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QUANTITY TRENDING TO SUPPORT SCOPE MANAGEMENT IN PULP AND PAPER INDUSTRY PROJECTS

Master of Science Thesis
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ABSTRACT

Akseli Lahdensuo: Quantity trending to support scope management in pulp and paper industry projects
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This master's thesis provides a solution for defining and tracking the scope of a project in a standardized way by utilizing measurable quantities. Quantities in this thesis mean amounts of items, for example pumps, motors or building square meters. Quantity trending system aims to solve problems in defining and communicating scope and noticing scope changes in time which were the main reasons for conducting this research. Research question of this thesis was, "How a project based firm can utilize quantity information in managing scope in the context of pulp and paper industry projects?"

Defining and tracking the scope of a project is crucial for project success. Scope acts as the basis for negotiations and planning, but it also ensures that all project stakeholders aim for the same solution and know expectations towards them. Changes in the scope during a project can lead to, for example, cost and schedule overruns. Detecting changes in the scope and possible overruns in advance gives project participants time to react and conduct mitigative actions. Problems in defining and tracking scope are very common for large projects according to project management literature. In the case company there was no clear process for defining scope or tracking it. Scope management methods in the case company were project manager specific and developed by project managers based on experience. Differentiating scope management methods between projects complicated the scope communication and disabled comparability between projects.

Research was conducted in an engineering company operating in pulp and paper industry. This research draws from a cross sectional single case study. Qualitative data was collected by interviewing project managers and engineers inside the case company. Quantitative data was collected from engineering tools and documents produced during design and implementation phases of reference projects. Qualitative data was analyzed by coding the notes from interviews under detected topics. Quantitative data was used for validating the quantity list and the solution by calculating correlation between quantities and project characteristics.

As a result of this research, case company's current scope management process was visualized based on the qualitative data analysis. Current scope management process acted as the basis for developing the new quantity trending process. In quantity trending the scope of a project is defined, validated, controlled and saved by collecting standard list of quantities and short qualitative description seven times during project life-cycle. Quantitative way of defining scope makes the changes easily detectable and enables visualization of the scope, which benefits scope communication. Standardized format of scope enables data collection and benchmarking by making the projects comparable. Comparability between projects and the possibility to use data from completed projects can lead to more accurate estimates about scope and needed working hours for future projects. Quantity trending gives a warning about possible scope change in time if the estimates are done properly. Main findings of this thesis were that the scope of a project can be defined by using quantities, and quantity based scope can be used as a baseline for tracking purposes.

Quantity trending system is not directly transferable to other industries or companies. The process of quantity trending needs to be modified according to company's scope management process, and the list of items to be tracked needs to be modified to describe the scope of specific industry. This research describes the steps required for creating the quantity trending system for other industries as well.

Keywords: scope management, scope definition, scope monitoring, quantity trending

TIIVISTELMÄ

Akseli Lahdensuo: Määrällinen seuranta laajuuden hallinnan tukemiseksi sellu- ja paperiteollisuuden projekteissa
Diplomityö
Tampereen yliopisto
Tuotantotalouden diplomi-insinöörin tutkinto-ohjelma
Joulukuu 2020

Tämä diplomityö tarjoaa ratkaisun projektin laajuuden määrittämiseen ja seuraamiseen tiettyjä määrätietoja seuraamalla. Projekteille tyypillisiä määrätietoja ovat esimerkiksi pumppujen ja moottorien lukumäärät tai rakennusten neliömetrimäärät. Diplomityössä kehitetty määrätietojen seuraamisjärjestelmä *”Quantity trending system*” pyrkii antamaan ratkaisun projektin laajuuden määrittelemiseksi, laajuuden kommunikoimiseksi ja laajuudessa tapahtuvien muutosten havaitsemiseksi. Tutkimuskysymyksenä tässä diplomityössä oli ”Kuinka projektiyritys voi hyödyntää määrätietoja laajuuden hallinnassa paperi- ja selluteollisuuden projekteissa?”

Laajuuden määrittäminen ja seuranta ovat projektin menestyksen kannalta keskeisiä tekijöitä. Projektille määritetty laajuus toimii suunnittelun ja neuvotteluiden perustana sekä varmistaa, että kaikilla sidosryhmillä on sama käsitys projektin tavoitteista. Projektin aikana tapahtuvat muutokset projektin laajuudessa voivat johtaa aikataulun venymiseen ja kustannusten kasvuun. Laajuudessa tapahtuvien muutosten havaitseminen ajoissa voi mahdollistaa korjaavien toimenpiteiden toteuttamisen. Kirjallisuuden perusteella voidaan todeta, että ongelmat laajuuden määrittämisessä ja laajuuden muuttuminen projektin aikana ovat tyypillisiä ongelmia suurissa projekteissa. Kohdeyrityksessä laajuuden hallinnankeinot olivat projektipäällikkökohtaisia ja kehitetty projektipäälliköiden kokemuksen perusteella. Toisistaan poikkeavat laajuuden hallintamenetelmät projektien välillä vaikeuttavat erityisesti laajuuden kommunikointia ja projektien laajuuden vertailua.

Tämä diplomityö toteutettiin tapaustutkimuksena insinööri- ja suunnittelutoimistolle, jonka yksi suurimmista toimialoista on paperi- ja selluteollisuus. Laadullinen aineisto hankittiin haastattelemalla suunnittelijoita ja projektipäälliköitä kohdeyrityksestä. Määrällinen aineisto on kerätty toteutettujen projektien suunnitteludokumenteista ja yrityksen käytössä olevista suunnittelutyökaluista. Laadullinen aineisto analysoitiin kategorisoimalla haastatteluista saadut muistiinpanot tunnistettujen aiheiden alle. Määrällistä aineistoa hyödynnettiin määrälistan ja kehitetyn prosessin validoinnissa analysoimalla korrelaatioita projektin määrätietojen ja ominaisuuksien välillä.

Tutkimuksen tuloksena kohdeyrityksen nykyinen laajuuden hallinnan prosessi määritettiin ja sitä hyödynnettiin kehitettävän määrätietojen seuraamisjärjestelmän perustana. Määrätietojen seuraamisjärjestelmällä projektin laajuus voidaan määrittää, validoida, hallita ja tallentaa keräämällä määrätietoja ja lyhyt laadullinen kuvaus projektista seitsemän kertaa projektin elinkaaren aikana. Määrätietojen kautta määritetty projektin laajuus on helpommin seurattavissa kuin laadullisesti määritetty laajuus. Seuraamisjärjestelmän säännöllinen hyödyntäminen mahdollistaa toteutettujen projektien määrätietojen hyödyntämisen uusien projektien suunnittelun ja arvioinnin tukena. Määrällisesti esitetty projektin laajuus voidaan visualisoida ja mahdolliset muutokset laajuudessa ovat helposti havaittavissa eroavaisuuksina määrissä, mikä helpottaa laajuuden kommunikointia eri sidosryhmille. Tutkimuksen päähavaintoina huomattiin, että projektin laajuus on mahdollista määrittää määrätietoa hyödyntämällä ja että projektin laajuuden seuranta voidaan toteuttaa määrätietojen avulla.

Kehitettyä ratkaisua ei voida suoraan soveltaa muilla teollisuudenaloilla tai muissa yrityksissä, sillä toimiva määrätiedon seuraamisjärjestelmä vaatii teollisuudenala- ja yrityskohtaisia muokkauksia. Tämän tutkimuksen periaatteita noudattamalla on kuitenkin mahdollista luoda samankaltainen järjestelmä muiden teollisuudenalojen ja yritysten projektien laajuudenhallinnan tukemiseksi.

Avainsanat: projektin laajuuden hallinta, laajuuden määritys, laajuuden seuranta

PREFACE

I am grateful for applying to Tampere University of Technology back in 2015. University has given me more than I could have ever hoped for. Even though this thesis is the last step of my studies for the time being, it is safe to say that although my studies are officially over the learning will continue.

I am thankful for the case company for giving me the opportunity to combine work and studies in this research. Thanks to all the employees of the case company who were able to participate in this research during the interviews and data collection. Special thanks to Philippe for guidance and for giving me the possibility to focus on the thesis. These past few years working in AFRY have already taught me a lot, and I am eagerly waiting for the challenges and opportunities ahead.

I would like to thank professor Tuomas Ahola for all the feedbacks given during the thesis process and for guiding the way of the research. Thanks also to Miia Martinsuo for providing fresh view and comments at the final meters of the thesis.

The biggest thanks of all goes to my parents who have supported me in my studies all the way from first grade in 2003. I am grateful for the friends I have made during my studies, and for the memories created together with them during these years. Special thanks to Ida-Kaisa for all the help in finalizing of the thesis and studies.

Vantaa, 13.12.2020

Akseli Lahdensuo

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ABBREVIATIONS

BoQ	Bill of Quantities
CO	Change Order
KPI	Key Performance Indicator
PDRI	Project Definition Rating Index
QEPSD	Quantity Engineering Project Scope Definition
WBS	Work Break Down Structure

1. INTRODUCTION

First chapter of this research tells about the background of the thesis, for example why the research was conducted and what where the main objectives. This thesis aims to offer a solution for utilizing quantitative information as a help in scope management process. Research was started because the case company had detected issues in the scope communication, detecting scope changes and reusing data from completed projects. This thesis is conducted for AFRY Finland Oy and the researcher has worked in the company before starting the research.

1.1 Business case

Well defined and managed scope is one of the key factors behind a successful project (Caldas & Gupta, 2017). Scope describes what the project is about and what participants need to do, so it is evident that it has to be done properly. Consequences of poorly managed and defined scope are cost overruns, delays and decreases in quality (Dumont et al., 1997). In the case company of this research problems with scope management have caused challenges in customer relationship, scheduling and resource usage.

This research's case company is an engineering company offering project management and design services for large industrial projects. This research is a part of case company's development project called "Bill of Quantities". Reasons for starting the development project in the case company were difficulties to justify increase in engineering hours during implementation and difficulties to create baseline for project scope. This research focuses on smaller part of the development project and the aim is to create a system for defining and tracking project scope with quantity information. In project management literature measuring is common topic and there are measuring systems created at least for risk, time, cost and quality of the project, but for scope management there were only few studies available (Chritamara et al., 2001; Song & AbouRizk, 2005).

There were three main business reasons identified in the case company for starting this research. Reasons for starting this research are listed in Figure 1. Reasons are linked to problems that the case company has with scope management. First problem is how to detect scope changes in time in order to mitigate the consequences. Second problem is how to communicate the scope and the changes in easily understandable way towards project stakeholders. Third problem is with using scopes and collected data from previous projects to support scope management in new projects. All these problems are related to not having standard process for defining and controlling scope as a part of scope management.

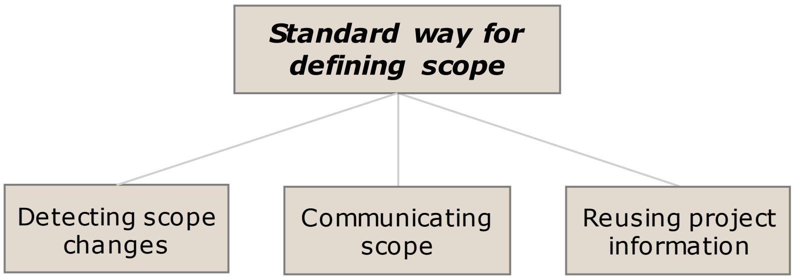

Figure 1: Reasons for starting the research

Defining a scope that would remain the same throughout the whole project is practically impossible (Caldas and Gupta, 2017). In projects of the case company, changes in the scope are often not easily detectable, they can happen for example because customer wants something to be added or changed or because the construction site was not what was expected. These changes might not be visible in the end result, which is for example still the same pulp mill, but they can affect the scope of engineering by creating new tasks to be done or documents to be produced, which are often hard to detect. Changes in the scope can force the engineering company to use more man hours than was expected and delay the whole project drastically. First problem is detecting changes in scope and estimating their impact for the project. Noticing scope changes and drifting from original scope in advance would give project management more time to react and plan corrective actions.

Second problem with scope management is how to communicate the scope and possible changes in it. Lack of communication and misunderstandings about the scope are a big reason behind project failures (Mirza et al., 2013). Even small changes, like adding one more equipment to a certain room, might add up to hundreds of hours to engineering, which might sometimes be difficult to explain to the customer. Communicating the changes in the scope towards project stakeholders and making customers to understand, why engineering needs more hours and the whole project might be delayed because of a small change, is hard to do.

Third problem that the case company has is with learning from completed projects and reusing the information produced in them. This is issue since data from completed projects and benchmarking could offer a good basis for defining the scope of a new project (Song & AbouRizk, 2005). In the case company there is no clear way to compare new projects to previously completed projects which means that estimates for engineering hours and project durations, have to be done for every project based on expert opinion. Collecting and analyzing scopes of projects consistently could offer valuable information for estimation and planning purposes.

The problems defined in the case company are closely related to scope management process and especially to steps of defining and controlling the scope. Scope management process can be portrayed as a three part process with steps of defining, validating and controlling the scope (PMBOK, 2018, p. 130). Scope management process is a constant process that aims to keep projects on track, so it is a crucial part of project management.

In project management literature there were no direct solutions that would help in every part of scope management process of engineering projects. Most of the solutions presented in the literature focused on single parts of the scope management process. For example for defining the scope there were tools like PDRI and QEPSD available, but they could not be used as they were to solve all the problems in the case company. (Dumont et al., 1997; Song & AbouRizk, 2005) For controlling the scope there were multiple methods like trend analysis and ESM available, however these methods did not offer solution for the first parts of the scope management (PMI, 2018, p. 170; Valdés-Souto, 2017). This research was conducted, because there were no solutions available in the literature for covering all the parts of scope management process.

1.2 Industrial projects from idea to production

Before industrial facilities like paper mills get built, there are usually three phases of engineering before final investment decision. Typical phases of industrial projects in the case company are displayed in Figure 2. Every phase of project life-cycle has its own scope, which needs to be handled with scope management process. Scope management process works the same way for every phase of the project, first the scope is defined and validated, before controlling it while doing the project work (PMI, 2018, p.130).

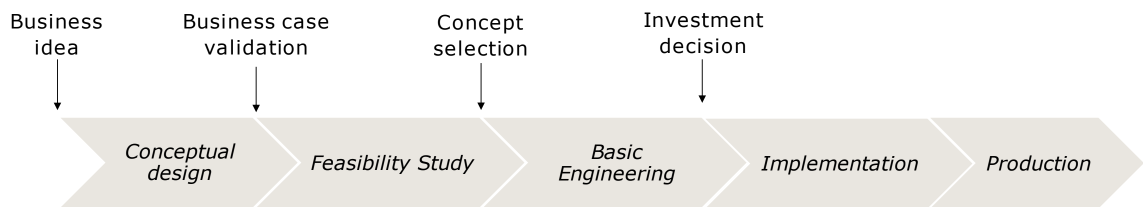

Figure 2: Engineering phases

Engineering projects are iterative processes, where changes happen during project and designs need to be adjusted accordingly (Nicholas & Steyn, 2017, p. 386). During engineering phases case company creates for example cost estimate, layouts, equipment lists and permit studies for the implementation phase of the project. Tasks and deliverables done during engineering phases vary during project, for example in conceptual design the main deliverables are usually cost estimate and process description whereas in basic engineering main ideas might be PI-diagrams for the facility. This means that all the phases of project have their own scope.

First of the three engineering phases is conceptual design, customers order conceptual design after getting a business idea. The main idea of conceptual design is to get verification is the concept possible to implement and is it financially reasonable, by the end of conceptual design customer can validate their business case. If customer wants to continue with the project case company offers feasibility study in order to create more accurate concepts of the facility. After feasibility study customer selects concept and continues to basic engineering, if the project still seems reasonable to implement. Final investment decision is usually done after basic engineering. After every engineering phase the scope of the implementation phase can be defined more accurately.

Customers can decide to end the project after any engineering phase, if for example the investment cost is too high or construction would be too complicated. After final investment decision projects proceed to implementation phase. Before project implementation begins the scope of the project is first defined based on the engineering phases and then validated in the contract negotiations. During implementation phase actual construction work and detail engineering happen simultaneously. Implementation is the phase where most of the unexpected changes happen due to delays and changes in equipment and customer’s new needs. During implementation the scope needs to be monitored and updated when changes occur. After implementation phase is completed and the facility is ready customer can start the production.

Changes in key stakeholders can happen at any time during the project life-cycle, for example in case company’s projects it is not uncommon that the customer changes main machinery supplier between basic engineering and implementation, or that the main engineering company is changed before moving on to next engineering phase. Design can also be awarded for multiple companies, there might for example be one company doing civil engineering, one HVAC engineering and one the rest of the engineering. After every change the scope needs to be adjusted accordingly, so that every party knows what is expected from them.

Targeted cost estimate accuracy after conceptual design phase is ±30%, after feasibility study it is ±20% and after basic engineering ±10% (AACE, 2004, p.121). Cost estimate accuracy increases because the scope and concept get clearer after each engineering phase and the engineering company knows better what kind of buildings, equipment, pipes and construction works are needed.

Figure 3 displays how the scope of a project gets clearer and changes as the design proceeds. The gray area between min and max scope portrays the area where engineering company assumes that the project cost, duration and scope will in the end be. The area for possible cost and duration will get smaller as project gets closer to implementation since plans are getting more detailed, equipment decisions are made and more information about the site is received.

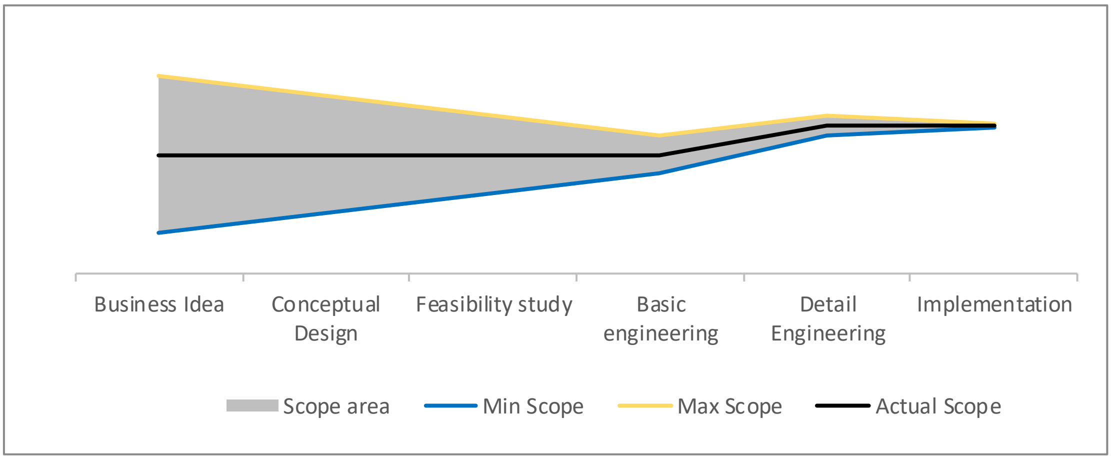

Figure 3: Development of scope

In Figure 3 there is a change in the scope after basic engineering, which affects the direction of the scope. This change could, for example be caused by customer selecting different supplier for machines than previously expected. As Figure 5 shows, engineering companies face a problem in defining the scope precisely for projects during the design phases. In their research Vuorinen and Martinsuo (2019) noticed that inadequate information and requirements from project can lead to engineering mistakes and cause changes to planned scope during later phases. Having enough time for design phases of large industrial projects is needed in order to create accurate plans.

1.3 Goals and scope

This research aims to develop a system for utilizing quantity information as a part scope management process in the case company's projects. Scope defines what the project is about, for customer the scope can be the facility they want, but for engineering company the scope can also be defined by using quantities or documents. Quantities in this research mean amounts of items, they can be for example meters of pipes, amount of motors or weight of concrete needed in foundation of the facility. Relationship between quantities and the whole project is visible in Figure 4.

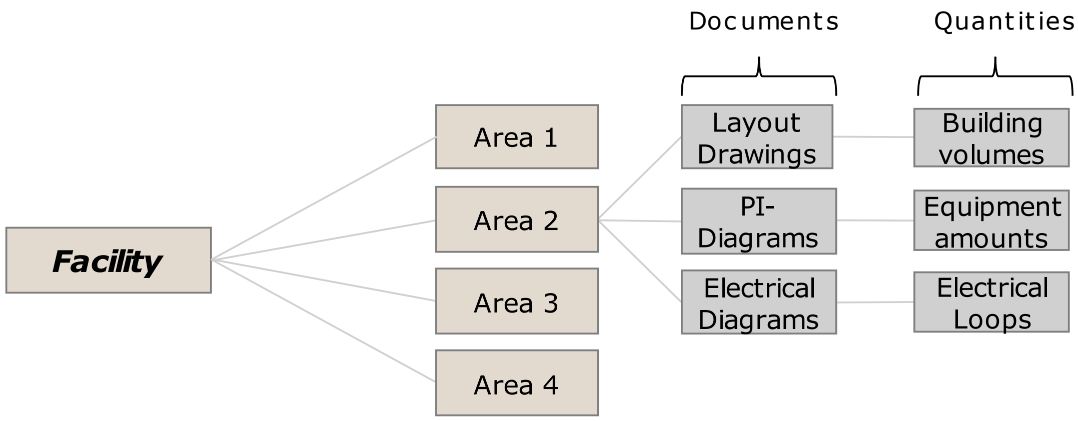

Figure 4: Relationship between quantities and project

Figure 4 shows how the designed facility is first broken down into smaller areas, for example buildings. Every building in the facility will require different kind of drawings and diagrams before it can be built. The drawings and diagrams describe the areas as a sum of different kind of quantities, for example electrical diagram could indicate that there are four motors and 200 meters of cable in this area. The amount of these motors and cables are called quantities. So, quantities are the amount of items that engineers design and how their work can be described in quantitative way.

