quality of the product as well as the project in automation project deliveries at Valmet Automation. With ongoing Lean implementation project at Valmet, also Lean principles were required to be applied in the new quality gate model created. In the beginning of this study a practical problem was already defined, there was a strong need to improve the project quality at the target company. As there was a need to solve the practical problem with a new model, a constructive research approach was chosen. With problem-solving approach, a new quality gate model for Valmet AUT project deliveries was constructed, which responds well to the practical requirements and will be implemented to project operations in the autumn 2016.

In order to construct a model suitable for practice, the first step of the research was to form an understanding about the current state of the project execution in Valmet AUT and the theoretical background of the theme. Especially important was to observe the current problems related to the project quality in order to define the areas that should be especially taken into consider in the construction of the model. The gate model was constructed with a fast schedule, mostly due to the iterative way of the construction, where the demo version of the model was presented for the interviewees and then remodeled after the feedback gathered. The intensive cooperation and interviews with the employees of the target company remarkably sped up the construction phase and the pilot version of the model was created in less than three months.

As a part of the construction process, a pilot trial for the model was conducted, and the suitability and usability of the model was tested altogether in six different ongoing projects. With the feedback and experience gathered from the pilot projects, the model was finished and evaluated against the feedback of the pilots and theoretical connections. More standardized way of project execution is presented in the quality gate model created in this study and the perspective of the quality assurance is shifted towards more proactive approach.

The major differences between the new quality gates and the current quality assurance milestones are the positioning and definition level of the checkpoint contents. When the current milestones are situated mostly on the on-site phase, most of the gates in the new model are concentrating on the in-house phases of the project. As a significant improvement, two entirely new quality checkpoints are added to the quality assurance of the projects, situated in phases with major importance to the quality assurance of the product. With the new milestones the focus on the early prevention of deviations is even more emphasize, and the earlier the quality deviations are noted, the less expensive fixing of them will be. Also, most of the problems related to project or product quality take place in the beginning of the project, so concentration on the early stages of the project is very reasonable.

Another big difference between the current quality checkpoints and the new gates is the perspective between past and future. The former milestones were centered around acceptances and activities that had been already done, keeping the focus on the past. In the new quality gate model the gates are focusing on the future and the forthcoming activities that need to be done in order to successfully shift to the next phase in the project.

One target of the gate model is to reduce project quality costs, but the impact on the costs is quite impossible to evaluate in the scope of this study, as the research was conducted in a tight time schedule and the duration of the projects is usually more than a year. The financial impacts of the gate model regarding the quality costs of projects can be noticed at the earliest in the beginning of the year 2017, as the gate model has been properly implemented into practice and the projects conducted according to the gate model are proceeding.

7.2 Evaluation of the research

The research done in this thesis responds to the objectives set, as a new quality gate model for Valmet AUT project deliveries was created and found suitable for practice according to the feedback gathered from the pilot tryout of the model. According to the pilot trial and interviews done for project managers, the model is seen to have potential to improve the quality of the projects in target company. The model is constructed so that it responds to the requirements and limitations set in the beginning of the study. The gate model is synchronized with the Valmet PEM model so that the gate numbering and coding is aligned and the implementation of the two models is made easier.

With the new gate model created, a more standardized way of project execution is presented, enabling the continuous improvement of the project processes better. However, in the standardization is taken into account the fact that the project sizes, scopes and types may vary significantly in the business of the target organization, and the scalability of the model is enabled in order to fit the model for different types of projects. Also, suitable Lean concepts and methods are successfully applied in the gate model according to the requirements. Actually, the few most important Lean principles compose the base for the gate philosophy.

The suitability of the model was validated in the pilot projects, and all out of five project managers were of the opinion that the model will improve the project quality if implemented to the operations. Especially the harmonization of project practices and more systematical way to conduct projects were highlighted, as well as the improved follow-up of the project and earlier recognition of defects.

The constructive research approach used in this study supported the intention of the study very well. The project phases of the constructive research guided the development process in practice very closely and helped to identify a systematic way to conduct the development of the new gate model. In constructive research approach emphasized validation of the construction with pilot case studies was the most appropriate way to ensure the suitability of the quality gate model created in this study as well. There were remarkable observations and conclusions made during the pilot trial of the model, and it was necessary to conduct regarding the success of this study. Although, one shortage regarding the pilot trial was that the entire model could not be tested in one project because of the long durations of the projects. Hence, the impacts of the gate model on the whole project lifecycle could not be evaluated, while none complete trials from the beginning of the project until the end could be conducted. Even so, all of the gates were able to be tested at least at one project in several different projects.

Well and thoroughly done interview study, with more than 40 interviewees, about the current state of the project execution in the target company was very important in order to construct a model suitable for the purpose. Also, close cooperation with the future users of the model during the construction phases was done to ease implementation phase. Understanding the current state and the genuine problems related to project quality ensured that right things were taken into consider during the construction phase and in the requirements of the gates. With recognizing the right problem areas and making precise observations the actual impacts of the gate model to the project quality can be maximized.