At the moment in the case company there is no standardized way of defining scope or utilizing quantities in the scope definition. Scope management is still mostly handled based on the experience and expertise of project managers. In quantity trending the idea is to collect and track quantities in project to clarify and monitor the scope of a project. In quantity trending the quantities could be used to create a baseline and definition for project scope during sales and planning phases. So, quantity based scope definition could also be used as a basis for contract negotiations and resource planning. When the project gets closer to end the baseline and scope get more and more accurate as concept gets clearer. During engineering and implementation phases quantities could be used for scope control, for example dramatic increase in amount of pumps or pipes could mean that project is drifting from the original scope or that project will need more time for engineering and implementation phases.

Case company selected quantity trending as the most promising method for scope management, since quantities are available in every case company's project and designing the amounts and locations of them is one of the main tasks of the case company. Project management prefers quantitative information since it is easy to communicate and understand (Snider et al., 2018). Quantities offer exact way to define scope with quantitative data, while usual methods offer subjective and qualitative description about the scope. Measurable scope is also easier to track and the changes are easier to explain than in written scope description. Other scope tracking methods would require more training and they would have to be adjusted to case company's project handling processes.

This research will focus on the end of basic engineering and the implementation phases. This is because after basic engineering the concept of facility to be built is quite clear and there are quantities available, which can be used to define scope. Implementation phase is also included in the research, because the scope changes are more common during implementation and actual amounts of quantities are available at the end of project. Actual quantities can offer valuable information for planning of new projects and analyzing the differences between actual and planned figures.

One of the biggest customer segment for case company is pulp and paper industry. In this research the main focus will be in pulp and paper industry's projects because there is lots of experience from them inside the case company. Pulp and paper industry's projects are typically huge investments with lots of uncertainties. Pulp and paper industry's projects require years of engineering before investment decision and even the construction phase for completely new pulp mill can take up to three years. Therefore the importance of well-handled project and scope management is evident

Main objectives guide the direction of the research and affect the decisions regarding research strategy and methods. This research's main objectives, that need to be considered in order to achieve the targeted outcome, are presented in Figure 5.

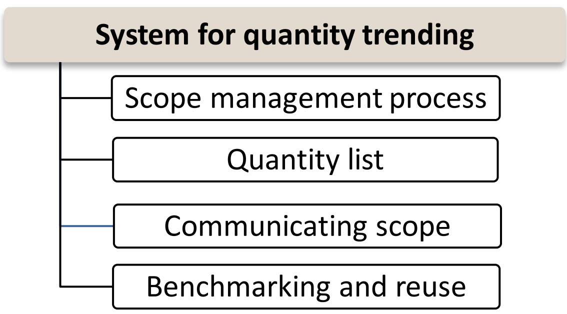

Figure 5: Main objectives of the research

Because the aim of the whole research is to develop a quantity trending system to support scope management, the first step is to describe the current scope management process of the case company. Understanding of the current scope management process is needed before possible changes to it can be suggested. In order for quantity trending to work it needs to have a clear process which defines at least tasks and responsibilities. Process should also include description how quantities are collected, when they are collected, from where the data is collected and how scope changes are detected. Defining a new process requires understanding of the project life-cycle in the case company and characteristics of engineering phases.

In parallel with clarifying the process for quantity trending the list of quantities to track needs to be finalized. Finalizing the quantity list it the second objective of this research. The most important output of the quantity trending process is the information about scope changes, which can be detected with comparison between actual and expected quantities. In order to get reliable results the quantities in the quantity list need to be selected correctly. There is a preliminary list of quantities in the case company collected from engineering experts but there is not yet certainty that the list is sufficient for this purpose. This preliminary list is first validated with interviews, and after that again with correlation analysis. Quantity list is one of the most important outputs of this research since it will be used as the basis for whole quantity trending process.

Second to last of objective of this thesis is to find a way to communicate the scope of engineering and the changes in it in an easily understandable way. By having a standard list of quantities the scope can always be communicated in the same way, however the changes and their consequences need also to be visible for the project stakeholders. Understanding how the scope should be defined and communicated requires input from employees that have been involved in the customer communication and know how the communication should be done.

Last objective of this research is to find out how quantities from old projects could be reused for benchmarking and learning purposes. By analyzing old projects relationships between quantities and, for example working hours or duration of the project can be found. Quantities from old projects can offer valuable insights when estimating resource needs, scope of a new project or when trying to learn from past mistakes. Past mistakes can also be found by analyzing the quantity trends during completed projects, for example dramatic changes in volume of the buildings can for example indicate possible design error in previous phases or misunderstandings about site conditions.

1.4 Research questions

This research aims to develop a system for quantity trending to support scope management. Developing a working system for scope management that utilizes quantitative information requires depth understanding about company’s project management processes, knowledge about scope management basics and analysis on relevant quantities. Therefore the main research question is:

"*How a project based firm can utilize quantity information in managing scope in the context of pulp and paper industry projects*?"

Research question aims to answer the business need and it should provide a comprehensive answer to the problems in the case company related to quantity trending. Answering the research question in detail creates basis for solving the business problem. Answering to the main research question requires answers to some sub questions as well. All the research questions are visible in the Figure 6. Research questions guide the way of the whole research. All the research questions are not case company specific, but finding the answers for these will help in the development of quantity trending system.

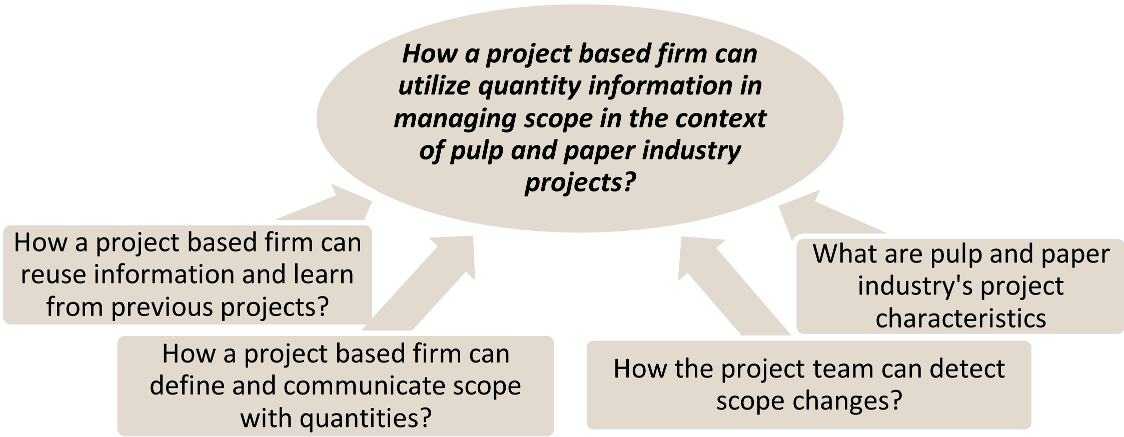

Figure 6: Research question and the sub questions of the thesis

First sub question is, "how a project based firm can define and communicate scope with quantities?" Answering this question helps in identifying how scope definition should be done and can quantities be utilized in identifying scope. Quantitative way of defining scope needs to be defined before questions about detecting changes and benchmarking can be answered.

Second sub question is, "how the project team can detect scope changes?" Answering this question requires understanding what are the sources of changes and what should be measured or done to detect scope changes.

Third sub question is, "How a project based firm can reuse information and learn from previous projects?" Benchmarking in project business is hard, since all projects are unique but answering this question should help in the benchmarking issue.

Fourth sub question is, "what are pulp and paper industry's project characteristics?" Engineering projects differ from typical implementation projects, since most of the output are intangible and developing scope is rather hard. Answer to this question should help in defining when the quantities should be collected during a project and from what sources.

1.5 Structure of thesis

This research began with introduction about the business need and background of the research. Second part of the study is literature review on topics relevant to research questions. Literature review is conducted by searching literature from databases like Andor, Google Scholar and Emerald. Literature review's key search words were, "Scope management", "Project scope", "Quantifying scope", "Scope definition". Search words were also combined using Boolean operators "AND" and "OR". Literature review helps in defining the phenomena behind the subject and gives examples about similar studies and systems already researched and developed.

Third part of the study is research methodology and data collection. Research methodology chapter describes the context of the research, methodology selections and describes the methods of analysis used in this research. Results are presented in the fourth part, where data is used to validate the quantity list by analyzing the importance of certain quantities for the project and comparing how different quantities have actualized in completed projects. Qualitative data is used to describe the current situation of company's scope management and to define the process for the new solution system. Quantitative data is used to validate results of interviews and the outputs of the created system.

After analyzing the collected data, the quantity trending system is created. Data analysis results contribute to the principles and features of the system. Analyzing results will be validated using the developed model for one more example project from the same industry. Last part of this research is discussion and conclusions, which describes how the research question was answered, what are the practical implications, what are the limitations of this research and what could be directions for future research.

2. LITERATURE REVIEW

Literature review of this research offers background for scope management as a part of project management, engineering project characteristics, reasons for scope changes and how benchmarking could be used in project business. Literature review also aims to provide information about tools created for scope definition and how quantitative data can be utilized in scope management purposes. This chapter first describes what is scope, how scope management process works and why it is done, second part talks about what kind of tools and methods there are for defining scope and how quantitative data can be utilized in the scope management. The last part describes the characteristics of pulp and paper industry's projects.

2.1 Scope in project management

"Project is a temporary endeavor undertaken to create a unique product, service or result" (PMI, 2018, p.4). Project business differs from regular businesses like factories, since projects always have an ending, but in order to know when the project is completed the end result needs to be defined. The end result is defined in the scope statement which is the description of the project scope, major deliverables, assumptions and constraints and it gives common understanding about project for all stakeholders (PMI, 2018, p.154). Scope statement needs to be clear for all the stakeholders to ensure that everyone is reaching for the same goal (Mirza et al., 2013). Project scope is defined with inputs from project charter, project management plan, project documents like assumption log, risk register and enterprise factors (PMI, 2018, p.151). So, project scope is the summary telling what all the stakeholders together aim for.

Scope can have both qualitative and quantitative side, for example acceptance criteria can be defined in quantitative way, while the deliverables of the project are described in qualitative way (PMI, 2018, p.154). For a paper mill project the high level qualitative scope for engineering company could for example be, "Designing a paper mill to specific location with a capacity of 500 000 tons of paper annually with specific equipment supplier". Shortened quantitative version of the same scope could be something like "paper mill will require design for approximately 800 process equipment and 50 pumps".

If simplified projects have three different constraints which define them, these three constraints are cost, time and quality (PMI, 2018, p.4). Project owners are often more concerned about cost overruns than the other aspects of project performance, this is visible in Cooke-Davies (2002) research were 136 projects were analyzed, average cost overrun was 4% but average delay of duration was 16%. This means that scope management and quality of the end product can be overlooked by project management since problems and consequences of scope issues are not easy to communicate or to define, while delays and cost overruns are easier to detect and communicate. Project management's purpose is to handle project so well, that it is finished in time and in budget with agreed scope and quality.

PMBOK (2018, p.10) tells that project management is applying skills, knowledge and techniques to meet requirements of the project, resolve issues and satisfy stakeholders. Project management is responsible for example for planning, resourcing, communication between stakeholders and change management. Scope management is one of the 10 knowledge areas under project management in PMBOK (2018, p.60). Also according to PMBOK (2018, p.60), project management consists of five different process groups, which are initiating, planning, executing, monitoring and controlling and closing. Process groups are needed in the listed order during projects. Scope management is part of planning and monitoring and controlling groups but it also gets inputs from other groups, for example from project charter made during initiating (PMI, 2018, p. 60). In large industrial projects, that can last for years, the importance of scope management as part of project management increases since there are lots of steps where the project can go wrong and forget the requirements agreed in the beginning. Scope management's role as a part of project management and process groups under it are displayed in Figure 7.

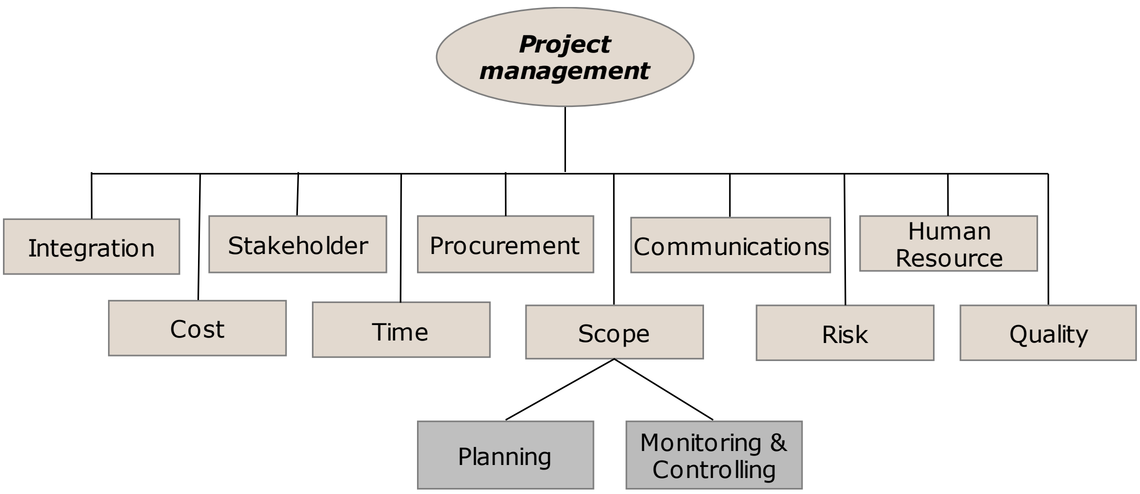

Figure 7: Project management knowledge areas, based on PMBOK (2018, p.60)

As can be seen from the Figure 7, scope management is only one of the ten knowledge areas under project management. Pinto and Slevin (1987) tell that main factors behind successful projects are linked and happen in certain order, for example well defined plan and scope help in overall project management and monitoring of project. This also means that failure in the first steps of the project can cause problems in the later steps during the implementation. So, it can be stated that scope management is important and crucial for success in every project starting from planning phase.

There is a lot of literature related to success factors of a project. The main factors behind successful projects are communication, top management support, skillful project management, availability of qualified resources and clearly defined objectives. (Pinto & Slevin, 1987; Frödell et al., 2008; Caldas & Gupta, 2017) Factors vary especially between countries and industries, Nguyen and Ogunlana (2004) tell how adequate funding during project is one of the top 10 factors in Vietnamese construction projects, while other studies like Caldas and Gupta (2017) and Frödell et al. (2008) did not even mention funding as a factor. Clearly defined objectives is a scope management related factor and it was one of the factors common for every industry and country.

Well defined and communicated scopes decreases the possibility of overlapping between contractors and allows contractors to focus on their role in the project (Caldas & Gupta, 2017). Scope needs to be defined for every participate in the project separately, for a construction company the scope in pulp mill project could be to build foundations and access road for certain areas of the mill. Poorly defined and managed scope can lead to, for example poor quality, cost overrun, delays and poor customer satisfaction (Dumont et al., 1997). This is because scope largening during the project leads often to extra work which increases the costs and duration. One of the biggest factors behind successful project according to Cooke-Davies (2002), are documenting scope well and handling scope changes correctly.

One of the key processes of project management is communication, in scope management communication is needed especially for making all the stakeholders understand their role, responsibilities and tasks (Ajmal et al., 2019). Pinto and Slevin (1987) show that communication and monitoring are constant factors of success throughout the project, while other success factors happen only during certain point of project lifecycle. Because scope management is constant work throughout the project, there is a process available in the project management literature to make sure that all the aspects of scope management are covered.

2.2 Scope management process

The main goal of scope management is to ensure that customer requirements are met with agreed responsibilities. In PMBOK (2018, p.130) scope management is portrayed as an constant process, with three steps defining, validating and controlling the scope.

Defining scope is a part of planning process group while validating and controlling the scope belong to monitoring and controlling process group of project management (PMI, 2018, p.60). This means that the scope management process starts already in the planning phase of the project and continues until closure. The process is constant, since if there are changes happening in the scope, redefining and validating of the scope is needed before going back to controlling the scope. Simplified scope management process is visible in Figure 8.

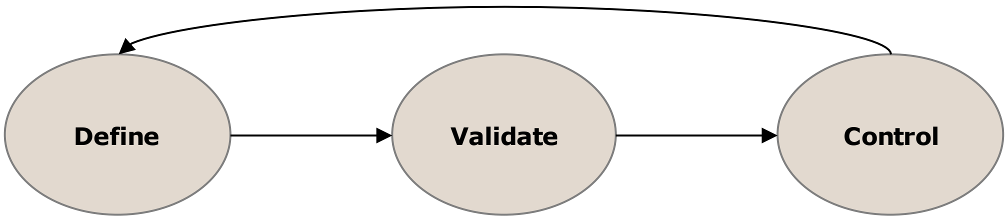

Figure 8: Scope management process (PMI, 2018, p.130)

Different sources and techniques like expert judgement, data analysis, product analysis can be used as a help for different phases of scope management (PMI, 2018, p.153). In the case company the usual way for defining the scope is a combination of discussions with stakeholders and engineering experts. Some researchers have tried to create lists that would define the scope with simple list of items, these researches are industry specific and the techniques are not commonly used in pulp and paper industry (Dumont et al. 1997; Song & AbouRizk, 2005). All in all, it seems to be hard to find a tool that would cover all three steps of scope management from defining to controlling.

2.2.1 Defining scope

The process of scope management begins with defining the scope, where inputs like project charter, project management plan and company specific aspects are considered in order to define what the project should include and what not (PMI, 2018, pp. 130-134). Scope is seen differently depending on stakeholder’s role in the project, customers can see large pulp mill projects as a sum of different areas, where as electrical engineers might think of hundreds of electrical diagrams they produce. However, in the end the scope is the same for both parties, they just define it using different methods. Defining the project scope in detail might not be the top priority for the customer but it is beneficial for the project success. (Frödell et al., 2008)

Discussions and constant communication between stakeholders is crucial, while defining the scope (Frödell et al., 2008). Expectations and requirements from stakeholders need to be taken into account when defining scope but at the same time the purpose of the project cannot be compromised. User involvement during design phases helps in having all the requirements included and reduces the need of change management later on in the project (Frödell et al., 2008). Involvement of contractors during planning benefits in defining the objectives and their capabilities. Discussions with contractors during scope defining process can be beneficial, since contractors experience might help in the responsibility and task planning (Chritamara et al., 2001). In conclusion, all the stakeholders need to be discussed with, before defining the scope in too detail (Fageha & Aibinu, 2013).

After the scope is defined, it is according to PMBOK (2018, p. 61), used to create the work break down structure for the project. In pulp and paper industry's projects the amount of stakeholders is high, there might be tens of contractors doing work in the site and tens of equipment manufacturers delivering equipment to the site. So, defining scope for each individual contractor requires lots time in the beginning of the project (Mirza et al., 2013). Scope of the whole project is the basis for defining scopes for smaller parts of project and contractors. After all the scopes are defined, the scope of the whole project can be seen as the sum of smaller scopes, because the scope can be summed up with bottom up approach by utilizing the work breakdown structure (Song & AbouRizk, 2015).

Scope can also act as the baseline for the project planning, but it needs to be updated when changes occur, so that the consequences of change can be estimated and project plans updated (Cooke-Davies, 2002). Having realistic assumptions, for example towards manhour planning, when planning and defining project scope is a key factor for successful project planning (Caldas & Gupta, 2017). Realistic assumptions can be conducted for example based on expert opinion or benchmarking (Caldas & Gupta, 2017). Choo and Gibson (2001) however mention that getting unbiases opinion about the level how well defined scope is might be tricky, therefore either neutral assessment person or comparing expert judgements in meetings to reach consensus is needed when defining the scope.

Floricel and Miller (2001) based on their research, conduct that the bigger the project the more important well defined scope and plan are to deliver project successfully. However, not everything can be planned before construction, there will always be a need for site specific modifications, for example in contractors work (Vuorinen & Martinsuo, 2019). During the implementation phase there are minor scope changes happening constantly in the site, which the project manager might be completely unaware of. This is why it is important also in the pulp and paper industry's projects to follow the scope and possible changes to it during the project implementation.

2.2.2 Validating and controlling scope

Validating and controlling of the scope are part of monitoring and controlling process groups of project management (PMI, 2018, p. 60). After the scope for the whole project and the scopes for individual contractors are defined, all the scopes need to be according to scope management process validated before moving on to controlling them. During validation the experience and expertise of stakeholders should be used, to make sure that the scope is valid and possible to achieve within budget, time and quality aspects (Chritamara et al., 2001). Caldas and Gupta (2017) tell that validating the plan with key personnel and stakeholders to ensure comprehensiveness of the plan and the baseline can also increase trust trough transparency and communication between stakeholders. During validation with stakeholders, the working procedures for scope management should also be agreed, for example how change requests are handled and how to react when delays are noticed.

Staying in scope is crucial for project success especially money and schedule wise, because scope changes have tendency to lead to extra work (Vuorinen & Martinsuo, 2019). Scope changes can happen, for example because of expected or unexpected risks realizing during project (Floricel & Miller 2001). Almost every project faces the need for changes and almost every change affects either time, cost or quality of the project (Lester, 2014, p.97). There are two ways, how scope of a project can change during the project, first one is agreed scope change and the second one is called scope creep. Scope change and scope creep are different things, scope change is agreed change to the scope discussed with stakeholders after noticing the need for change, whereas scope creep happens without decision and can force project team to change the scope. (AACE, 2004, p. 233) Both scope change and scope creep can affect the duration, cost and quality of the project, but the difference is that scope changes are known and scope creeps need to be detected. Task of scope control is to detect creeps and react to scope changes and creeps. Once the scope creeps are detected they can be treated as a scope changes. Outputs of the scope control are work performance information, change requests, updated project management plan and document updates (PMI, 2018,pp. 170-171).

Change control system should follow three steps, set standard, compare actual to standard and if needed make corrective actions to remove variance (Nicholas & Steyn, 2017, p.390). Making changes to the original scope requires change requests, that should be handled by the project team. Change request should include information about what needs to be changed, why and how will it affect the project. (PMI, 2018, p. 170) Received change request needs to be evaluated compared to the originally defined scope statement. Project scope statement defines, if changes are seen as additional work or are they included in the original plan. Project statement also helps in re-planning and creating new baseline for the project if needed. (PMI, 2018, p.154) Controlling the scope is also relevant for other parts of project management since if the changes are not noticed and reported, the effects on the cost and schedule are not noticed in time.

During design phases of pulp and paper industry's projects one of the main focus areas of project management should be to control scope, so that there will be no features outside the scope added without change orders (Nicholas & Steyn, 2017, p. 387). If new features are added or something is changed in the plan it almost always has an effect on the budget, time or quality of the whole project. During implementation phase the scope needs to be handled by defining it well in the beginning for every participant, and after that with change requests received from participants.

2.3 Scope changes

Possibility of scope changes is the reason why scope needs to be monitored during the implementation and the occurrence of scope changes often leads to need of defining the scope again (PMI, 2018, p.171). Knowing the typical reasons for changes in the scope is crucial for this research since knowing the sources of scope changes helps to identify how they should be tracked and detected during projects. Typical reasons can also indicate where the focus of scope management should be at certain points of project and how the scope should be defined. According to Caldas and Gupta (2017) defining scope for large industrial projects that would stay the same through the whole project life-cycle is practically impossible. This is quite obvious, since for example changes in requirements, unexpected site environment, regulation and underperforming contractor can trigger the need to modify original scope in pulp and paper industry's projects.

Keane et al. (2010) tell that reasons for scope change are often categorized based on their source, the categories are owner, consultant and contractor related reasons. Hsieh et al. (2004) however divided causes into two main categories administration and construction, construction reasons included for example site conditions and safety, while administration reasons were for example legislation, coordination and political aspects. It is relevant to understand, that every stakeholder in a complex project can affect the end result since if tasks are not done in planned time, cost and quality, they will affect other parts of the project.

Researchers had different ideas that what are the most relevant reasons for scope changes. According to Keane et al. (2010) errors from any party involved are the biggest reason for scope changes and lack of communication the second biggest. Amoatey and Anson (2017) on the other hand, told that requirement changes are the main reason for changing the scope, while Floricel and Miller (2001) said that lack of communication is the biggest reason. Because researchers had different approaches towards defining the most critical reasons, the most common reasons for scope changes based on literature were listed in Table 1. All the mentioned reasons from 10 different studies were collected and combined into table, where reasons that had less than 2 mentions were excluded.

Table 1: Reasons for scope changes

Reason for Scope change	***Ajmal et al., 2019***	***Alnuaimi et al. 2010***	***Amoatey & Anson, 2017***	***Chritamara et al., 2001***	***Fageha & Aibinu 2013***	***Hsieh et al., 2004***	***Keane et al., 2010***	***Memon et al., 2014***	***Mirza et al., 2013***	***Song & AbouRizk, 2005***	***Mentioned***
Complexity of the project	X				X		X	X		X	***5***
Design error or change		X		X		X	X	X			***5***
Inadequite information		X		X		X	X			X	***5***
False assumptions / Bias estimate		X				X			X	X	***4***
Poor Project Management					X	X		X		X	***4***
Unclear definition of objectives	X	X	X	X	X		X	X	X		***8***
Lack of communication	X	X	X	X	X		X		X		***7***
Unforeseen risks	X		X	X							***3***
Lack of experience and skill	X	X					X	X			***4***
Client requirement change	X	X	X	X		X	X		X		***7***
Inadequate project funding							X	X			***2***

As can be seen from Table 1, the most commonly mentioned reasons for scope changes in literature were lack of communication, change in requirements, unclearly defined objectives. Lack of communication and unclearly defined objectives are project management related issues, but changing requirements towards the project are caused by the project owner. More rarely mentioned reasons lack of experience, funding and complexity are mostly construction related issues that contractors can cause.

The biggest reason for changing the scope in Table 1, was unclearly defined objectives of the project. Poorly done design phases and lack of communication can lead to stakeholders having different view about the objectives (Mirza et al., 2013). Stakeholders can also have similar view about the objectives, but it might be insufficient in order to meet the project requirements, this usually happens if the plans are not comprehensive or design has flaws (Alnuaimi et al., 2010). Objectives of the project are the basis for planning, so if they are not correctly defined, changes to them will lead to need for re-planning.

According to Table 1, client change in requirements was the second biggest reason for scope changes in all projects. In case company's projects customers have often so much power compared to the case company, that they can drive changes through how they like. Project managers might also be unwilling to say no to customers, since their goal is to meet customer requirements (Amoatey & Anson, 2017). Customer changes are a major cause of scope changes in design projects and design companies do not want to complain about customer changing the scope since it might affect the relationship (Vuorinen & Martinsuo, 2019). Changing customer requirements will always have impact on the project plan and scope since meeting the new requirements might require, for example changes in the designs and updates to the schedule. Changing requirements can be handled with sufficient change order management starting from the beginning of the project (Amoatey & Anson, 2017). Need for scope changes should be minimized by sufficient planning, communication and defining objectives clearly during the design phases.

Needs for scope changes are linked, for example poor communication and design errors will usually lead to unclear definition of objectives or false assumptions. Communication and collaboration between stakeholders is crucial for succeeding in all the other factors (Floricel & Miller, 2001). Communication issues were also the second biggest issue resulting in scope changes in Table 1. Importance of constant communication between stakeholders as a scope control technique is evident. Large industrial projects face more unexpected surprises than other projects, this happens especially because the amount of stakeholders is higher. Amount of stakeholders also increases the amount of different laws and regulations affecting the project. (Floricel & Miller, 2001) Since communication has such a big role and it affects all project stakeholders, it can be seen as a common task of every stakeholder, and project management is responsible for facilitating it.

According to Table 1, the biggest factors how consulting and engineering companies affect the need for change order are design changes, engineering errors and false assumptions. Engineering errors and design changes are often human errors and they are bound to happen in every large project. False assumptions however are not necessary, they often happen because of lack in experience or information (Alnuaimi et al., 2010). Assumptions can be made more accurately by collecting and analyzing information from past projects, and also by including experienced workers in the estimation tasks.

Scope changes can also be caused by individual stakeholders of the project, for example inadequate funding might force the project owner to decrease the magnitude of the project (Memon et al. 2014). Keane et al. (2010) tell how lack of expertise and skills of individual stakeholders can cause changes to the scope if, for example contractor is not able to perform the tasks expected from it. Scope changes related to individual stakeholders should be considered as risks already during the planning phase of a project. Other reasons for scope change that were mentioned more rarely, for example inadequate information and complexity of the project should also be considered when planning the project and defining scope. These reasons are present in every project and some of them might force the scope to be changed (Alnuaimi et al., 2010). Not every risk and missing information can be considered during project planning. Therefore, in addition to defining the scope well, project management needs to monitor the scope and detect possible changes.

In conclusion the amount of scope changes could be reduced, by following scope management process more precisely and especially by defining scope in more detailed with all the project parties. Having a common understanding about the scope requires at least constant communication, accurate planning information and well-handled project management. By having all these aspects handled correctly, project management could tackle most of the typical scope change reasons and therefore reduce the amount of scope changes.

2.3.1 Detecting scope creeps

During all the phases of project, controlling the scope is relevant in order to detect possible risks of overruns in advance (PMI, 2018, p.171). If noticed in advance project managers have time to react to scope problems, for example with corrective actions like change requests. Detecting scope creep requires constant monitoring of the scope which, on the other hand, requires baseline scope that acts as the basis for monitoring. The baseline scope should be done already in the planning phase of a project but since it requires resources and does not create value immediately, it might be postponed or not done at all. (Valdés-Souto, 2017).

Techniques for detecting scope creeps are for example variance analysis and trend analysis (PMI, 2018, p170). In variance analysis baseline scope is compared to actual scope, and checked if corrective actions are needed. In trend analysis the development of scope examined over time to see trend, and to detect is the project going better or worse. Methods collected from literature for detecting scope creeps are listed in Table 2.

Table 2: Methods for detecting scope creep

Name	***Description***
Number of change orders (Choo & Gibson, 2001)	Tracking the amount of change orders indicates magnitude of change in the scope of a project.
Variance analysis (PMI, 2018, p.170)	Comparing current scope towards baseline scope defined in the beginning of project.
Trend analysis (PMI, 2018, p.170)	Comparing current values towards planned values so far.
Earned Scope Management (Valdés-Souto, 2017)	Scope is described with amount of use cases in software projects. Change in the amount indicates that scope is change.

Choo and Gibson (2001) told that amount of change orders can be used as metric for noticing that the scope has changed from the baseline. Using amount of change orders gives a good picture about how much did the scope change from original, however it does not give the project management anytime to do corrective actions in time. Therefore change orders are a good metric for analytics after project, but cannot be used as a tool for project management to control or monitor scope during project. Valdés-Souto (2017) presented a framework where the scope is described with use cases and the amount of them is tracked and estimated, in order to detect variance to baseline estimate.

In this thesis one of the aim was to easily detect and communicate changes in the scope. For this target the best techniques is variance analysis, where the current scope is compared towards baseline scope. For the variance analysis to work the scope needs to be defined in a unambiguous way, so that the current scope can be easily compared to the baseline scope. Quantitative data is easily comparable, it is explicit and it also indicates clearly any variance in the scope. Quantitative definition requires technical understanding and expertise from the stakeholders and estimators, so it is not suitable for every project (Collins et al., 2017).

2.3.2 Reacting to changes in scope

Scope of the project might change due to agreed scope change or due to detected scope creep that forces the project team to modify the scope. Project management should always evaluate what is the best way in specific project to react to changes in the scope based on targets of the project and requirements from project stakeholders. Creating working procedures about how to react to scope changes is the first step of scope management, and should be done before starting the project (Caldas and Gupta, 2017). Having procedures ready eases the project management work during project, when every stakeholder knows how to act when scope creep is detected. Validation of the need for changing the scope can be done by project management asking themselves "Is this change necessary?", before accepting any changes (Lester, 2014, p.99). After the need is validated and deemed necessary for the project, the effects need to be estimated and communicated to project owner who is responsible for approving the change and the consequences of it (Lester, 2014, p.99).

In the end project owner makes the decision, if the change request is accepted because it might have significant effect on budget or schedule of the project. While making the decision about whether to approve or reject change request project owner needs to understand what changes, why and how does it affect the project as a whole. Communicating the impact and the need of scope change is often a hard task for project manager. For example in pulp and paper industry the consequences of adding one equipment to the plans might vary from 10 to 1000 more engineering hours.

Last step of change management after getting the change approved by project owner, is to make corrective actions to project plan and scope (Nicholas & Steyn, 2017, p.390). Vuorinen and Martinsuo (2019) found four different patterns of change management, creating alternative paths, re-planning, catching up and optimizing performance. After scope changes and creeps some project managers choose to accept that they occur while others try to fight them to the end (Hussain, 2012). Suitable action depends especially on project situation, for example in the beginning of project re-planning might be better solution than catching up.

Floricel and Miller (2001) tell that project management usually reacts to changes using either adapt or fight approach. Adapting usually means making changes to project plan and schedule, whereas fight could mean working more hours or increasing resources. These approaches usually lead to earlier mentioned schedule delays or cost increases. Change management actions noticed from project managers by Vuorinen and Martinsuo (2019) were negotiations with customer and schedule modifications, while people working with the design had to adjust their working methods to minimize schedule impacts. Reason for this is that increase in project management working hours will not help in speeding up the project, but increasing resources in engineering can minimize the consequences of scope change.

Before the selected corrective action can be taken, the change of scope and consequences of it needs to be communicated and agreed with the owner of the project. This is why it is important to be able to describe the change and consequences of it clearly.

2.4 Quantity trending

In quantity trending the aim is to support scope management process, especially by helping in estimation, detecting scope changes and easing the scope communication towards customers. In quantity trending the scope is defined with amount of items to be designed and with short qualitative description of the project. So, the targeted solution includes both qualitative and quantitative sides of scope definition. It is clear that using only quantitative definition is not sufficient since if just knowing the quantities does not clarify what the project is about. Therefore the qualitative description of the scope is always needed. Both ways of defining scope have their strengths and weaknesses, which are listed in Figure 9.

	Qualitative scope definition	***Quantitative scope definition***
Strenghts	Flexibility (Collins et al., 2017)	Comparison between projects (Song and AbouRizk, 2005)
	Doesn't require technical knowledge (Collins et al., 2017)	Project planning benefits (Song and AbouRizk, 2005)
	Easy to modify (Collins et al, 2017)	More accurate description (Chritamara et al., 2001)
	Inputs for scope definitions are qualitative (PMI,2018)	Easy to detect changes (Collins et al., 2017)
	Easy to create (Song and AbouRizk, 2005)	
Weaknesses	Possibility for misunderstandings (Song and AbouRizk, 2005)	Requires work to create (Song and AbouRizk, 2005)
	Comparison between projects hard (Song and AbouRizk, 2005)	Requires technical knowledge (Song and AbouRizk, 2005)
	Changes harder to detect (Collins et al., 2017)	Every input cannot be quantified (PMI, 2018, p.140)
		Lack of flexibility (Collins et al., 2017)

Figure 9: Strengths and weaknesses of qualitative and quantitative scope definitions

As can be seen from Figure 9, understanding the quantitative scope requires understanding of the items listed and how they are linked to the project. So technical knowledge is needed for quantitative scope definition, while qualitative scope is often easier to understand (Collins et al., 2017). Qualitative scope can however leave some room for interpretation which might lead to misunderstandings (Song & AbouRizk, 2005). Scope definition is done in collaboration with all the project parties, and if there is no technical knowledge available from other parties, the quantitative definition cannot be done. It is also true, that all the aspects of scope cannot be turned into quantified form, for example some tasks or parts of project plan can only be explained in qualitative way (PMI, 2018, p.140).

Scope of a project is constantly updating because of decisions made and concepts clarified during implementation. Unforeseen risks and changes can cause the need to define scope again if the changes, for example affect the workload of contractor (Chritamara et al., 2001). Because project scopes are updating, the way of definition needs to be flexible enough to be modified according to changing needs. Between qualitative and quantitative scope definitions, the qualitative definition is more flexible.

Quantitative scope enables comparison between projects and benefits the estimation calculations of new projects, if the definition is done in a standard way (Song & AbouRizk, 2005). Comparability is hard to achieve with qualitative scope definition and qualitative definitions are harder to use as a base for calculations. Changes are also easier to detect from the quantitative definition, since changes in quantities compared to changes in text or phrasing are usually easier to detect (Collins et al., 2017).

Quantitative scope definition requires more work during the definition, since the scope needs to be defined in lower level than in qualitative definition but at the same time quantitative definition is often the more accurate one (Chritamara et al., 2001; Song & AbouRizk, 2005). Therefore combining both ways of definition requires more work during defining but enables tracking and comparability benefits of quantitative scope, without compromising the understandability of qualitative scope.

Overall usage of quantitative metrics as a tool in project management has increased drastically during past years, this is happening because amount of available data is increasing and world is moving towards more data driven decision making (Vanhoucke et al. 2016). Quantified measures are favored in management, since they give wanted information quickly, are easy to understand, can be automated and require less analysis than qualitative information (Snider et al., 2018). Vanhoucke et al. (2016) also mention, that companies involved in projects produce massive amount of data, for example in the case company all the working hours are booked for specific project and task, all engineering is done with programs that support data collection, and all the estimates are done based on quantitative data. Available data in the case company includes, for example meters of pipes and volumes of buildings which are created as a part of design. Amount of available data and possibility to automatize work are also aspects that could be utilized in the quantitative scope definition.

2.4.1 Deliverables and quantities

PMBOK (2018, p.60) shows that WBS for the whole project is created based on the defined scope. Song and AbouRizk (2005) tell how the scope of engineering could be defined with work break down structure of the whole project, because engineering scope is a sub scope of the whole project's scope. Issue in this approach is that the companies buying engineering are not sure about the scope of engineering since they are not always aware what is actually needed Therefore the WBS does not always include all the tasks needed to define engineering scope in detail.

In the engineering projects the lowest level of WBS is deliverables which are for example documents or models created. According to Hanna and Ruwanpura (2007) the deliverables of engineering can be used for project planning purposes but they can also be used for defining the scope of certain engineering discipline, because they are the actual outputs of engineering. Deliverables describe quite well the scope of engineering disciplines but the workload needed to complete certain deliverable can vary a lot between projects.

In construction projects a document where the needed items and their amounts are collected is called bill of material or bill of quantities. Bill of quantities is also a way for estimating the costs of a project based on amount of items using bottom up approach. (AACE, 2004, p.384) Lester (2014, p.61) tells how bill of quantities of a project can be collected by analyzing, for example architectural drawings and counting quantities from documents, for example for walls and ceilings. There is a clear correlation between deliverables of engineering and quantities, for example the more there are buildings the more architectural drawings are needed, which means that the engineering scope is bigger. This indicates that the same quantitative information used in bill of quantities method, could also be used to describe the output and therefore the scope of engineering.

2.4.2 Creating quantity trending system

Targeted quantity trending system is measuring system used as a part of scope management during defining, validation and controlling parts of scope management. Tracking project and its health is one of the key factor behind project success (Cooke-Davies, 2002). Measuring is also one of the easiest ways of detecting problems and deviations or verify the performance of a project. In quantity trending the measuring is needed especially during the controlling phase of scope management in detecting the possible scope changes. Because needs for measuring vary, modifications need to made according to the nature and size of the company, projects and project teams (Gries & Restrepo, 2011). Since pulp and paper industry's projects are long lasting, project specific modifications are feasible to do, in smaller projects modifications might require too much time compared to the duration of the project.

According to Parmenter (2007 p.10) measuring is a constant process with simple steps it starts by selecting what needs to be monitored, involving personnel to figure right way of tracking, create the measuring system, use it and make adjustments based on experiences. Especially the outputs of the measuring system are crucial in quantity trending since they could be used for communicating the scope towards customers during scope definition and validation phases. In this research the issue is with finding the right quantities that would define the scope of pulp and paper industry's project.

Parmenter (2007, p. 160) states that key personnel and project management should be included in the development and reviewing the metrics, in order to make them learn and believe in the system. Involving key personnel can also offer insights on what is actually relevant and what needs to be measured. In general, measuring systems should be used frequently, acted by senior management, indicate what actions are needed, tie responsibility down to team, have impact and encourage appropriate action (Parmenter, 2007, pp.10-12). Fulfilling all these requirements might be hard and will require motivation from the project management to develop. It is also relevant to notice that, if company uses too many metrics measuring might face inflation, this often happens when every possible metric is created, whether is needed or not (Gries & Restrepo, 2011). Therefore it is important first to design what needs to be tracked and involve key personnel in development, and not to create too complicated way for defining or tracking the scope. Engineers doing the actual designing and project managers leading the projects should be included to the development of the quantity trending system, in order to find right quantities and suitable process for the measuring.

In order to work the quantity trending system needs data. Data collection for measuring needs to be comprehensive enough to cover every aspect and give adequate picture, but cannot be too big because it would be costly and hard to handle (Nicholas & Steyn, 2017, p.391). In quantity trending the data could come directly from design tools used in engineering of pulp and paper industry's projects. Gries and Restrepo (2011) bring up the problem with harmonizing the available data which is often collected from various sources. In the case company this problem is very relevant since almost every engineering discipline uses their own design tools. IT needs of creating measuring system needs also be considered, because measuring systems require data collection, maintaining and development (Gries & Restrepo, 2011). Pulp and paper industry's projects have lots of stakeholders which increases the amount of data sources and makes the collection and utilizing data harder.

Quantity trending system should not be updated in less than six months since constant updates make measuring pointless and decreases the validity, because in a short time frame company cannot draw any conclusions (Parmenter, 2007, p.159). So, after the quantity trending system is created it needs to be tested for a while and then validated by checking if measures are giving right information. Validation of the information received from quantity trending system can be done by benchmarking. Benchmarking should always be part when measuring is done frequently, because it increases the reliability of conclusions (Parmenter, 2007, p.17). Benchmarking requires comparability between items analyzed. Therefore the list of quantities should remain standard in all the projects, where quantity trending is used. Creating standardized quantity list for quantity trending system requires depth analysis on previous pulp and paper industry's projects, and insights from experienced personnel who have worked in those projects.