Although, it must be noted, that the current state analysis done in this research is based mostly on the interviews, in which the quality can always vary. The content of the interviews rely strongly on the relationship between the interviewer and the interviewee on how honest and straight opinions will be collected. Also the subjective interpretation of the researcher must be noticed. When making observations and interviews about the research target and theme, the individual interpretations of the researcher are always somewhat related to the conclusions. In this study, there were altogether quantitatively large amount of interviews made, and so the repetitions of certain issues which came up in many interviews confirm the reliability of the conclusions made. Also, the information was gathered from multiple resources to improve the reliability of the findings and corroborate the observations.

Even the model has been proven to be suitable for practice, the generalization of the model straight to other companies or organizations is not so simple. As the model is constructed according to the special characteristics and needs of the target company, it is probably suitable only for very similar companies having the same kind of project business. But instead the actual model, the principles behind the gate model can be well suitable for companies with project business. Principles complied in the gate model, such as proactive approach, proceeding only with sufficient requisites and doing things right at first, early focus on quality assurance, increase of communication, visual project management and more standardized model to execute projects can be profitably applied to project operations also in other companies. Also, the principles mentioned above were found to be closely related to the project success factors and Lean project management principles in this study. In addition, generally can be noticed that if creating a new working method for organization that is suitable for practice also, a thorough understanding of the current state as well as a sufficient tryout of the model in practice is required to succeed. Also, the phases of the constructive research done in this study and the environment of the research target are described in detail to ease the evaluation of the applicability of this study to another case.

As the schedule regarding this thesis and the construction of the gate model was tight, one thing that could have been done in greater depth was the building of theoretical background. For example the general quality assurance of automation systems could have been more researched. But on the other hand, the understanding of the quality assurance of precise automation systems delivered by Valmet AUT was built during the interviews to the sufficient level to determine the required actions for the gates. Also, regarding the objective of this thesis, the main point was reasonably kept on the current state analysis to understand the possible ways to actually improve the quality in the projects of the target company.

7.3 Suggestions for further research

A logical and interesting topic of further research related to this study would be the validation of the benefits of the model created. Further study could be conducted after few years of the implementation of the model, so that enough data could be collected about the impacts of the model to project quality. Also the economic effects of the model to the quality costs generated in projects could be noticed and evaluated. In addition, the current literature among Lean project management is clearly missing empirical studies about the benefits of Lean project management. As there exists considerable large amount of empirical studies about Lean principles and applications regarding manufacturing environment, and also some about the Lean project management in construction industry, there is a clear gap in applying Lean principles and approaches in project environment. With further research conducted about the model also the impacts of applying Lean principles in project business could be researched.

As the importance of communication and effective flow of information came up in this study, a potential further study form the project success factors could be communication as a project success factor. For example the real impacts of effective transfer of information on the project time, cost or quality factors could be interesting field to study.

Also, regarding the literature review done in this thesis, there is clearly a less researched study area among the project manager’s role in project success. As notified in chapter 2.2. even though project manager is considered as one of the most important project success factor, no detailed features of the project manager are commonly discussed. In general, certain managerial skills are mentioned, such as communication skills, but no deeper discussion is provided. For example the leadership style or skills are not so much discussed, whereas among general management literature they are very much emphasized. Even though project success factors have been already somewhat discussed, the impact of the project manager to project success in more detailed level would be good addition to the research done in the field of project management.

7.4 Recommendations

In the target company, it is important to take into consider that even though the model was seen to be well suitable for practice according to the feedback gathered form the pilot trial, it will require adjustment and improvement in the near future. As the model will be implemented to the larger amount of projects, it is definite that more feedback will be gathered and new issues brought up regarding the suitability of the model. Especially as the pilot projects used in this research were led from Tampere, and the model will be implemented to the global project operation and bigger variety of projects will be confronted. After implementation, the feedback from projects must be actively collected and analyzed, in order to do corrective changes to the model. The improvement and sustenance of the gate model must be a permanent practice also in the future and in order to implement Lean thoroughly into organization, emphasizing continuous improvement of processes in necessary (chapter 2.5.). Also, the project business of automation deliveries is fast changing project environment, and the model must be modified according to the changes for example in customer requirements, project management tools, organizational form or new technology.