2.4.3 Benefits of quantity trending

Problems in noticing the changes of the scope and communicating the scope to project stakeholders was one of the issues behind this research. Utilizing quantities could especially help in the comparison between baseline and actual scope, and make the changes more detectable. Setting the baseline is the first step of using a measuring system since all the figures afterwards are compared to the baseline, in quantity trending this step would be defining the scope (Vanhoucke et al., 2016). Scope definition or the baseline for a project can be created with quantities, for example based on previous projects by benchmarking. Nicholas and Steyn (2017, p. 158) tell that many companies have the false assumption that projects are too unique for learning purposes or benchmarking. There are always similar aspects between projects, they might be, for example, certain areas in the project or ways how the project is handled. In pulp and paper industry's projects the process areas needed in the facilities are quite standard and have very little variation in them between projects. Therefore benchmarking could definitely be utilized in pulp and paper industry's projects.

Reusing the information collected and lessons learned in the previous projects was one of the main objectives of this research. Benchmarking is relevant for this research since according to Alnuaimi et al. (2010) collection of data from previous projects could help in defining scope and give information for estimating the actual figures for a new project. Song and AbouRizk (2005) state that data from previous projects and benchmarking offer the best information for defining the scope of a new project. Using data from previous projects requires benchmarking process and at the moment there is no such a process in use at the case company. Pulp and paper industry's projects have lots of similarities when comparing for example needed equipment and buildings between projects, there are however big differences, for example, in construction methods and supplier selections. Therefore benchmarking in pulp and paper industry projects requires understanding of the project specific decisions, just comparing capacity and equipment is not enough when looking for similar projects.

Benefits of benchmarking are clear in the literature, if done correctly it can lead to cost savings and better project management through learning and improving (Bhutta & Huq, 1999; Kim & Huynh, 2008). Improvements achieved by benchmarking in project based firm can for example be better estimates, more comprehensive plans or more suitable manning plan. Benchmarking gives good chance to learn from past experience, but the team needs to want to learn and analyze the past projects. (Kim & Huynh, 2008) So, personnel of the case company needs to be motivated to conduct the extra work need for collecting and analyzing quantitative information, for example by showing them the benefits of properly done benchmarking with examples.

Important part of benchmarking, similarly to measuring, is to involve key personnel and make the benchmarking constant process (Bhutta & Huq, 1999). Person that was not involved in the project might not know the project specific aspects that affect performance, for example country related differences in regulation. In order to understand the project as a whole Kim and Huynh (2008) suggest that collected information needs to be validated with people involved in the project to verify the findings. The importance of validating data is huge especially when doing the benchmarking for the first time, during the first analyses wrong conclusions might happen, and those need to be corrected before implementing any changes.

2.5 Quantitative scope management methods

There was no measuring system for utilizing quantitative information and benchmarking in literature that would exactly solve the needs of the case company. However, there were some methods in literature that used standardized formats and quantitative information in the scope definition. Chritamara et al. (2001) showed that a model can be created to estimate the magnitude and the scope of a project based on quantitative information from previous projects. In order to work the model will need deeper understanding about relevant information to use and project characteristics in specific industry. This means that universal solution for defining the scope of a project using quantitative way cannot be developed. In this sub chapter three methods developed to support scope management, that have similarities to quantity trending, are presented. These methods are project definition rating index presented by Dumont et al. (1997), quantity engineering project scope definition presented by Song and AbouRizk (2005) and earned scope management by Valdés-Souto (2017).

2.5.1 Project definition rating index

One tool that can be used to help in scope management process is project definition rating index “PDRI” presented by Dumont et al. (1997). PDRI is an checklist tool created for construction industries projects, it defines scope of a construction project using standardized checklist of elements and assessing the level how well they are defined. The working principle of PDRI is to use standard list to define scope and asses how well the scope is defined. The principle is different to quantity trending but the idea of using standard checklist in the scope definition is relevant for quantity trending as well.

All 70 elements in the checklist are given a number between 0-5 to indicate what is the level of definition, 5 meaning poor definition, 1 meaning complete definition and 0 not applicable. Elements have weighting to indicate their importance towards the whole scope, for example poorly defined design criteria could have more weight to the end result than poorly defined objective statement. When the level of definition is estimated for all the element is the checklist, the score can be calculated as a sum of element’s points to indicate the level of detail of the whole scope. Low score means well defined scope and high score indicates poorly defined scope (Cho & Gibson, 2001). Example of one section’s elements and the scoring of them is visible in the Figure 10.

Element		Definition Level					Score
		1	2	3	4	5	Score
A. Business Strategy							
	A1. Building Use	1	12	23	33	44	
	A2. Business Justification	1	8	14	21	27	
	A3. Business Plan	2	8	14	20	26	
	A4. Economic Analysis	2	6	11	16	21	
	A5. Facility requirements	2	9	16	23	31	
	A6. Future Expnsion	1	7	12	17	22	
	A7. Project Selection considerations	1	8	15	21	28	
	A8. Project Objectives statement	1	4	8	11	15	
				Category Total (max 214)			
B. Owner Philisophies							
	B1. Reliability Philosophy	1	5	10	14	18	
	B2. Maintenance Philosophy	1	5	9	12	16	
	B3. Operating Philisophy	1	5	8	12	15	
	B4. Design Philosophy	1	6	10	14	19	
				Category Total (max 68)			
C. Project Requirements							
	C1. Value Analysis Process	1	6	10	14	19	
	C2. Project Design Criteria	1	7	13	18	24	
	C3. Evaluation of existing facilities	2	7	13	19	24	
	C4. Scope of Work Overview	1	5	9	13	17	
	C5. Project Schedule	2	6	11	15	20	
	C6. Project Cost Estimate	2	8	15	21	27	
				Category Total (max 131)			
				Section Total (max 413)			

Figure 10: Example of PDRI section and scoring (Dumont et al., 1997)

Other sections of PDRI checklist include elements like project strategy, heat & material balances, flow diagrams, long lead items and training requirements (Dumont et al., 1997). In their research Dumont et al. (1997) were able to present that projects where the PDRI score was 200 or less out of the maximum 1000 were more often completed in original budget and schedule, whereas projects with score over 200 had more cost overruns and delays. This means that there was a clear relationship between well-defined scope and project success time and money wise. Choo and Gibson (2001) also state that well defined scope does not necessarily mean successful project, but combined with good project management and execution it will increase the probability of success. PDRI tool was created for construction industry's projects but the same logic could also be applied to other projects with standard structures, by creating industry specific checklist to present the scope of the work.

2.5.2 Quantity engineering project scope definition

Song and AbouRizk (2005) present framework called “QEPSD”, meaning quantity engineering project scope definition. This framework is used to estimate working hours in an engineering project based on outputs of engineering, for example tons of designed items. So, in QEPSD the scope can be defined with quantities of items to be designed. In QEPSD the aim is to estimate needed hours more accurately based on the estimated scope defined in quantitative way. This framework does not help in the scope definition but it clearly indicates that if the scope is defined in quantitative way it has clear benefits in project planning.

Song and AbouRizk (2005) created their framework by analyzing completed projects and their outputs, by using this approach they were able to create more accurate estimate about needed manhours than experienced estimator. Writers noticed that the complexity has high correlation to work hours, and therefore weighting needs to be created and all the deliverables cannot be similarly valued (Song & AbouRizk, 2005). This is clear since not all the engineering tasks are as hard, for example drawing straight pipeline between two areas and designing turns to piping are done by the same person but designing the turns requires much more time and effort due to complexity. In QEPSD the complexity of each possible item was weighted, standard item was steel column with no fittings and it was called “drafting unit”. All other items were weighted based on how hard they were to design compared to designing a steel column.

Estimate made by engineering expert and the estimate made with QEPSD framework are visible in the Table 3. The estimate made by the engineer is visible in the third and fourth column of the table, the estimation is done by multiplying weight of each item with productivity factor, which was decided by the experienced engineer. The QEPSD estimate is in the columns five, six and seven of the table. (Song & AbouRizk, 2005) Needed units per each category are visible in the sixth column of Table 3 they are calculated based on distributions created based on completed projects. Each quantity unit requires same amount of work, so in the end just counting quantities times hours needed per quantity unit describes the needed working hours for a project.

Table 3: QEPSD estimate based on quantities (Song & AbouRizk, 2005)

		Engineer		QEPSD			
Category	**Weight**	**Productivity (h/t)**	**Estimated hours (h)**	**Distribution**	**Quantity (unit)**	**Estimated hours (h)**	**Productivity (h/t)**
Rolled shapes 15-31 kg/m <2,744 mm	2,44	26,07	63,61	Normal	176,68	82,19	33,68
Rolled shapes 32-61 kg/m <2,744 mm	3,46	16,53	57,19	Normal	113,39	52,16	15,08
Rolled shapes 62-100 kg/m <2,744 mm	0,29	14,45	4,19	Normal	3,62	1,67	5,76
Rolled shapes 32-61 kg/m >2,744 mm	14,37	14,39	206,78	Normal	161,69	74,38	5,18
Rolled shapes 62-100 kg/m >2,744 mm	3,32	12,48	41,43	Normal	18,22	8,38	2,52
Rolled shapes 101-150 kg/m >2,744 mm	5,90	9,83	58,00	Normal	32,21	14,82	2,51
Bracing-WT Section <2,744 mm	1,16	27,20	31,55	Normal	99,50	45,77	39,46
Bracing-WT Section >2,744 mm	2,43	24,13	58,64	Normal	61,65	28,36	11,67
Girt < 30kg/m >2,744 mm	0,17	22,53	3,83	Uniform	4,04	1,86	10,94
Girt > 30kg/m >2,744 mm	0,42	16,14	6,78	Uniform	2,31	1,06	2,52
Web stiffereners W14-W18 section	0,02	59,00	1,18	Normal	2,28	1,05	52,50
Web stiffereners >W18 section	0,05	59,00	2,95	Normal	5,00	2,30	46,00
Ladder	0,92	40,49	37,25	Normal	82,68	38,03	41,34
Handrail-straight	4,40	44,66	196,50	Normal	457,39	210,40	47,82
Handrail-sloped	1,76	44,66	78,60	Normal	337,34	155,18	88,17
Total	***41,11***	-	***848,5***	-	***1558,00***	***717,61***	-

Quantity units estimated with the QEPSD method are calculated from item specific distribution, visible in the fifth column of Table 3. Distributions were calculated from completed projects, and they show how many quantity units are needed for designing specific weight of certain item. (Song & AbouRizk, 2005) Distributions increase the accuracy of the estimates, since they are based on completed projects and take into account the complexity difference between designing first and second ton of similar item.

Song and AbouRizk (2005) started their framework development with the realization that cost and hours used for an engineering should not be used to define scope of engineering, because they are the inputs and the scope could be better described with outputs like documents or design objects. When creating the framework one key factor of success is finding the right quantities that describe the scope of engineering. Quantities for describing the scope should have high correlation to the inputs of the project, so in engineering projects the correlation should be to working hours (Song & AbouRizk, 2005). Even though the QEPSD has differences to quantity trending, QEPSD shows that by analyzing completed projects and by benchmarking the estimates about engineering work can be made more accurately.

2.5.3 Earned scope management

Earned scope management, shortened “ESM”, is a method developed for tracking the scope performance of software projects. In ESM the scope of a project is defined in the planning phase by listing the use cases that act as the basis for planning. List of use cases will then act as the baseline of the project’s scope. During the project implementation estimate of use cases to be completed is updated and compared to the baseline. (Valdés-Souto, 2017) Creating a baseline in the beginning of the project and updating the estimates during implementation is the key principle in detecting scope changes in quantity trending as well. ESM method is not directly transferable to other industries since the ideas behind use cases is not transferable, for example, to construction projects. In quantity trending the use cases are replaced with quantities of selected items but the quantitative scope definition and variance analysis could be conducted in a similar way.

Valdés-Souto (2017) shows how the scope changes are clearly visible when new use cases are added to the project scope, and how the scope can be easily visualized with a chart. The visualization of software project's scope is visible in Figure 11. Blue line describes the scope of the whole project in use cases per each month, orange line shows how the scope is planned to be filled and gray shows how the scope is actually filled. The scope changes made during moths four and five are clearly visible as an increase in the blue scope line.

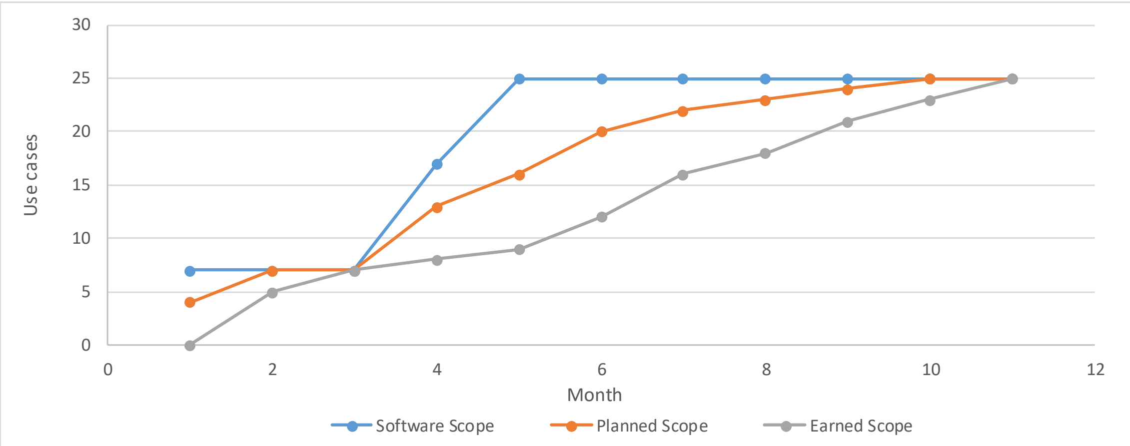

Figure 11: ESM Scope visualized (Valdés-Souto, 2017)

As can be seen from Figure 11, the ESM method also enables the tracking of the scope's progress since the earned scope can also be measured with use cases. In quantity trending the planned scope could be assessed per each of the tracked item, in order to see how much is still left to be designed.

2.5.4 Comparison of methods

The three presented methods all have similarities and aspects that could be useful in the quantity trending system. All of the methods offer a way for defining a scope but the objects used in the definition are different between the methods. PDRI and ESM also enable monitoring of the scope. PDRI and QEPSD both also enable benchmarking and reusing the data from completed projects. The ways how methods help in scope management are listed in Table 4.

Table 4: Comparison of quantitative scope management methods

	PDRI	***QEPSD***	***ESM***
Scope definition	Standard checklist of elements	Standard list of objects	Amount of use cases
Communication	List of elements	Estimate of needed hours	Visualization of baseline, planned and earned scope
Monitoring	Level of detail vs. baseline	-	Use cases vs. baseline
Benchmarking	Lists from previous projects	Hour estimation based on completed projects	-

Dumont et al. (1997) tell how PDRI method offers a way for defining and communicating the scope with a list of elements to be done, while QEPSD method presented by Song and AbouRizk (2005) is used mainly for estimating the working hours and ESM method by Valdés-Souto (2017) describes the amount of use cases in the project.

Scope defined with QEPSD could only be monitored through used working hours (Song & AbouRizk, 2005). The monitoring of scope defined with PDRI can only be done by assessing subjectively the level of detail of individual elements. (Dumont et al., 1997). ESM method enables the monitoring of the scope by visualizing the differences between baseline, planned and earned scope (Valdés-Souto, 2017). Regarding the benchmarking, in PDRI individual projects can be compared and QEPSD utilizes the quantities collected from completed projects as the basis for estimation. Scopes defined with ESM method are not comparable, since use cases are so high level entities.

From these methods PDRI is the most suitable method for defining the scope of a project in a project based firm. In project based firm it is important that the scopes are comparable, so that they can be used as the basis for new projects. ESM method does not make the scope comparable between projects, and in industrial projects there is no such thing as use cases in the projects which could be used for defining high level target of the project. The communication and monitoring techniques of ESM method are the most suitable ones for making the scope easily understandable and changes visible for all the stakeholders of the project.

2.6 Pulp and paper industry’s projects

Because the scope of the whole project is more likely to change and harder to estimate in the beginning of a pulp and paper industry’s project’s life cycle, it is important to look into the characteristics of typical pulp and paper industry’s project and its life cycle. This will help in identifying when and why the scope might change or get clearer during the project.

In this research the focus is on pulp and paper industry's projects which are typical large industrial projects where investment cost can vary from few hundred million up to 2,5 billion euros (UPM, 2020). Industrial projects can also have a huge impact on companies or even on whole countries, for example UPM has started to build a pulp mill in Uruguay which, after production starts will generate electricity for about 1% of Uruguay's energy demand (UPM, 2020). Handling a project this big will require well defined plans and lots of project management activities. Since industrial projects are so complex, project owner companies often outsource engineering and project management work for companies with experience from similar projects.

2.6.1 Engineering phases

Engineering for pulp or paper mill can last up to 5 years, if detailed engineering during construction is included. Case company offers engineering for every need in these projects. Possible needs are for example piping, structural, architectural and HVAC engineering. Importance of successful engineering phase is evident since engineering mistakes can cause problems, like cost overruns and delays in the construction phase (Vuorinen & Martinsuo, 2019). Doloi (2010) states that during engineering phases the most important task is to validate the concept which allows the scope to be defined more clearly. In engineering phases case company creates process descriptions, layouts and drawings to describe how the facility will actually work. These engineering outputs describe the concept of the whole facility to be built.

Nicholas and Steyn (2017, p. 386) describe design phases as iterative processes, first element and technology related decisions are made to select needed equipment and guidelines for the process to fulfill requirements. After equipment and guidelines are designed all equipment, areas and parts need to be connected to create picture of the whole concept. Because engineering projects are iterative and concept is defined more precisely as the project proceeds, the scope can also be changing based on the decisions made regarding the concept. In the case company first disciplines to create design basis are process and mechanical engineering who according to customer requirements select equipment and create preliminary layouts and process descriptions for the facility. After first disciplines have first designs ready, other engineering disciplines can start their work based on the selections made in the beginning of project. Any change to the concept from the customer forces the engineering company to assess the design from the beginning, and might create a need for changing the scope (Doloi, 2010).

Because projects are coming more and more complex the need for design management is increasing (Doloi, 2010). In design management the importance of people management and team building is huge since the aim is to get the engineers to perform as well as possible. Measuring the performance of engineering and detecting possible changes is much harder than measuring the performance of construction works where the objectives are tangible. Changes to concept are also more likely to occur during engineering phases, than during implementation phase since customers are making decisions as the designs get more accurate. Therefore it is important for engineering companies to be flexible and to be able to estimate the consequences of changes accurately.

The scope of engineering phase is usually for example to assess the economic feasibility of the project or to design the facility with certain criteria. Customers usually want to hurry to construction phase after having a business idea, however cost of design is usually small compared to implementation costs, and sufficient design is crucial for the success of implementation and staying in schedule and budget during implementation phase (Nicholas & Steyn, 2017, p.388). This is why it is important to do the planning and engineering well before moving to implementation. Changing design usually leads to investment cost increasing during the whole project life-cycle (Nicholas & Steyn, 2017,p.388). The sooner in the project life-cycle possible changes to plan and concept are made the smaller the effect of changes will be to the budget and duration of the whole project.

The documents and drawings produced by the engineers during engineering phases describe the working principles and the concept of the facility with quantities. For example buildings, pipes and equipment are placed to the model. The quantities can vary a lot during the engineering because of changes in the concept are happening, decisions related to main machinery are maid and because more information is received, for example about site and regulation (Song & AbouRizk, 2005). So, in the beginning of engineering phase defining the scope based on the quantities is practically impossible because of constant changes.

Vuorinen and Martinsuo (2019) tell that project team needs to be involved in planning schedule and scope, because top management decisions or customer demands are not always possible to be delivered in, for example, given time frame. Defining the concept clearly in the beginning of project is one key factor behind successful design projects (Doloi, 2010). In order to get clear picture of the whole scope all the stakeholder need to be heard, this also increases the trust and commitment of stakeholders towards the project (Fageha & Aibinu, 2013). Engineers need input from other stakeholders for example customer is often responsible for giving information about the site and suppliers for providing specifications for the equipment that could be used in the facility. There is always a risk of mistakes when inputs for engineering are coming from multiple sources. Vuorinen and Martinsuo (2019) tell how insufficient information about the site and inexperienced suppliers can lead to engineering mistakes, these mistakes might not be detectable before the project actually goes to implementation and constructions begin.

2.6.2 Implementation phase

The scope of implementation phase is usually to build the facility designed earlier during the engineering phases, from this scope the engineering company is responsible for finalizing the designs and making needed changes to the plans according to additional information received. Design phases build up towards better project plan and more detailed concept which can be utilized in the implementation phase (Nicholas & Steyn, 2017,p.390). In the case company the implementation phase is usually the longest individual phase of a project's life-cycle.

Engineering phases define the scope of implementation phase but the design continues also during the implementation when more precise information is received form the suppliers. Inadequate project management and optimism bias plan are two biggest factors behind project failures during implementation (Floricel & Miller, 2001). Most common reasons for problems in project management during implementation are lack of communication between parties, bad quality of project plan, poorly defined scope and unforeseen risks realizing. (Pinto & Slevin, 1987; Dumont et al., 1997; Nguyen & Ogunlana, 2004)

Most of the reasons for problems during implementation are happening because of poorly executed engineering phases and because the amount of stakeholder increases drastically. During implementation phase there will be companies doing foundations, installations of equipment, construction works and delivering of materials in the site while designing of the facility continues somewhere else. In large projects there might be tens of different companies in the site and tens more working remotely towards the same goal, and in the end project success relies on customer, consultants, contractors, suppliers and end users working together (Lester, 2014, p.16).

Managing implementation phase of a project differentiates a lot from managing the design phases. In implementation phase there are more stakeholders, longer duration and more possible risks than in the design phases. The results are also usually tangible and easier to track since even visual inspection might give quite a good idea about the readiness of a certain part of project (Floricel & Miller, 2001). Amount of parties involved and working together increases the project managements role as an organizer and communicator. During implementation possible changes to concept and designs are harder to do and will have bigger impact on the three project constraints time, quality and cost (Nicholas & Steyn, 2017,p.388). This means that during implementation of pulp and paper industry's projects the importance of scope management is even more important project success wise than during design phases, therefore monitoring the scope should be one of the constant tasks of project management.

2.7 Scope management in pulp and paper industry

In this thesis the aim is to create a system that utilizes quantities in the scope management process of pulp paper industry's projects. Success in scope management is according to literature one of the key factors behind successful project and failures in the scope definition and control can lead to cost overruns, delays and quality issues (Caldas & Gupta, 2017; Cooke-Davies, 2002). The literature part of this study gave answers and ideas to some of the research questions of this study.

One of the sub research questions were, "how a project based firm can reuse information and learn from previous projects?" Nicholas and Steyn (2017, p. 158) told how benchmarking and utilizing data from completed projects can help in the estimation also in the project business. Quantity engineering project scope definition method presented by Song and AbouRizk (2005) explained how analyzing the quantities from completed projects might benefit especially in the planning phase of a project. Therefore, it is clear that by collecting information and by analyzing it especially the planning phase of projects can be supported with quantities.

According to Kim & Huynh (2008) benchmarking requires involvement and motivation from the employees in order to work since benchmarking often requires extra work. Benchmarking should also be constant, so that there would be enough data to learn from (Parmenter, 2007 p.10). So, reusing and learning from completed projects requires involvement of the employees and consistency in the data collection. Gries and Restrepo (2011) emphasized the importance of collecting the data in standard format so that the comparability between projects could be enabled.

Second sub research question was, "How a project based firm can define and communicate scope with quantities?" In literature there were three methods that used somewhat quantitative approach to defining scope, these methods were QEPSD, PDRI and ESM. PDRI method presented by Dumont et al. (1997) used a list of standard items as a basis for defining the scope. In ESM the idea was to quantify the scope and to track how the scope is filled during the project (Valdés-Souto, 2017) QEPSD was a method used for estimating the needed working hours based on estimated quantities and quantities from completed projects which presented the scope of engineering (Song & AbouRizk, 2005). In all these methods the definition of scope was done based on a standard list of items, which was the basis for defining the scope in a quantitative way. Communication of the scope could also be done using the standard list of items, at least towards stakeholders with sufficient technical knowledge. Therefore in pulp and paper industry's projects the scope definition based on predefined list of items seems to be the most suitable way of defining the scope.

Third sub research question was, “what are the pulp and paper industry project characteristics?” Pulp and paper industry's projects are huge projects and they can last for years, the size of the project also means that the importance of project planning increases (Pinto & Slevin, 1987). According to literature, managing engineering projects differs from implementation project management. During engineering phases the focus is on managing individuals and getting all the concept related decisions done in an iterative process, while in the implementation phase communication and monitoring require more attention from project management. (Doloi, 2010; Nicholas & Steyn, 2017, p. 386) Scope changes are more common and have less consequences during the engineering phases, since the concept related decisions should be made during the design phases (Nicholas & Steyn, 2017,p.388). This means that tracking the scope changes is important especially during the implementation phase, when the consequences are significant but should also be done during engineering phases, when the changes are constant, and can affect the workload of the engineering company.

Earned scope management method presented by Valdés-Souto (2017) helped in answering fourth sub research question, “how the project team can detect scope changes?” In ESM the scope changes were detected by comparing the estimated scope to the baseline scope defined in the beginning of the project, variance analysis was also presented in PMBOK (2018, p.170). Variance analysis and visualizing the quantitative scope could also be utilized in the quantity trending system, since detecting changes from quantitative data is easier than from qualitative description.

It is also important to understand the common reasons for scope changes in projects in order to define how the solution could help in the scope management process. Most common reasons for scope changes were lack of communication, changes in requirements and poorly defined scope. (Alnuaimi et al., 2010; Mirza et al., 2013; Amoatey & Anson, 2017) For example the of lack of communication and poorly defined scope should be treated as one of the issues the solution system is aiming to solve. Scope definition could also be developed to be more accurate, if the projects would be comparable and data could be reused from completed projects. So, the most common reasons of scope changes offer a good idea of the problems where the quantity trending system could help.

The main research question of this study was, “How a project based firm can utilize quantity information in managing scope in the context of pulp and paper industry projects?” All in all, it seems that the scope management process can be supported by utilizing standardized list of quantities in the scope definition. Quantitative definition could also help in monitoring of the scope and detecting possible variance in a visual and easily understandable way (Valdés-Souto, 2017). Creating such a system will require standard list of items that should be tracked in specific company’s and industry’s projects (Dumont et al., 1997). In order to compile standard list, engineering experts need to be involved, so that right items to be measured can be found. Project management needs also to be involved in order to define appropriate way of doing the collection as a part of company’s project management practices (Parmenter, 2007, p. 160).

3. RESEARCH METHODOLOGY

This chapter first describes the strategy of this research, second part focuses on the case company and the context of the research. Last part of this chapter tells how the qualitative and quantitative data were collected and how they were analyzed. This research is a case study conducted in an engineering company in order to explain how quantitative information could be utilized in scope management process.

3.1 Research strategy

This research is a cross-sectional single case study about how to utilize quantities in scope management. The aim of this research is to form an idea and describe how tracking of quantities and the development of them could be used to support scope management. Case study is suitable research strategy for this thesis, since case studies can be used for describing phenomena in depth (Saunders et al., 2016, p.197). Case studies also enable multiple data collection methods and allow the phenomena to be researched in its real-life context (Saunders et al., p.198). This research will be conducted by collecting both qualitative and quantitative data from the case company to form understanding about the current situation of scope management and boundaries for the solution.

In this research the aim is to create working system by analyzing past projects and experiences from experts, so the research approach can be categorized as inductive. Inductive approach is preferable for researches where the aim is to develop a framework based on research and analysis (Saunders et al. 2016, p.147). Inductive approach enables the research first to focus on data collection and analysis, before defining the boundaries and principles for needed solution. Literature review, done in the beginning of the research, provided information about scope management process in general, similar methods developed for scope management and what is needed when developing a quantity trending process. Scope management literature supported the analysis of qualitative data and description of current situation. Similar methods and the system development literature were utilized in the development of the new quantity trending system.

3.2 Context and case company AFRY

This thesis is done for AFRY Finland Oy to process industry division's project and construction management team. AFRY is an international engineering, design and advisory company, that was created in a merger between ÅF and Pöyry in the beginning of 2019. After the merger, company has over 17 000 employees in more than 40 countries. AFRY does more than 10 000 projects for various industries annually, so there are lots of data available and reference projects to be used. Because of the amount of employees is so high and there are so many different divisions in the company offering project services, there are also lots of different kind of tools in use. This research will focus on only process industries division and methods used in Finland.

AFRY has five divisions, which are infrastructure, digital solutions, energy, process industries and management consulting. Process industry division focuses on large industrial projects and offers for example mechanical, process, electrical engineering. Project and construction management team, is a part of process industries division and specializes in handling large industrial engineering and construction projects. Project and construction management team is in charge of scheduling, cost estimation and project management. Researcher has worked in project and construction management team in the case company before starting this thesis. AFRY's organization structure relevant for this thesis is presented in Figure 12. Engineering disciplines and their scope during projects is the main focus of this research, engineering disciplines are visible in the lowest level of Figure 12, marked with red borders.

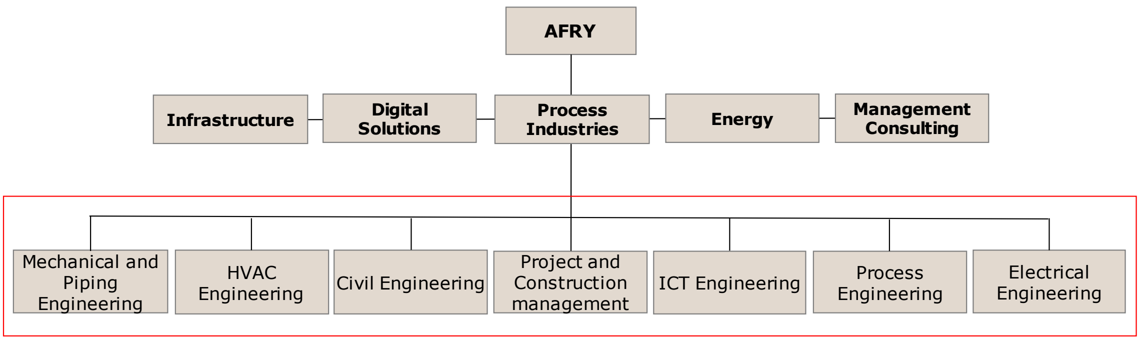

Figure 12: AFRY Organization structure simplified

Designing a working facility requires lots of collaboration between engineering disciplines. Disciplines they are depended on each other, for example mechanical engineers cannot place equipment in the blueprints before they know needed specifications or suitable places designed by other disciplines. So, in large industrial projects all the disciplines under process industries division are needed to create a working facility.

3.3 Research methods

Data collection was done using mixed-methods, both semi structed interviews and engineering tools were used as the data source for this research. Using multiple data sources require comparison on how the data sets support each other and allow to ensure reliability of deductions using concurrent triangulation (Saunders et al. 2016, p.146). In this research's qualitative side the aim is the get insights from engineering experts on what quantities are the most relevant scope wise and what are the best sources of quantitative data. In the quantitative side focus will be on the actual quantities of selected reference projects collected from engineering tools and design documents. By analyzing the actual quantities the aim is to validate that the selected quantities based on the interviews are correct and that the created system works in the wanted way.

Qualitative data for this research was collected with semi-structured interviews from employees in case company. Qualitative data can offer wider perspective in to the research subject, however the data collection and analyzing requires lots of work (Saunders et al. 2016, p.168). Semi-structured interviews were used to keep the focus on certain phenomenon and to increase the reliability of research when conducting limited amount of interviews (Saunders et al. 2016, p.297). By not having too strict structure in the interviews the persons interviewed will also have the possibility to bring up ideas that might have been missed or overlooked while creating the interview structure.

Most of the experts from the reference projects selected for quantitative analysis were not available, so the interviews were be done using purposive sampling. Purposive sampling is suitable for case study and while it may not represent the whole organization it will offer sufficient view of certain phenomenon when sampling is done carefully (Saunders et al. 2016, p.301). Interviews were conducted in two parts, first project managers were interviewed about scope management practices and benchmarking in the case company. After project manager interviews, data collection moved on to engineers, the focus of engineer interviews was on relevant quantities and methods for defining the magnitude and scope of engineering work. All the major engineering disciplines, that produce most of the documents design documents in case company's projects, meaning piping, mechanical, civil, process, electrical and HVAC engineering were interviewed.

3.3.1 Qualitative data collection

Interviews were the source of qualitative data for this research and they were conducted for three project managers and six engineers from the case company. List of engineers and project managers to be interviewed was gathered in collaboration with manager of project and construction management team and with engineering discipline leaders, so the interviews were done using purposive sampling in order to include relevant persons from every engineering discipline. List of interviewed employees with their title, date of the interview and duration is in Table 5.

Table 5: Interviewed employees

Title	Expertise	Date	Duration
Project manager 1	Chemical industry	1.9.2020	1h 20min
Project manager 2	Project management	2.9.2020	1h 5min
Project manager 3	Paper industry	4.9.2020	35 min
Engineer 1	Electrical engineering	3.9.2020	58 min
Engineer 2	Mechanical engineering	3.9.2020	45 min
Engineer 3	Process engineering	3.9.2020	50 min
Engineer 4	HVAC engineering	4.9.2020	1h 20 min
Engineer 5	Civil engineering	16.9.2020	1h 2 min
Engineer 6	Piping engineering	29.9.2020	58 min

Project managers are in case company's projects the ones responsible for scope management and for communicating with the customers. Project managers input was especially needed for understanding the project life-cycle in the case company and for understanding how the scope should be communicated towards project stakeholders. Aim of the interviews with project managers was to clarify the current situation with scope management, how scope is defined, controlled and changed in case company's projects and what are the features and criteria for a good scope management tool. Project managers were asked questions like "how do you define a scope of a project?" and "How do you handle changes to the scope?".

Engineers are the ones in the case company doing the actual design work and their input was needed for detecting how the scope is defined and tracked in practice during a project. In the interviews engineers were asked for example what are the most relevant quantities from engineers view point, how engineers handle scope and how they estimate workloads. Questions focused on defining what engineers think that are the most important quantities and how do they estimate the needed quantities and work hours for a project.

Both project manager and engineer interviews were semi structed and the structure for project manager interviews is available in the appendix A and for engineering interviews the structure is in the appendix B. All the interviews were conducted virtually and recorded. Qualitative data was collected during discussion by taking notes, after the interviews the notes were completed by listening to the recordings and by adding comments that were not originally written in the notes.

3.3.2 Quantitative data collection

For quantitative analysis four completed paper industry projects were selected. The quantities from these project were used to validate the quantity list formed with engineers. Reference project selection was done during a workshop discussion with the whole development project team. These reference projects were selected since the case company's scope in them was quite standard, the projects have lots of similarities, the projects were not too old and there was lots of data available from them. All of the selected projects were greenfield paper mill projects in Europe constructed between 2008-2020. Project specific information is confidential, but project countries and completion years are visible in the Table 6.

Table 6: Selected reference projects

Name	*Project 1*	*Project 2*	*Project 3*	*Project 4*
Industry	*Paper*	*Paper*	*Paper*	*Paper*
Country	*Sweden*	*Germany*	*UK*	*Poland*
Completion year	*2019*	*2008*	*2012*	*2010*

Quantitative data is a good sources for finding relationships between variables but often requires work for making the data clear structed for analyzing purposes (Saunders et al. 2016, p.166). Most of the design work in the case company is done using tools that generate quantitative data. The data from engineering tools had project specific differences so it could not be used to the data collection. Quantitative data for this research was collected mainly from engineering documents available in the document management system. For example cost estimates, final reports, equipment lists and flowsheets analyzed for the data collection.

All of the collected data from the reference projects was collected into one table per each quantity on project level, so for every quantity in the final quantity list there was four values. Combining all the data into one table was helpful towards the data analysis part of this research. Purpose of the quantitative data analysis was to find out what quantities have the highest correlation towards the project outputs and inputs. For analysis outputs and inputs of the project were described with duration of project in months, investment cost, capacity of the build facility and engineering hours used for design. Duration was counted from main machinery supplier selection until production start-up.

3.3.3 Qualitative analysis

Notes and additions from the recordings were collected under the questions of the question structures and verified before moving to analyzing them with tool called Atlas.ti. Using analytical tools for qualitative data analysis can make the analysis more systematic and reliable (Flick et al., 2015, p. 292). First step of qualitative data analysis was to create code structure. The structure was created by going through the notes and detecting the main themes of the data. There were clearly two main themes defining scope and scope control, under these codes there are sub codes for example methods under scope control, where the persons interviewed told about the methods they are using for scope control. The whole code structure is visible in Figure 13. The count how many times each code was used is visible in the figure after the code's name in brackets.

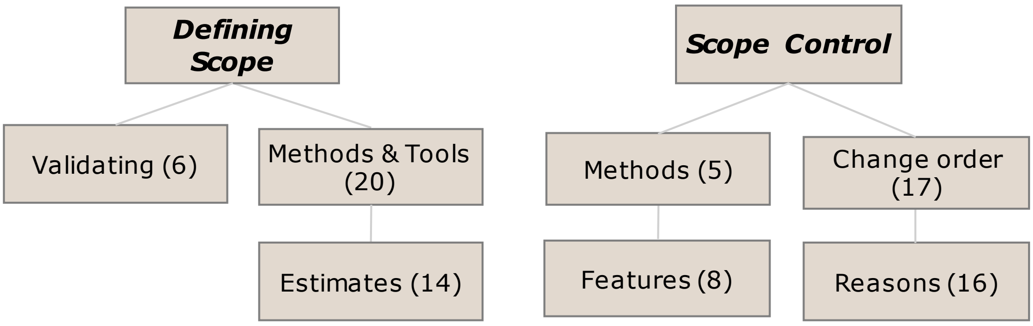

Figure 13: Code structure for the qualitative analysis

Second step of the analysis was to categorize the notes under the codes and it was done with Atlas.ti. In the tool all the parts from the interview notes were categorized under one of the codes. After the notes had been categorized under the codes, comparison between notes from different interviews were easy to conduct. It is clearly visible how validating scope and scope control were mentioned less times than other codes. Categorized notes were then used to clarify the situation of the case company and for example to describe the current situation of the scope management.

3.3.4 Quantitative analysis

First step of the quantitative analysis was to calculate correlations between project characteristics and each quantity collected from four reference projects. Second step was to assess what quantities have the biggest correlation towards project outputs and how does this information compare towards the engineering interviews. Correlation calculations were done using Pearson-correlation. Pearson correlation seeks relationships between variables, it is suitable for data where there are no outliers (Rousseau, 2018, p.85). In this research the data is collected from quite similar projects, so there should not be many outliers.

Reliability of the research was considered when selecting projects for data analysis and when collecting the data for analysis, conducting similar analysis for multiple projects should result in similar conclusions. Validity of the research was considered when selecting the quantities to track and the points of project life cycle when the quantities are collected. It cannot be definitely stated what is suitable sample size for correlation analysis, but the four reference projects in this research is not enough to draw definite conclusions about correlations (Rousseau, 2018, p.85).

After the quantity list and the process of quantity trending was finalized data from one more reference project was used in testing if the process would work in needed way. Purpose of the validation was to test would the happened scope changes be visible in the scope definition and indicate the scope change. This validation could also show if the scope changes would be communicable towards the project’s stakeholders.

4. RESULTS

In first part of this chapter the current scope management process of case company is described. Based on the project managers description of the current scope management process, it was clear that the scope needs to be monitored constantly and that the defined scope should be easy to communicate. In the case company the scope is often described using qualitative description and list of documents, which makes the monitoring of scope hard since not all changes cause increase in the document amounts. Scope monitoring methods and techniques are project manager specific.

In the second part the current usage of quantities in the case company is described. Estimation methods for scope and workload used in the case company during planning phases are discipline and sometimes employee specific. Some disciplines have developed databases and estimation tools while others are using the experience of engineering experts. Having multiple methods for managing and estimating scope leads to wide variety of scope definitions and makes combining them practically impossible

In the third part the list of quantities that could be used to describe the scope is validated first with engineering interviews and then with quantitative data from reference projects. Final quantity list after the validations is much shorter than the preliminary list. Based on the quantitative correlations, it was clear that few items have high correlation towards the project characteristics and changes in them might indicate that the scope is changing. Because the amount of available data was low, no reductions to the quantity list were made based on the correlation analysis. In the end 57 quantities were selected to describe the scope of the project. In the last part of this chapter the criteria and the basic principles about the scope management process of the case company are combined from the interviews and used as a criteria for the solution system.

4.1 Scope management in case company

Project managers need scope management skills in four different parts of scope management process, these parts are defining, validating, controlling and changing (PMI, p. 130). Case company's project managers talked about these same parts of scope management and how steps are handled in case company's terms. They told that in the case company scope defining is done during proposal phase based on the previous engineering phase. Validating the scope is done during contract negotiations with the customer. Controlling and changing the scope are done during the implementation of the project. Scope management process described by the project managers in the interviews was visualized and linked to scope management process presented in the literature, and it is displayed in the Figure 14.

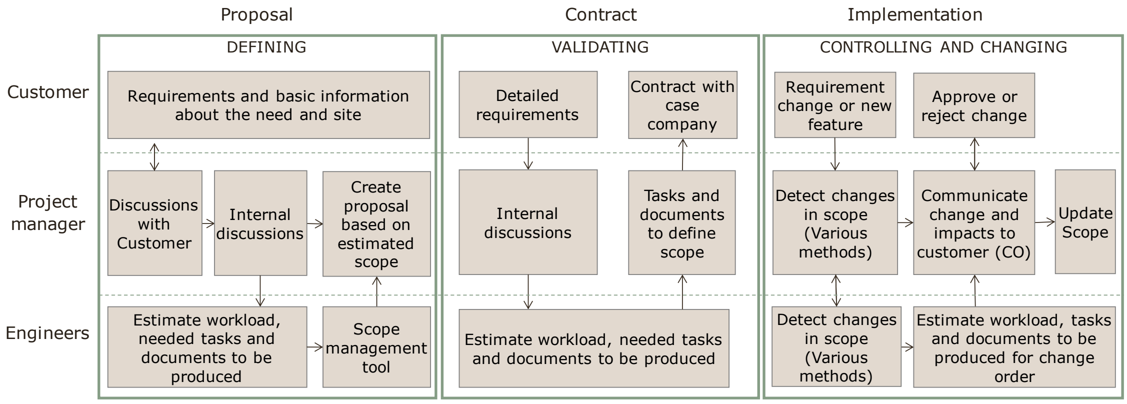

Figure 14: Scope management in case company

Scope management process in the case company is mostly handled by the project managers based on the received inputs from the customer and project engineers. So, in the Figure 14 there are three different responsible parties in addition to three earlier mentioned phases. Customer is responsible for providing requirements and specification for the project planning which is then done by the project manager and engineers in collaboration. Engineers are responsible for giving estimates of their own engineering discipline's work and tasks based the specifications received from project manager and the customer.