Even though the construction process of the gate model was conducted in a close cooperation with Valmet AUT employees and the future users of the model, a significant concentration and effort should be put into the implementation of the model. The intention of the close cooperation during the research process was not only to ease the construction of the model but also to commit employees to the upcoming model. A lot of effort should be invested in the implementation of the gate model, as it will be a considerable change in the project operations of the target company. Also, the implementation and training phase will probably have a significant impact on the adoption and usage of the model in practice. As mentioned in chapter 2.2., one of the distinguished project success factors is the support from higher management, and it is probable that it is also a matter of high importance in the implementation project of the gate model. Especially in the beginning of the implementation the commitment of the management is crucial, and even the top management may be involved. When talking about continuous improvement

Related to the practical implementation of the model, the development of visual project management is recommended, for example new TV-screens with project statuses, or a special project room for project meetings, which includes the visual presentations of each project followed. Visual management could be realized with no major investments and it could improve the communication about project statuses remarkably.

7.5 Quality KPI's

As the new quality gate model has taken the project quality into closer focus in the target company, including the three project quality processes, quality planning, assurance and control, defined in the chapter 2.4., the next reasonable step could be the addition of the fourth process, quality improvement. As Rose (2005, p. 41) mentions, quality improvement is a necessary process while it is strongly associated with customer satisfaction and competitiveness. Especially, if regarding the long-term objective of reducing quality costs in the target company, to achieve continuous improvement and results, the improvement process us crucial. To create the beneficial change in organization, objective measurement and data is required, and therefore, the creation of indicators to measure the quality performance related to the gates could be the next reasonable development project to take into consider.

Also, to understand more closely and to demonstrate the impacts of the new gate model on the operation and project quality, it must be measured. A proper way to measure the project quality must be created also to define the problem areas in the future and to be able to concentrate the corrective actions and resources to right subjects. In addition, a measurement system is crucial in order to carefully estimate the impacts of corrective actions done and to guide the decision making.

As the project process is now described more detailed and standardized, key performance indicators or other measures could be related to the quality gates. With the implementation of the gate model, the same information can be gathered from projects, even regardless of the project size, which eases the project follow-up and data gathering remarkably. With more standardized way of project execution the improvement of the process is made easier. Although, in the development of quality indicators it is important to take into consider the whole end to end project, avoiding indicators that concern only a certain phase of a project done by certain function. Optimizing one phase in the project chain can cause unwanted impacts to the other project phases and may not improve the quality of the whole project.

As the project quality is seen in the target organization mostly as a combination of customer satisfaction, on-time and in-budget delivery with the product responding to the customer requirements (chapter 5.1.), some of those criteria could be reasonably used as a guidance to build key performance indicators for the quality of projects.

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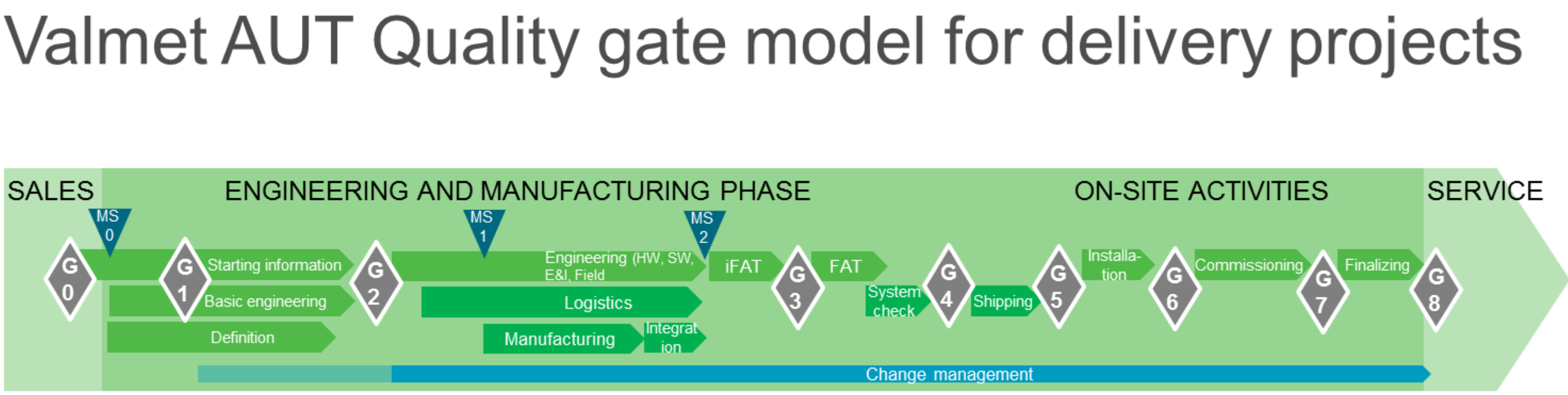
APPENDICES (1 PIECE)

APPENDIX 1: The delivery project flow chart.



G0	**Set up project**
G1	**Project started**
G2	**Start detail engineering**
G3	**Ready for cFAT**
G4	**Ready for delivery**
G5	**Ready for installation**
G6	**Ready for commissioning**
G7	**Take over**
G8	**Close the project**

G Project gate

MS Project Milestone

MS0	**Transfer from sales**
MS1	**Ready for Manufacturing**
MS2	**Ready for iFAT**