4.1.1 Defining scope

At the moment the scope management in the case company begins in the proposal phase when the scope is defined with documents and tasks to be delivered to the customer during the project. Project manager 1 said that before proposal is sent, project managers should, *"talk with the customer and preferably visit the site and, also if possible, discuss with people who are familiar with customer or site where the project is done because they can offer valuable information about site conditions and customer collaboration, which might affect the scope and project success."* So, customer and internal discussions are the first steps in the scope management process of the case company visible in Figure 14.

Project manager 2 told how case company's own scope definition tool is used during proposal phase of a project. In that tool all the engineer disciplines fill in what documents they produce during project to meet customer requirements. This scope definition acts as the basis for work estimation and scheduling. These tasks are visible in Figure 14 in the engineering lane, and they are linked to the project managers tasks since engineers need input from the project managers and customer for the scope definition. So, both project managers and engineers are involved in scope management already in the proposal phase.

Project manager 1 told that during proposal preparation, data from reference projects is needed in order to estimate the scope of engineering, especially if the case company has not been involved in the previous engineering phases. Because projects are always unique, comparing them is not used that much. However, project manager 1 said that he uses information from completed projects to estimate how much engineering hours does the case company need and what the actual quantities could be by the end of the project. If there is no exact reference project available, project managers 1 and 2 told that they use KPIs which are calculated based on multiple reference projects. Based on the KPIs and agreed scope, project managers can estimate workload and schedule of the project.

Usage of reference projects differentiated a bit between project managers. Project manager 2 said that, *"reference projects are rarely in use, since it is hard to find relevant references especially for re-build projects."* Project manager 1 wanted always to use a reference project to estimate needed amount of documents and hours, while project manager 3 was more into using KPIs and expert opinions from completed projects.

Problems in using reference projects according to project managers were that there is no database available, available data is too old, their project is unique and they do not have enough information about other than their own projects. The main reason behind not using reference projects was that project managers did not know possible reference projects well enough. Knowing the project specific aspects is crucial for projects managers in order to know how the reference project's scope differs from their own project. Project manager 2 emphasized that, *"tasks and documents produced in a project vary a lot between different industries, so standard list need to be at least industry specific".*

Because pulp and paper industry's projects are complex, they are usually managed in smaller areas of the facility, for example storage and paper machine are separate areas in paper mill. Project manager 1 mentioned that scope can be defined per these smaller areas where the concept is easier to understand than in the whole project. It was also stated by the project managers in the interviews that process areas in pulp and paper projects are so standard that they can be compared between projects. So, projects that are in other ways not comparable could be compared per individual process areas.

4.1.2 Validating scope

If the case company is selected for the proposed assignment, the next steps is contract negotiations where the scope is validated and agreed with the customer. Usually in the beginning of the contract negotiations, case company receives bit more information and requirements from the customer. During contract negotiations the scope defined in the proposal phase acts as the basis for the negotiations and modifications are done based on internal discussions. Changes to the proposal scope might occur during the negotiations due to more detailed requirements and additional information received from the customer.

After negotiations when rough time schedule and scope are agreed with the customer, the contract can be signed. Project manager 3 said that, *"scope of the engineering shall be clearly defined in the contract and it acts as the basis for all project planning activities, therefore it is also important to include engineering experts in the negotiations".* Contract usually includes description of case company's scope and documents to be delivered it can also sometimes include estimated quantities needed for implementation. Quantities are only available in the scope definition if the customer has the technical knowledge and resources available for understanding and validating the quantitative scope. Case company's working hours estimation is for some engineering disciplines based on the documents to be produced and quantities to be designed. Project manager 3 also told that, *"When competition for the project is tough the contract is sometimes done with too few hours in order to win it, this however often leads to multiple change orders during implementation."* So, in order to succeed, the scope and schedule need to be realistic as was already mentioned in the literature part of this research as well.

Project managers had similar ideas about how the scope is defined for a project, and all the project managers told that it is important to define the scope well already in the proposal and contract negotiation phases with both customer and engineers. This assures that case company and customer have both understood the requirements and the scope properly. Project manager 2 said that *"changes in the scopes are part of projects' nature which needs to be understood when defining scopes".* This means that the project managers are expecting the scope to change during the project, and they know that the monitoring of the changes needs to be constant.

4.1.3 Controlling scope

After the contract is signed and the project moves on to implementation phase, the scope management process moves on to the last phase, called controlling and changing in the Figure 14. Project managers are allowed to handle scope control as they see fit, and there were no common tools or methods for scope control in the case company. Freedom to choose methods by themselves had led to a point where all the interviewed project managers had different methods for controlling the scope. Customer discussions and project meetings in house were common methods of scope monitoring for the project managers. Project managers had also developed own tools for scope monitoring. Project manager 1 was following revision history of documents to detect if there unusual amount of revisions for single documents which might indicate that changes are happening. Project manager 2 told how, "*hour usage might indicate unregistered changes if used hours differentiate from budgeted hours*", while project manager 3 said that, *"discipline lead engineers are in charge of monitoring their own scope, budget and reporting all the changes to the project manager".* The differences between how the needs for scope changes were detected among project managers are present since there is no standard tool available for scope control in the company.

Earlier presented PDRI framework was known by all the project managers, and project manager 1 had actually used it in a project in the case company. In that project the customer had requested the case company to analyze how well the scope is defined in the end of engineering phase. PDRI helped to see that everything was done, but there were differences between what was agreed in the contract and what was expected in the PDRI checklist. Project manager 1 emphasized that the PDRI should be included in the contract negotiations in order to see what is expected and what that requires. Project manager 1 mentioned that, *"Using PDRI in the scope definition requires more work than regular scope definition, but can help especially in monitoring of the scope".*

Engineers, as the project managers, described the reacting part same way, first engineers inform project manager about possible scope change, and then they estimate consequences together, and finally submit change request to the customer. However, there were lots of differences in the scope change noticing methods between disciplines, for example process engineers were sometimes contacted directly by the customer asking for a change, while electrical engineers might notice the change only when they get more information during project meeting. Engineer 1 said that, *"Scope changes are usually noticed when new decisions are made and compared to the contract to see if the decision is part of the agreed scope."* On the other hand engineer 2 emphasized that, *"discussions with other disciplines are needed in order to detect scope changes."* Engineer 6 brought up that , *"changes can also appear, for example in case company's finalized list made by the machinery supplier."*

Different ways of noticing the changes in the scope between disciplines exist since the changes in the design are usually done in the process engineering part, which affects other engineering disciplines differently. For example engineer 1 told how addition of one more process equipment might not cause much extra work for electrical engineer while engineer 2 said that one additional equipment might even cause changes to layout and the consequences have to be assessed case by case.

All in all, the most common way of noticing a scope change seems to be according to engineers during project meetings through discussions with other disciplines. The project meetings are the only place where all the engineering disciplines are available at same time and able to discuss the changes to their plans that might not be visible in other tools or are unknown for other disciplines. This finding indicates that a common way for communicating and seeing the scope of other disciplines would be beneficial for the scope monitoring of engineering, so that the changes to scope could also be detected before the project meetings.

4.1.4 Changing scope

Scope changes, according to interviews, are handled using a standard change order process, and the working principles were the same according to every project manager interviewed. Defining the impacts of change order was always done first with lead process engineer, and after that with all the disciplines separately. If a change is made to the plan, the new plan and scope are estimated by making the change to one plan and estimating how it affects other engineering disciplines. According to project manager 2, documenting every change and saving precise information about it is crucial for scope control success. Based on the interviews, it is evident that the case company has a working processes related to change orders and managing them but the issues in scope control are related to monitoring scope and detecting possible scope creeps.

Project manager 1 said that, *"most common reason for scope changing during engineering project is misunderstanding of the requirements during negotiations."* Project manager 2 said that *"There are at least three kind of possible changes to the scope: customer wants something new to be added, project team notices that something needs to be changed, or customer wants something to be changed."* All in all, the reasons for scope changes during a project were quite similar according to all the interviewed project managers. Most common reasons for scope changes in case company's projects based on the interviews are listed in Table 7. Source column of the table indicates which project managers mentioned this specific reason.

Table 7: Reasons for scope changes in case company

Reason	*Source*
Inadequate starting information	PM1, PM2, PM3
Changes to concept of the end product	PM1, PM2, PM3
Misuderstandings during contract negotiations	PM1, PM2
Lack of communication between stakeholders	PM1, PM2
Scope not defined well for every party	PM1,PM2
Insufficient planning during design phases	PM1, PM3
Minor changes not logged as change orders	PM3
Underestimating the scope	PM1
Human error in estimation	PM2
Differences in customer and case company	PM2

Inadequate starting information and change to the concept were mentioned by all the project managers interviewed. Other mentioned factors behind scope changes were, for example, underestimating the scope, human errors in estimation and communication lack between engineers and stakeholders. Most of these problems are related to defining scope or to communication between project parties. Solving the communication related issues is not possible with tracking tool but the communication can be made more understandable by standardizing the ways of communication which benefits also the scope defining.

Understanding the common reasons for scope changes is crucial for this thesis since they can be used to guide the development of the quantity trending system. For example, communication between stakeholders could be enhanced with quantity trending by standardizing the way of scope definition, and the importance of starting information could be reduced by having data from reference projects available. Interviewed personnel were also asked about features that would help them in defining and monitoring the scope.

4.1.5 Conclusion

In the case company, scope definition is done in collaboration with engineering experts, project managers and customer. Scope definition and validation phases of the scope management process seem to be handled in a standard way. Change order process is also standardized, and all the project managers explained it the same way. However, there were no common tools or methods for controlling the scope or detecting possible scope changes. At the moment scope changes are either noticed by the engineers or the project manager based on increase of work, during project meetings or when the customer brings them up. The biggest issue related to scope management process of case company is controlling the scope and noticing changes. This was also one of the main reasons for starting this thesis, and the problem seems to be valid according to project managers.

Project managers utilized the expertise and experience of the employees both in scope definition and working hours estimates but there was no benchmarking process or database for reusing the data from previous projects. Some engineering disciplines were able to utilize the data from completed projects to support their estimation of tasks, quantities and working hours. However, similarly to project managers, there was no standard way for reusing the information from old projects and data collection was handled by individual engineers. Standardizing the data collection and harmonizing the format of collected data could benefit the project management and especially planning tasks in the future.

Communication of the change to the customer is usually done by estimating both the consequences and working hours to complete the change. Currently in the case company these consequence estimates are based on experienced engineers opinion. Method of scope communication is done in a project specific way, which is affected by customer capabilities and the project team preferences. Common way of communicating the scope in the company would make the projects more comparable and help employees since scope communication methods would not have to be defined separately for every project.

4.2 Quantities in case company

The work of the engineers in pulp and paper projects consists of working with models and design documents needed for construction. The facility to be built is designed in detail in the models, these models include quantities of, for example, equipment, pipes, cables and building areas. Case company also produces investment cost estimate at the end of each engineering phase which is done based on quantities. So, the quantities are closely tight to engineering work but the usage of them in the case company is mostly limited to the cost estimate. The list of trackable quantities defined with engineers is presented in this sub-chapter.

4.2.1 Estimation methods

While conducting the interviews for engineers, it came clear that the working principles, tools and estimation methods for estimating scope and tasks needed for fulfilling it were different for every discipline. Engineer 1 said that, *"defining the requirements and tasks for engineering disciplines requires lots of discussions with the customer and project team".* Engineer 2 told how mechanical and piping workloads are estimated based on

KPIs from completed projects. Engineer 4 told that, *"HVAC engineering quantities are estimated based on typical drawings for systems, for example specific ventilation requires usually certain amount of pipes and machines."* Few engineering disciplines had even developed their own databases for collecting data from completed projects that could be reused in future estimates. Estimation methods for engineering workload and scope used by the disciplines are listed in Table 8.

Table 8: Estimation methods used by engineering disciplines

Discipline	Expert / Experience	Reference project	Own database	Own Tool	KPIs	Quantities
Process	X	X				
Mechanical			X		X	X
Piping			X		X	X
HVAC	X	X	X	X		
Electrical	X	X				
Civil	X					

Engineer 1 said that ,"*Information about completed projects is hard to retrieve, so usually reference projects are selected from the projects that the engineer has been involved*". Engineer 2 talked about the database created for piping quantities of the projects and how, *"KPIs calculated from previous projects are the basis for estimating workloads of piping and mechanical engineering. KPIs, for example meters of pipe per pipeline, are calculated for areas in the project because then KPIs can be compared between projects."* According to interviews only piping and mechanical information was stored in a standard format after every project.

Other disciplines are doing the estimations mostly based on reference projects and expert estimation. Engineer 5 mentioned that, ”*best source for the reference data are well executed final reports which define the concept of the facility in addition to the quantitative information".* Engineer 6 told how*, "previous phase of engineering is the best basis for estimations, and if that is not available, then reference projects are to be used."*

Differences between ways of working between disciplines exists probably because engineering disciplines use different tools, have different starting information and start working at different times during the project. However, having the data collected in one harmonized way would help the project management a lot and also reduce the amount of different databases to be maintained in the company. Having similar principles would also be beneficial for collaboration when all the parties would know what is meant by a certain quantity, and possible correlations between disciplines could be found. All the engineers brought up the importance of clarifying the scope for all the disciplines in the beginning of the project because when one discipline exceeds the original scope it will affect other disciplines as well.

4.2.2 Quantity trending basis

All engineering experts said that the scope cannot be defined only with quantities since, for example, country of the project and site conditions affect the scope of work, and this information might not be visible in the quantities. Good example from this is HVAC engineering, according to engineer 4 HVAC engineering discipline's scope is depended on other disciplines' selections and site conditions, *"the warmer climate the more cooling power is needed, and the more machines the more heat they will create".* Therefore, if quantities indicate that there was lots of cooling power in the plant, it might mean that the project was in a warm climate or the process required lots of machines. This is why it is also important to collect project basic information describing the process and site conditions briefly in order to conduct right conclusions from the quantities. So, the quantity trending system should also have a short qualitative scope definition in addition to quantities.

Engineer 4 said that, *"facilities and the plans created for them are getting more and more complex especially because planning systems have moved from 2D to 3D environment".* The increase in complexity has, according to engineers, affected the needed hours per tasks which has also increased. Complexity differences between quantities was something that divided the interviewed engineers, engineers 3 and 6 said that all the quantities are equally hard to achieve, while rest of the engineers said that first quantity is lot harder than rest but after that the work is equally hard for every quantity. In practice this means that, for example, designing third pump requires same amount of work as twentieth pump.

In order for quantity trending to be possible, there needs to be a list of items that is constant and can be filled in the beginning, during and in the end of the project. Quantity list should cover every discipline in order to describe the scope of the case company. There should also be multiple quantities from every discipline because not all quantities are present in every project, but at the same time the list cannot be too long because filling the data would require too much work.

4.3 Quantity list

There was a preliminary quantity list to start from in the case company. The list was collected by interviewing leaders of engineering disciplines, this preliminary list was not validated and it was only based on expert opinion. Preliminary quantity list of 173 items acted as the basis for this research. First 16 items of the preliminary quantity list are visible in Table 9, and the whole list is available in the appendix C.

Table 9: Part of preliminary quantity list

Discipline	*Quantity*	*Unit*
Process	Flowsheets	pcs
Process Engineering	Pumps	pcs
Process Engineering	Standard pumps	pcs
Process Engineering	Special pumps	pcs
Process Engineering	Vacuum pumps	pcs
Process Engineering	All equipment in BOP	pcs
Process Engineering	process equipment	pcs
Process Engineering	Tanks	pcs
Process Engineering	Agitators	pcs
Process Engineering	Pipe lines	pcs
Process Engineering	Number of different flow media	pcs
Mechanical Engineering	Various steel structures	pcs
Piping Engineering	Piping	m
Piping Engineering	Piping large pipes (DN>500)	m
Piping Engineering	Piping small pipes (DN<50)	m
Piping Engineering	Piping medium pipes (50≤DN≤500)	m

During the interviews engineers 2, 3 and 4 brought up the idea about tracking the quantities per smaller areas of whole project. Engineer 3 said that this would be beneficial since there might be different persons in charge of different areas, and one person might not be able to give all the wanted quantities for the whole project. Engineer 2 and 4 emphasized that having the information available in area level would be beneficial when using data as reference for smaller projects where all the areas are not present. Because project managers brought up this same idea about managing large projects in smaller standard areas, the area split idea was combined into the quantity list.

There was a readymade area split for paper mill projects available in the case company. This area split consists of eight main areas and 74 sub-areas in total. The main areas and examples of sub-areas are visible in Table 10.

Table 10: Main areas of paper mill

Main Areas	*Example of sub-area*
RCF/OCC	Bale handling and pulping
PM	Press section
Utilities	Effluent system
Coating color kitchen	Waste water treatment
Wet-end chemicals	Retention system
HVAC	Severs in special rooms
Electrical split	Power distribution
Areas/Buildings	Product warehouse

In this thesis, the data collection for the reference projects will be done on project level. This is done because the correlation analysis is done on project level by comparing the quantities towards project specific figures, for example duration and capacity. Project level correlation analysis will be used in the validation of the quantity list. Data collection on project level is also suitable for this research since the reference projects are all completely new paper mills with all the main areas included.

4.3.1 Validation of quantity list with interviews

The preliminary quantity list was validated during the interviews by going it through and removing items that the engineers did not think correlated with their discipline's scope. For example, if there was no correlation between pumps and tasks completed by the process engineering discipline, pumps were removed from the quantity list. Some disciplines were sure that their scope could be described using one or only few quantities, for example piping engineering scope is defined only based on pipe lengths, pipe weights and hand valves, while civil engineering needed building areas, pile amounts, elements and concrete foundations to describe their scope sufficiently.

After interviews with engineering experts, a list of quantities to track was combined, and the standard area split of a paper mill was added to the table. The quantity list for paper mill projects is presented in Table 11. The Quantity list was reduced from 173 items to 57 items that, according to engineers, define the scope of each engineering discipline in the case company.

Table 11: Validated quantity list with area split

Discipline	QTY Description	UNIT	RCF/OCC	PM	Utilities	Coating color kitchen	Wet-end chemicals	HVAC	Electrical split	Areas/Buildings
Process	Flowsheets	pcs								
Process	Pumps	pcs								
Process	Process equipment	pcs								
Process	Tanks & Towers	pcs								
Process	Agitators	pcs								
Process	Pipe lines	pcs								
Process	Number of different flow media	pcs								
Piping & Mechanical	Various steel structures	kg								
Piping & Mechanical	Piping	m								
Piping & Mechanical	CS pipes	m								
Piping & Mechanical	SS Pipes	m								
Piping & Mechanical	Plastic and FP pipes	m								
Piping & Mechanical	Hand valves	pcs								
Piping & Mechanical	Total weight of piping	t								
Piping & Mechanical	Supports	pcs								
Piping & Mechanical	Support mass	t								
Electrical	Motors	pcs								
Electrical	Motors	kW								
Electrical	Cable trays	m								
Electrical	Distribution transformers	pcs								
Electrical	Lightning protection	m								
Electrical	Pipe bridge lighting	m								
HVAC	HVAC HW+SW E-Circuits	pcs								
HVAC	HVAC HW+SW I-Loops	pcs								
HVAC	Junction Box (70%)	pcs								
HVAC	Office area	m²								
HVAC	Process area	m²								
Process Control	HW+SW DCS+SRS E-Circuits	pcs								
Process Control	SRS Loops	pcs								
Process Control	ATEX Loops	pcs								
Process Control	I/O's	pcs								
Civil Engineering	**Building**	m²								
Civil Engineering	Very demanding building	m²								
Civil Engineering	Demanding building	m²								
Civil Engineering	Normal building (Warehouse etc.)	m²								
Civil Engineering	Building volumes	m³								
Civil Engineering	**Piles**	pcs								
Civil Engineering	Pile capacity <3000kN	m								
Civil Engineering	Pile capacity 1500 - 3000kN	m								
Civil Engineering	Pile capacity 700 - 1500kN	m								
Civil Engineering	Pile capacity >700kN	m								
Civil Engineering	**Pre cast concrete elements**	pcs								
Civil Engineering	Beams	pcs								
Civil Engineering	Wall elements	pcs								
Civil Engineering	Columns	pcs								
Civil Engineering	Slabs	pcs								
Civil Engineering	**Cast in situ concrete**	m³								
Civil Engineering	Building foundations concrete	m³								
Civil Engineering	Building foundations reinforcement	kg								
Civil Engineering	Building frame, columns, beams, walls, concrete	m³								
Civil Engineering	Building frame, columns, beams, walls, reinforcement	kg								
Civil Engineering	Floors, concrete	m³								
Civil Engineering	Floors, reinforcement	kg								
Civil Engineering	Large machine and tank foundations, concrete	m³								
Civil Engineering	Large machine and tank foundations, reinforcement	kg								
Civil Engineering	Small machine and tank foundations, concrete	m³								
Civil Engineering	Small machine and tank foundations, reinforcement	kg								

In total the quantity list after the engineering interviews there was 57 quantities to track. These quantities can be used to define the scope of each engineering discipline's work on a regular paper industry's project according to interviewed engineers. The main difference between this list and the preliminary list was reduction of specifications, meaning for example that pipe meters were only collected based on their material not based on the dimensions, and pumps were collected only on high level and not based on their types.

Engineer 6 said that, *"pipes with small dimensions are slow to design while large pipes are much easier and faster to add to model".* This would mean that more detailed specification of the quantities could reveal possible correlations with specific quantities and work hours. With more simplified approach, the data collection is easier for the engineers, and at the point of scope definition, the quantities of lower level items like special pumps are too hard to estimate. Engineer 2 said that the lower level of quantities describes well the complexity of the project but it is not necessarily needed for the scope definition since these are not even present in every project.

4.3.2 Validation of quantity list with quantitative analysis

After the quantity list was validated with engineers during the interviews, it was also possible to assess the validated list with data from four reference projects. Quantitative validation was done by collecting data for all the available rows in the validated quantity list from four reference projects on project level. Importance of the quantities were assessed by calculating Pearson correlation between each quantity and project figures, meaning project duration, investment cost, discipline's engineering hours, total engineering hours and capacity of the paper mill built within the project. If the quantity had significant correlation towards any of the project figures, it was categorized as important.

Because there was only four projects that could be used in the correlation analysis, the results are not reliable. Sufficient correlation analysis would require more reference projects and data from them (Rousseau, 2018, p.85). The correlations found in this chapter might also be caused by undetected factors, for example quality requirements might differ a lot between the selected projects. The correlation analysis conducted in this chapter however offers one solution how the validation could be done for the quantity list.

4.3.3 Data quality

Overall data quality for the selected items was poor. Most of the information about the quantities was collected from document management system and directly from engineering documents, for example from equipment and pipeline lists. The naming was different for the items in every project and, in some cases, it was written in other languages. Differences in the naming and formats made the data collection difficult and time consuming. There were several quantities in the quantity list that could not be collected. Quantities that were not available in the document management system were asked from engineers involved in the specific project, most of the engineers were not reached.

Other common reason for missing data was that the case company had not done all the engineering in a specific project, which lead to multiple rows with data missing from one or two projects. Case company had only done civil engineering for two of the five reference projects, which meant that actual structural and building information was available only for two projects, so they could not be included in the quantitative validation analysis.

The data that could be collected to the quantity list is visible in Table 12. If the data was not available, the reason is also told in the reason column of the table. Data in the last four columns is presented in units. The data for all the four reference projects were available only for 13 quantities from total 57 quantities in the quantity list that was validated with engineers. Data availability, meaning available quantities divided with all the quantities, per each reference project is indicated in the first row of table. The reference project 1 had the best data availability with over 40 % of the quantities available, while the other projects had only around 25% of quantities available.

Table 12: Available data per reference project and quantity

			Data availability		44 %	23 %	25 %	25 %
Discipline	QTY Description	Available	Reason	UNIT	Project 1	Project 2	Project 3	Project 4
Process	Flowsheets			units	245	110	140	295
Process	Pumps			units	2547	941	1050	704
Process	Process equipment			units	437	300	127	135
Process	Tanks & Towers			units	129	46	47	69
Process	Agitators			units	329	195	87	65
Process	Pipe lines			units	7682	2825	3036	2930
Process	Number of different flow media			units	61	68	48	56
Piping & Mechanical	Various steel structures	NA	Not available in documentation	units	-			
Piping & Mechanical	Piping			units	17437	11066	4737	11455
Piping & Mechanical	CS pipes	NA	Not available for all projects	units	437	-	-	-
Piping & Mechanical	SS Pipes	NA	Not available for all projects	units	9985	-	-	-
Piping & Mechanical	Plastic and FP pipes	NA	Not available for all projects	units	7105	-	-	-
Piping & Mechanical	Hand valves			units	1178	718	678	948
Piping & Mechanical	Total weight of piping			units	248	140	85	134
Piping & Mechanical	Supports	NA	Designed by supplier	units	-			
Piping & Mechanical	Support mass	NA	Designed by supplier	units	-			
Electrical	Motors			units	260	154	80	114
Electrical	Motors			units	14333	17840	10609	7693
Electrical	Cable trays	NA	Not available in documentation	units	-			
Electrical	Distribution transformers	NA	Not available for all projects	units	7	-	-	5
Electrical	Lightning protection	NA	Documented by supplier	units	-			
Electrical	Pipe bridge lighting	NA	Documented by supplier	units	-			
HVAC	HVAC HW+SW E-Circuits	NA	Not done by case company	units	250	-	-	-
HVAC	HVAC HW+SW I-Loops	NA	Not done by case company	units	517	-	-	-
HVAC	Junction Box (70%)			units	155	119	101	189
HVAC	Office area	NA	Not available for all projects	units	2092	-	-	-
HVAC	Process area	NA	Not available for all projects	units	54902	-	-	-
Process Control	HW+SW DCS+SRS E-Circuits	NA	Not available for all projects	units	573	-	-	-
Process Control	SRS Loops	NA	Not available for all projects	units	12	-	-	-
Process Control	ATEX Loops	NA	Not available for all projects	units	35	-	17	-
Process Control	I/O's	NA	Not available for all projects	units	5229	-	-	-

The data for this research was mostly collected directly form design documents, but case company also saves the design information to database from the engineering tools. Equipment information in the database, however, has some limitations because of different ways of working with the tools between projects. Data in the database, for example, includes deleted equipment and areas, and collection of certain equipment cannot be easily done since the names are typed in different ways and in different fields in the tool. The data in the database can also include equipment designed by other project parties as a part of their scope since designs are usually combined in the engineering tools of the case company, so that the design would cover the whole project. Data quality issues should be taken into account when implementing the quantity trending system. For example standardizing the usage of engineering tools should be considered, so that the quantities could be automatically collected from database.

Engineers are obligated to book their working hours on project and discipline level to case company's ERP-system. The engineering hours for the reference projects were collected on discipline level. These collected hours include all the hours used for the projects, so the hours needed for completing change orders are also included. Capacities of the mills and durations of the projects were collected from final reports of the projects. Investments costs are the costs estimated by the case company in the beginning of the implementation phase.

4.3.4 Correlation analysis

Defining project scope with one or two figures is problematic since, for example, the capacity of a paper mill does not directly affect the work amount of electrical engineer which is more depended on the equipment, building and concept related decisions. For data analysis the relevance of quantities were assessed by comparing the correlation between quantities and five different figures defining the scope of a project, these figures were capacity of the paper mill, duration of the project, used engineering hours per discipline, total engineering hours and estimated cost of the whole project. Project figures for the four reference projects are visible in Table 13.

Table 13: Project figures for reference projects

Name	*Project 1*	*Project 2*	*Project 3*	*Project 4*
Cost (units)	1212	1206	1140	759
Duration (months)	24	21	25	13
Capacity (t/a)	550000	650000	425000	470000
Total engineering hours (units)	3887	2193	3344	1566
Process hours (units)	37	23	58	17
Piping & Mechanical hours (units)	78	91	91	63
Electrical hours (units)	219	131	212	95
HVAC hours (units)	1384	135	1060	2
Process control hours (units)	140	43	65	34

Correlations between the collected quantities and project aspects are visible in Table 14. First columns shows the discipline which is responsible for designing the items present in second column. Third column of the Table 14 is the unit in which the quantity is reported. Columns from 4 to 8 are the calculated correlations between the collected quantities and project characteristics, meaning cost, total engineering hours, engineering hours per discipline, duration and capacity of the mill.

Table 14: Quantities and their correlation to project scope

Discipline	QTY Description	UNIT	PEARSON Correlation Cost	PEARSON Correlation Engineering	PEARSON Correlation Discipline	PEARSON Correlation Duration	PEARSON Correlation Capacity
Process	Flowsheets	pcs	-0,70	-0,17	-0,39	-0,61	-0,36
Process	Pumps	pcs	0,54	0,82	0,26	0,55	0,18
Process	Process equipment	pcs	0,63	0,53	-0,12	0,41	0,67
Process	Tanks & Towers	pcs	0,14	0,55	-0,03	0,15	0,07
Process	Agitators	pcs	0,67	0,63	0,00	0,50	0,59
Process	Pipe lines	pcs	0,40	0,73	0,15	0,41	0,14
Process	Number of different flow media	pcs	0,33	-0,19	-0,66	-0,09	0,98
Piping & Mechanical	Piping	m	0,10	0,18	-0,45	-0,11	0,50
Piping & Mechanical	Hand valves	pcs	-0,10	0,31	-0,63	-0,12	0,05
Piping & Mechanical	Total weight of piping	t	0,29	0,45	-0,29	0,15	0,42
Electrical	Motors	pcs	0,44	0,50	0,35	0,27	0,53
Electrical	Motors	kW	0,82	0,26	0,21	0,51	0,89
HVAC	Junction Box (70%)	pcs	-0,74	-0,42	-0,32	-0,79	-0,09

Correlation over 0 indicates positive correlation and less than 0 negative correlation between variables. The closer the correlation is to 1 or -1 the stronger it is. (Rousseau, 2018, p.174) In Table 14 the green color indicates that correlation coefficient is more than 0,8 or less than -0,8, and yellow background indicates correlation coefficients over 0,7 or under -0,7. According to data analysis, only three quantities had strong correlation with projects characteristics. Based on the quantitative analysis, only six quantities had correlation towards the project characteristics, these quantities were flowsheets, pumps, pipelines, number of flow media, motor power and junction boxes. These quantities could be utilized when describing the scope of a project in a quantitative way.

There were no quantities that had strong correlation to the discipline's own engineering hours but pipelines and pumps had correlation towards the total used project hours. This might indicate that amount of pumps and pipelines describe the amount of engineering in total and have affect to other disciplines as well. Correlation between capacity and different flow media was almost one, which means very strong correlation. This means that if the capacity to be build is known, the number of different flow media could be estimated based on it.

Motor power, flowsheets and junction boxes had strong correlation towards the cost of the whole project. Flowsheets are used to describe the processes in the mill, and generally, the more complicated the mill is the more flowsheets are needed. Correlation between motor power and cost is not that surprising since the more there are motors or big motors the more the cost will be.

4.3.5 Final quantity list

First reductions to the preliminary quantity list were made with interviewed engineers. The quantity list could then be reduced more by validating the importance of each quantity towards the project characteristics with correlation analysis as done in previous chapter. Reductions to the list based on the correlation analysis were not conducted as a part of this research since the data availability was poor and most of the quantities could not be analyzed. Also, the lack of reference projects meant that the significance of the correlation analysis was very low.

For the implementation of the quantity trending system, the quantity list to be used for the data collection is the quantity list validated with engineers during the interviews. Having a validated list of items to track is one of the key parts of quantity trending system since quantity list is the document that is going to be filled as a part of scope management process.

4.4 Criteria for the solution

Project managers interviewed gave suggestions and ideas what kind if features would be beneficial to have in the quantity trending system, interviewed project managers also gave some criteria about what the system to be built must have. Because the case company has no tool or common method for detecting scope changes or communicating scope, finding out the needed features for the system is crucial part of the system development. Criteria and features mentioned in the interviews are visible in Table 15 with the count of how many times they were mentioned. The rows defined as criteria are, according to interviews, must have items and rows with feature categorization are useful features but they are not inevitable in supporting the scope management.

Table 15: Criteria and features for the solution system

Item	*Count*	*Category*
Usability	3	Criteria
Communicatable	3	Criteria
Integration	2	Criteria
Flexibility	2	Criteria
Comprehensive	2	Criteria
Possibility to track hours	2	Feature
Baseline for scope	2	Feature
Information saving	2	Feature

First and the most important criterion for the solution was mentioned by all the project managers, and it was usability of the system. By usability the project managers meant that the system should be easy to use, and project manager 1 emphasized that system should not cause extra work for the project team. Project manager 2 said that, *"Creating quantitative baseline in the beginning of project requires time and resources but it could help in the scope control."*

Second criterion for the solution was the possibility to communicate scope easily. Project manager 3 said that, *"communication between all the project parties is the most important factor behind successful scope control".* One of the issues with scope management, according to project managers, was how to communicate scope and its changes to the customer. By having a clear report that shows exactly what has changed in the quantities and how it affects the scope of engineering would be very helpful for the project managers.

Third criterion was integration with current processes or tools. If the new system could be integrated to already existing processes or tools, it would ease the workload of the users during a project. Project managers suggested that the quantities could be collected, for example, in project monthly meetings from every discipline and combined to the cost estimate. Fourth criterion was flexibility. Because all the projects are bit different, the system cannot be too strict and require, for example, something that a smaller project cannot produce. However, at the same time system should also be comprehensive enough to cover all the usual quantities of a project and describe the scope of every discipline at least briefly.

Project managers also described features that they thought that would be useful to have in the system. According to project managers, system should have possibility to track actual hours per month, track amounts of documents produced, track amounts of equipment and items in the plan and compare values from plan to actual. System should offer a place where to save baseline for quantities and hours, this baseline could then be compared to actual and reported to the customer when needed. Combining all the information requested by the project managers a offers challenge since, for example, document amounts are available in the document management system and hours are booked to ERP-system, so the amount of data sources is high.

Case company is also lacking a tool for saving the information from previous systems in a standard format. Project managers have their own tools and methods for estimating the workloads and scopes of projects. Project manager 2 told how discussions with colleagues is one of the best techniques for defining the scope and estimating the workload but the possibility to also check actual figures from previous project would be useful. Possibility to benchmark previous projects was also mentioned by other project managers as one possible feature for the solution system, therefore the solution system should have the possibility to save the collected figures in a standard format for benchmarking purposes in the end of every project.

5. IMPLEMENTATION

This chapter describes how the quantity trending process could actually be implemented in the case company, and how the information produced during the process can be utilized in scope management process. Process of quantity trending needs to be adjusted according to company specific aspects because the needs during project life-cycle vary depending on project management methods and principles. Company specific modifications also allow existing processes to be utilized in the quantity trending process.

Process for the quantity trending was defined based on the analysis about the current situation of case company's scope management process. Quantity trending consists of four different steps that cover all the steps of scope management process. Steps for defining, validating and monitoring of the scope as a part of scope management were decided by selecting suitable points from the case company's current scope management process, and last step of saving the scope was added to the end of the implementation phase. Scope definition is done after last engineering phase and the scope validation is done during proposal phase. During implementation the scope is monitored four times when the project sponsor sees fit. After project completion the actual quantities are collected for benchmarking purposes.

Responsibilities for different gates and phases of the process are also discussed in this chapter in addition to data collection methods and outputs of the quantity trending process. There is a defined responsible person for every phase during every gate in order to ensure that all the steps are completed. Responsible persons are in charge of, for example, collecting the data and using it to support scope management process. Outputs of the process were, based on validation, able to visualize the scope and give indication about possible scope changes during the implementation.

5.1 Quantity trending steps

Because there are multiple steps in the scope management process, quantity trending also needs steps in order to be beneficial for the whole scope management process where the scope of a project needs to be defined, validated and controlled (PMI, 2018, p.130). In case company's current scope management process there are three phases proposal when scope is defined, contract when scope is validated and implementation where the scope is controlled and changed if needed. So that all the steps of the scope management could be covered, quantity trending system should include at least the three steps of the standard scope management process. Because the quantity trending system also includes benchmarking aspect and data from completed projects might help in the scope estimation process of new projects, fourth step for saving the actual scope is also needed in the quantity trending process.

The quantities to be collected during quantity trending are the same during each step of the process. Using same quantity list during the whole process enables the variance analysis between steps and projects. The list of quantities to be used in quantity trending is the list validated with engineers, and it is visible in Table 11.

After basic engineering, the scope of potential implementation project can be defined based on the quantities designed during engineering. This step is the first definition of the project scope. During proposal phase the scope of upcoming project could be validated with customer by going through the estimated quantities. Validation with customer requires capabilities, resources and technical understanding from the customer's side as well, so it cannot be done in every project. Validation can also be done only by the case company by comparing estimated quantities to a reference project and basic engineering phase's quantities. The quantitative scope validated in the proposal phase acts as the baseline for implementation phase and workload estimation.

During implementation phase of a project the actual trending of the quantities can be used to detect possible scope changes, to communicate changes to customer and to estimate progress of the project. Possible changes could be detected as a variance between baseline and estimated quantities at completion of the project. The estimates collected during implementation should be collected from the engineering disciplines when they are able to give more accurate estimate of the quantities.

After the project closure actual quantities should be collected by engineering disciplines in order to reuse them as references for defining and validating the scopes of new projects. This last step is not part of the scope management process anymore, since the project would already be over at the time of this last quantity collection. Collection of the quantities at this point is, however, very relevant for creating more accurate estimates in future.

5.1.1 Defining and validating scope

Defining and validating the scope are the first steps of scope management. Definition and validation should be done in the beginning of the project when the concept of the facility to be build is starting to clarify. Based on the company's scope management process, the points for defining and validating the scope before implementation are clear. Case company estimates quantities during the basic engineering for cost estimating purposes and during proposal phase for work load estimation. So, the scope can be defined with quantities first time after the last engineering phase, called basic engineering. Validation of the scope can be done during the proposal phase of the implementation when the concept and requirements are agreed with the customer in the contract.

The ideal place for defining the scope for a project is after last engineering phase, basic engineering, when the concept of the facility is clear. This phase is not always done by the case company but if done it can offer good basis for estimations to be made during proposal phase. After basic engineering the collection of quantities is called bill of quantities 1, or shortened "BoQ1 ", and it is done in order to define the scope of the project for possible proposal phase of the implementation. In the projects where the case company has not done the basic engineering and cannot therefore collect the BoQ1, the scope management process should start at the proposal phase.

Second point for quantity collection is during proposal phase of implementation, and the quantities collected at this time act as a baseline for work load estimations. Quantity collection during proposal phase is called bill of quantities 2, shortened "BoQ2", and it is done during contract negotiations before moving to implementation part of the project. BoQ2 acts as the basis for project planning and resourcing before implementation. BoQ2 values should be validated internally or with the customer during contract negotiations. If the customer does not have the technical knowledge, resources or is not willing to participate in the validation, BoQ2 should still be collected based on the additional information received during contract negotiations.

5.1.2 Controlling and changing scope

Collection of the quantities during the implementation is called bill of quantities 3, shortened "BoQ3". Unlike BoQ1 and BoQ2, the BoQ3 is divided into four different gates. The gates are needed since monitoring of the scope should be constant process and monitoring only once during the implementation would not help in detecting the scope changes. Because the scope gets clearer as the project moves forward, the development of quantities should be monitored against the baseline during the project when the estimates at completion can be made more accurately.

Engineers were asked that when they receive more information and can make more accurate estimates during the project implementation. Answers to this question differentiated a lot between the disciplines, for example process engineering has most of the needed information available as soon as the main machinery supplier is selected and rest of the information is available when all the equipment for the facility are bought.

When process engineering discipline has most of the needed information, other engineering disciplines can barely start working, since they need lots of information from process engineering, for example electrical engineers need to know power needs of the equipment while HVAC engineers need to know heat loads from process engineering and amounts of electrical rooms and their equipment from electrical engineers. During the interviews there were two milestones mentioned by multiple disciplines as a point when they receive more information, these points were procurement completion and PID freezing. Even though some disciplines receive more information at these points, these points do not have a clear link to every engineering discipline. Therefore, based on the interviews standard collection points could not be defined.

Defining the right steps for comparing quantities towards the baseline that would work for every project is practically impossible since the needed decisions and selections vary a lot between projects. The gates should also have some flexibility since it is possible that the project scope changes drastically during the implementation and a new baseline needs to be estimated for the quantities. Therefore, it was decided that the project sponsor can request the quantities to be estimated four times during the implementation when project sponsor sees fit.

The first collection BoQ3 should be done as soon as possible after project kick-off, and it is called BoQ3-0%. It could be collected for example after the main machinery supplier is selected. Other steps of BoQ3 are called BoQ3-30%, BoQ3-60% and BoQ3-90%, the percentages in the names refer to the readiness of the implementation phase and how the collection should happen regularly during the implementation. Project sponsor can make the decision for conducting the quantity collection, for example, after receiving information from the engineers that they have now received more information, or the collection points can also be agreed in the beginning of the project.

5.1.3 Saving scope

After the implementation phase is completed, quantities are collected for the last time for benchmarking purposes in step called bill of quantities 4, shortened “BoQ4”. The last step is not directly related to the scope management process of specific project but it is needed for benchmarking purposes and it can be utilized in future projects’ scope definitions and estimates. In addition to having all the figures collected, it is also important to save qualitative information about the project to describe the project characteristics, for example site conditions, main machinery supplier and project special decision information.

Collection of BoQ4 should be done after the project is closed and the actual quantities from the construction works are known. Since these quantities will be used again in future projects, they have to be validated before saving the data. Validation should be done by different person than collection to ensure the reliability and quality of the data.

5.2 Quantity trending phases

During every step of quantity trending there will be five similar phases need to be completed. Quantity trending process needs to be first initiated and setup before the data can be collected, and after the data is collected analysis can be made and used in the scope management process. After the information and data are used, they need to be saved for upcoming bill of quantity steps. So, the phases for every step of the process are initiate, setup, collect, use and save.

Every step of the process requires initiation and setup, meaning that someone has to be in charge of starting the process and creating the basis for quantity collection. In practice, during these steps the quantity trending system excel is created, area list of the project is selected and the project team is notified that the quantities will be collected. During setup phase the qualitative description of the project is also updated. After the setup is complete, the quantities are collected from engineering tools and other sources by each engineering discipline. Actual quantities collected act as the basis for estimating the quantities at the end of the project.

After the quantities are collected, they can be used in the analysis. However, the use cases depend on the step the project is at, for example at BoQ2 the quantities are used to validate the scope and basis for project planning while at BoQ4 the quantities are only collected for benchmarking and saving purposes. After the quantity trending information is used, it needs to be saved in standard format. Saving the data to document library in standard format is the last phase of each step and it is done so that the data and quantity trending excel are easily accessible at next step.

5.3 Quantity trending process

Criteria from the project managers was used as a basis for the quantity trending process, project managers mentioned that the process should be as simple as possible and utilize already existing processes. Project managers also emphasized that process of quantity trending should not require much extra work from the engineers, but at the same time it should help in every step of scope management. The process of quantity trending should cover all steps of the project life-cycle, from the proposal to the closure and all the steps of scope management from defining the scope to controlling the scope.

Quantity trending process consists of four different steps, BoQ1, BoQ2, BoQ3 and BoQ4, as presented earlier. BoQ1 is done after last engineering phase of a project, BoQ2 is done during proposal phase, BoQ3 is completed during implementation and BoQ4 is collected after project closure. There are four different steps because after each of these steps the scope can be defined more accurately, and these four steps cover the whole project life-cycle and, therefore, the scope management process as well.

Case company’s current scope management process, presented in previous chapter, consists of three steps, define, validate and control and change. The quantity trending process requires one more step to be added to the process, and it is saving the scope which is done after the project implementation. Saving of the scope is needed for the benchmarking and reusing purposes. Other than that, case company’s current scope management process will remain the same on high level.

There are five different phases during each step of quantity trending process, also presented earlier. The phases are initiate, setup, collect, use and save, and the phases describe what needs to be done and, depending on step, who is the responsible of the task. These phases were not present in the case company’s scope management process previously, which was mainly handled by the project manager. Quantity trending process will require involvement of the engineers to the scope management through data collection and estimation tasks.

In order for quantity trending to be utilized in the support of scope management, some changes to the case company’s current scope management process are needed. In quantity trending the controlling and monitoring parts are constant, and the scope is monitored by checking a standard list of items multiple times during project life-cycle. Process created for the quantity trending system is visible in the Figure 15.

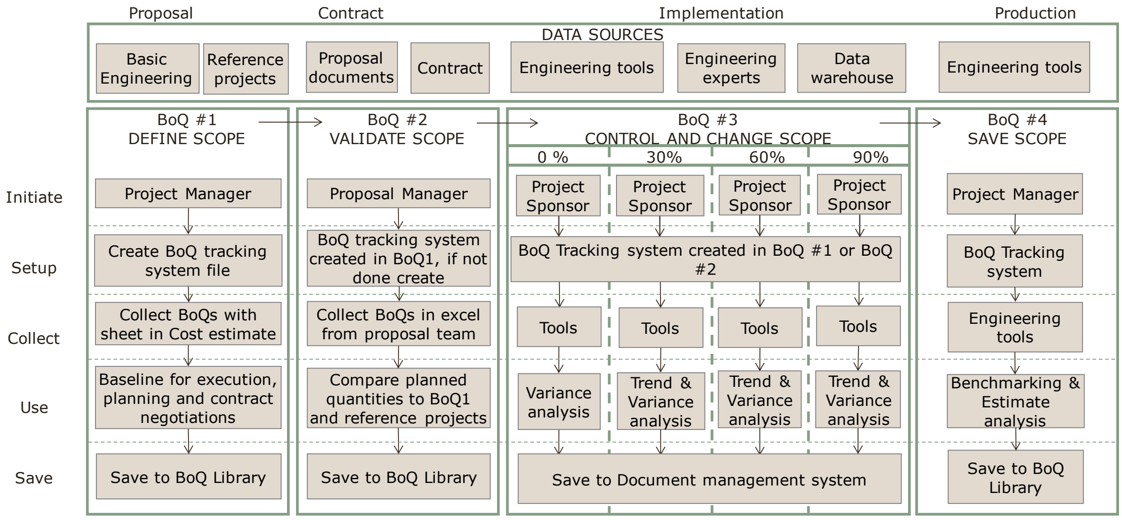

Figure 15: Quantity Trending Process

Process starts at the end of third engineering phase called basic engineering, last design phase gives quite accurate estimate about the quantities that need to be designed during the next phase. Quantities collected at this point are called BoQ1. The main deliverable of design phases for customers is the investment cost estimate created by engineering company. Customers need this document in order to validate their business case and to see that the project is economically feasible. In order to create accurate cost estimate, all the engineering disciplines need to be involved and costs need to be estimated based on their designs. Design documents have, for example, amounts of equipment and buildings for which the costs are estimated. While collecting amounts for cost estimating purposes, the needed quantities for scope definition can also be collected. This way case company's current cost estimation processes can be used as a part of new quantity trending process during the design phases. Therefore, BoQ1 is collected as a part of the cost estimation process of the case company. The collected quantities can be used to validate the design phase by comparing the quantities to reference projects but also as the basis for possibly upcoming proposal phase. In addition to the quantities, the basic information about the project is also collected to create qualitative description of the scope. This project basic information includes, for example, short description about the facility to be build, site conditions and type of the project.

After basic engineering, the quantities are collected during contract negotiations, these quantities are called BoQ2. These quantities are collected to tracking system from proposal team and used to validate the scope by comparing it to the scope defined at BoQ1. BoQ2 acts also as the basis for project planning since the quantities can also be used to estimate workload and duration of the implementation. The project's qualitative basic information is also collected and updated if needed. After BoQ2 is collected and used, the data is saved to bill of quantity library.

During the implementation phase bill of quantities is collected four times. After design phases, collecting, checking and forecasting the quantities is harder, because there are no existing processes that could be used. During the implementation there is also the need to forecast how much there will be quantities at the point of completion. Forecasted figures need to be collected from design experts at certain steps using a new process. Forecasted figures are very important since they can be compared towards the baseline, and if there is variance towards the baseline it might indicate that the scope is changing.

Project sponsor is responsible for requesting the quantity collection from the engineers during implementation. Collection dates can be agreed before the project or the collection can also be done when project sponsor notices need for checking the scope. Project team collects the quantities and estimates the quantities at completion of the project. Both actual achieved and forecasted quantities are then saved to the tracking system. Project manager conducts trend and variance analysis on the quantities, and gives report to the project sponsor. During implementation the collected quantities are used to detect possible scope changes before overruns happen and to communicate scope situation towards stakeholders of the project. During each gate the qualitative information of the project should be updated if necessary, for example the site conditions might be something other than expected.

After project, the actual quantities, called BoQ4, with project basic information are saved to tracking system. Saving information from past projects allows the case company to benchmark previous projects when defining the scopes of new projects. It is also necessary to save basic information, for example site location and specific conditions, to the system to help reference project selection in the future. BoQ4 quantities need to be validated by the project team to assure that they are collected correctly and they match the scope of the project. Accurate and validated information is saved to the bill of quantities library, and saving the data in standard format is the key for successful benchmarking.

5.4 Responsibilities

In order for the process to work, responsibilities and roles need to be clear for everyone involved. During project life-cycle there are multiple responsible persons to ensure smooth flow of the process, responsibilities during different bill of quantities and different steps are defined in Table 16. Every bill of quantity gate has their own responsible person for initiating, setting up, collecting, using and saving. These responsible persons should be contacted in the beginning of the project and made sure that they understand tasks to be done as a part of quantity trending process.

Table 16: Responsibility Matrix

Phase	BoQ1	BoQ2	BoQ3 0-90%	BoQ4
Initiate	PMO	Proposal manager	Project sponsor	PMO
Setup	Cost estimator	Proposal manager	Project manager	Project manager
Collection	Engineer	Proposal team	Engineers	Engineers
Usage	Project manager	Proposal manager	Project manager / sponsor	-
Saving	Cost estimator	Proposal manager	Project manager	Project manager

Initiator for the quantity trending process is either the project management office of the case company, proposal manager or the project sponsor. Setup of the quantity trending excel is done by cost estimator, proposal manager or by project manager. These responsible parties are visible in the first and second row of Table 16. During BoQ1 the responsible for setup is cost estimator since the quantities are collected with the inputs to cost estimate. At BoQ2 the setup is done by the proposal manager, and during and after implementation the setup responsible is project manager. These managers are in charge of managing those parts of the project anyway, so the setup is practical addition to their managing tasks.

Actual data collection for the quantity trending is done by engineers of each discipline or by the proposal team. In practice, during the collection, engineers run report from design systems in order to receive list of quantities per each area. Collected quantities are then used as a basis to estimate the quantities in the end of the project, and eventually the estimates are saved to the quantity trending system excel. The collection is done by the engineers since they are able to validate the quantities and give accurate forecasts what the quantities could be in the end of the projects.

During implementation and BoQ1 the usage is done by the project manager, and during BoQ2 the user is proposal manager, so the responsible for the usage is always the one managing that part of the project. In practice, during BoQ4, there is no usage for the data since the data is only saved to support scope management process of future projects.

Last task of each step is to save the data. While project is ongoing, the quantities are saved to document management system, and at other steps the data is saved to a separate BoQ library. Saving is done by the same person who was in charge of the setup. So, at BoQ1 the saving is cost estimator's task, during BoQ2 saving is done by the proposal manager and later parts of the project are handled by the project manager.

5.5 Data collection

As told by Bhutta and Huq (1999), data quality is one of the key factors in a working benchmarking system. Data quality in quantity trending system is handled by collecting the data in standard format. During every step all the data will be collected to BoQ tracking system that has quantity list and area split ready. Because the list of items and the areas are standard, the engineers will only have to insert asked quantity to right cell. Data quality is affected by the sources, and therefore the data needs to be validated before it can be added to the tracking system.

During BoQ1 the quantities are collected from cost estimates created by engineering disciplines. During BoQ2 the quantities are collected from the contract and proposal documents by the proposal team. During BoQ3 and BoQ4 the quantities are collected from engineering tools and the estimates at completion are done by the discipline engineers. Example of the data collection matrix where piping engineers input their data is visible in Table 17. The columns marked with green color are the columns where engineers input their estimate at completion values per item and area.

Table 17: Example of the data collection matrix for piping engineering

Discipline	QTY Description	UNIT	BoQ	SUM EAC	RCF/OCC	PM	Utilities	Coating color kitchen	Wet-end chemicals	HVAC	Electrical split	Areas/Buildings
					EAC	EAC	EAC	EAC	EAC	EAC	EAC	EAC
Piping	Various steel structures	kg	BoQ1	400		100			300			
Piping	Piping	m	BoQ1	664		644			20			
Piping	CS pipes	m	BoQ1	250		150			100			
Piping	SS Pipes	m	BoQ1	374		344			30			
Piping	Plastic and FP pipes	m	BoQ1	170		150			20			
Piping	Total number of stress critical lines	pcs	BoQ1	384		344			40			
Piping	Hand valves	pcs	BoQ1	465		405			60			
Piping	Total weight of the CS piping	t	BoQ1	310		220			90			
Piping	Total weight of the SS piping	t	BoQ1	300		220			80			
Piping	Primary support weight	t	BoQ1	332		282			50			
Piping	Secondary support weight	t	BoQ1	174		100			74			
Piping	Support position summary	pcs	BoQ1	262		220			42			
Piping	Various steel structures	kg	BoQ2	182		150			32			
Piping	Piping	m	BoQ2	454		220			234			
Piping	CS pipes	m	BoQ2	362		220			142			
Piping	SS Pipes	m	BoQ2	333		220			113			
Piping	Plastic and FP pipes	m	BoQ2	498		405			93			
Piping	Total number of stress critical lines	pcs	BoQ2	241		150			91			

In the quantity trending excel, there is a separate sheet for every engineering discipline where they input the estimated quantities at completion during all the steps of the process. Data from previously completed projects is also easily transferable to this format by copying the BoQ4 rows from a completed quantity trending excel to the quantity trending excel of the new project.

After the data is collected and used, the quantity tracking system and the data in it are saved to a document library in a standard format. In addition to the collected quantities, the updated project qualitative information, for example site conditions and main objectives, will be saved to the library in order to clarify the project for users and make finding reference projects easier from the library. Benchmarking is encouraged during the first steps of the scope management process, so the data has to be easily accessible and always in same format to make the usage of reference project data easy.

5.6 Outputs of the process

One of the main objectives of this research was to create a system that could be used to communicate scope clearly and to detect possible changes in scope. Project managers gave criteria for the outputs of the process. According to the interviews, the outputs should be easy to read and communicate but also similar to every project. Output of the system should offer easily and quickly understandable status of the scope for project owner and manager with information about where the possible issues are and how has the project scope changed.

The solution was validated by collecting quantities from one project, validation project was similar to four reference projects used in the validation of the quantity list with much less quantities available. Validation project was a paper mill project with a duration of 25 months from main machinery supplier selection until production start-up, and the facility had a capacity of 750 000 tons of paper annually.

Project's baseline was created by collecting the estimated quantities from contract documentation for three items, these items were pumps, tanks and total pipe kilometers. These items were selected because they were the items used as the basis for the engineering hour estimation in that project and they were the only quantities available in the contract. Actual quantities for those three items were collected at 30%, 60% and 90% gates from engineering tool used for process and piping engineering. The actual quantities were then multiplied based on the readiness of the project in order to create the estimate at completion for the quantities. Collected figures for these quantity trending gates are visible in Table 18.

Table 18: BoQ2, BoQ3 and BoQ4 for the validation project

	BoQ2	***BoQ3-0%***	***BoQ3-30%***	***BoQ3-60%***	***BoQ3-90%***	***BoQ4***
Pumps (units)	192	192	183	183	178	176
Tanks (units)	67	67	63	65	63	57
Pipe kilometers (units)	121,5	121,5	133	133	139	145,5

Outputs of the quantity trending process depend on what phase the project is at. After design and proposal phase, the output is a combined list of quantities estimated with comparison to selected reference project. After first two phases, quantities are used for defining and validating scope and as a baseline for the implementation phase. According to project managers, comparing the scope towards reference projects and expert opinions is very useful when creating a proposal. Proposal figures, meaning BoQ2, should be compared to reference projects and to BoQ1 if they are available. Table 19 shows the comparison between BoQ2 from validation project towards the BoQ4s from two reference projects.

Table 19: Comparison between validation project BoQ2 and two reference project BoQ4

	Validation Project	Reference Project 1	Reference Project 2
Capacity (t/a)	700 000	550 000	650 000
Duration (months)	25	24	21
Pumps Baseline (units)	192	358	176
Tanks Baseline (units)	67	103	62
Pipe kms Baseline (units)	121,5	178,9	121,6

During implementation phase the output of the process is a variance analysis showing where the estimation at completion differs from the baseline. The variance in quantities between steps might mean that the project is drifting from the scope, or that the estimates are not done properly. The same approach could also be used to compare reference projects and the quantities form BoQ1 and BoQ2 in order to validate the proposal. The variance of the quantities can also be used to estimate impact of the change, for example in working hours. After, for example, a requirement change from the customer, the case company should first re-estimate the quantities at completion, and then the case company could communicate towards the customer a graph displaying the impact of the change in quantities and working hours.

In actual implementation of the quantity trending, the estimates at completion would have been done by the engineers in charge of the design so that the estimates would have been more accurate and not done based on the readiness of the whole project. All the collected quantities were added to same graph in Figure 16 in order to visualize the variance between the baseline, actual and estimate at completion quantities.

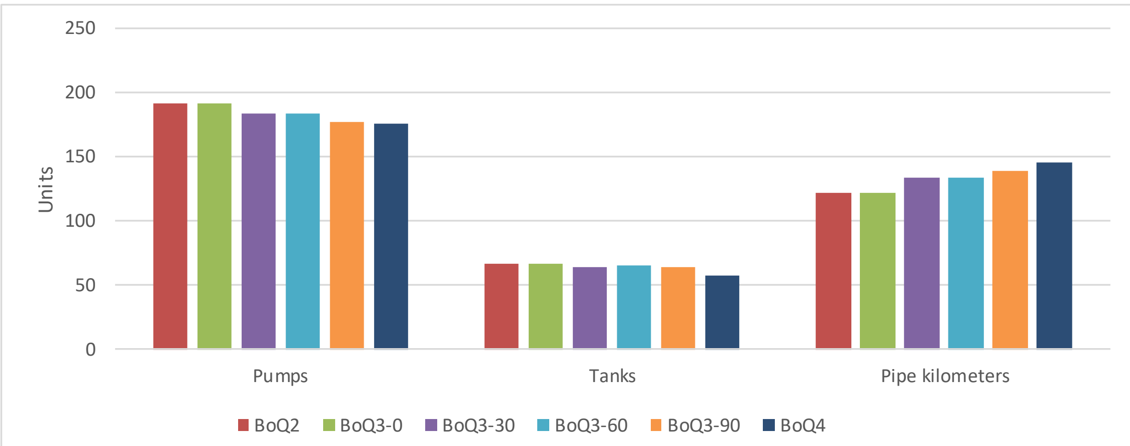

Figure 16: BoQ2-BoQ4 from validation project visualized

In Figure 16, it is clearly visible how the BoQ4, meaning the actual amount at the end of project, for pipe kilometers is higher than the estimate given at the beginning of the project, while pumps and tanks matched quite well the estimates written in the contract. Increase in the needed pipes at BoQ3-30%, which is almost 10% more than estimated at previous gate, should alarm the project manager to at least assess the situation with piping engineer. The variance between estimated quantities of pumps and tanks was smaller but the reasons could also be verified with the engineers.

According to Figure 16, it seems to be possible to give accurate estimate about needed quantities for a project before starting the last design phase. All in all, it seems that the process outputs give indication about possible scope creeps. However, in order to get indication in time, the estimation of quantities at completion needs to be accurate and estimate should be done based on the actual situation of the project rather than based on the baseline. Having unbiased estimate from engineer that created the original baseline might be impossible, therefore inaccurate estimates decrease the change of detecting scope creeps.

Standard format of data collection ensures the data quality and comparability between projects. The quantities collected in standard format during the project can later be read to analysis tools, for example to analyze the correlation between quantities and project characteristics or to evaluate how the actual quantities developed during the project.

6. DISCUSSION AND CONCLUSIONS

This chapter first explains how the research question and the sub questions were answered by this research. Based on the research, it can be stated that quantity information can be utilized in the scope management to support all the parts of scope management process. Utilizing quantity information will require both company and industry specific knowledge in order to work.

Second part of this chapter compares the differences between results of this research to scope management literature. In literature, there were no similar solutions available but the created system has lots of similarities to existing scope management methods. Third part of this chapter discusses the practical implications of the solution to the case company, and how quantity trending affects the scope management in case company's pulp and paper industry's projects.

Fourth part focuses on the limitations of this research and its results. As mentioned in the literature, creating a standard list of items to track requires knowledge and understanding about both the company and the industry. So, the results are directly applicable only for the case company of this research and pulp and paper industry's projects.

In the last part, few ideas of future research related to this thesis are discussed. The usage of quantitative information to support project management is a topic that is not widely researched in the project management literature. In the project management literature, there were only three methods developed for controlling and monitoring the scope of a project systematically.

6.1 Answers to research questions

Research question of this thesis was, "How a project based firm can utilize quantity information in managing scope in the context of pulp and paper industry projects?" Based on the results of this thesis it can be stated that the scope of a pulp and paper industry's project can be defined, validated and controlled with quantity information of predefined list of items. Definition of scope can be done with quantities and short qualitative description, and validation of scope is supported especially with the possibility to compare projects and quantities from them. Scope control and detecting changes in scope can be supported with variance analysis between baseline and estimated scope of a project. The main benefits achieved by utilizing quantity information in scope management are a common way for defining scope, quantity based scope monitoring and possibility to reuse data from previous projects. Common way of defining scope makes the projects more comparable and can make the scope management process more efficient if the items are known by the project team.

One sub research question was, “What are pulp and paper industry’s project characteristics?”. According to interviews, engineering projects are hard to handle since every discipline is linked to each other and delay in one task always has impact on somewhere else. Changes to scope were, according to literature and interviews, more common during the engineering phases when the construction works had not yet begun (Nicholas and Steyn 2017, p. 386). Pulp and paper industry’s projects usually last for multiple years and the amount of stakeholders is high, which increases the importance of project management.

One of the reasons for starting this thesis was the problem in communicating scope and its changes to customers. The second sub question of the research question was, “How a project based firm can define and communicate scope with quantities?”. Definition and communication of the scope, according to literature, can be done by using a standard list of quantities or items. Using quantities was one of the scope definition methods according to interviews as well. By having the scope described in a standard way with same quantities in every step during project life-cycle, engineering company can easily describe and show to the customer if there are changes in the quantities and where they are. Created quantity trending system, according to validation, can easily visualize the scope of each engineering discipline and the changes in it. Regardless of the customer’s understanding about the quantities, the scope control and internal scope communication can still be done by using quantities in the case company. Explaining the reasons behind scope changes is still a responsibility of the project manager and lead engineers, and it cannot be done solely with the quantity trending system.

One problem behind this research was with creating reliable estimates of scope and workload. The third sub question of the research question was, “How a project based firm can reuse information and learn from previous projects?”. Data from completed projects can be utilized in the estimation of workload and tasks. Benchmarking can also be used in validation, and it increases the reliability of estimates according to literature. In the case company discussions with project managers and employees that have worked in some specific projects is a common way of getting more knowledge and learn. By having quantitative data collected and stored in standard format on area level per each quantity should allow the company to benefit from benchmarking in future estimates. In order to create sufficient database of quantity information, the process needs to be used for a while. In addition to the quantitative data, a short qualitative description of the project basic information and scope needs to be saved. Qualitative scope definition is needed especially for selecting the right reference projects and understanding the project specific conditions and decisions.

Last reason for starting this research was problem with noticing scope changes, and the fourth sub question of the research question was, “How the project team can detect scope changes?”. According to literature and interviews, scope changes can be detected by any project stakeholder and after that, they should be communicated to the project management. In literature there were methods, like earned scope management, developed for monitoring the scope of a project. In the case company every project manager had their own methods for tracking the scope. According to interviews, some scope changes are visible in the quantities, for example dramatic increase in pump quantity might indicate that some requirement has changed and therefore designing of more pumps is needed from the case company. So, scope changes can be detected from the quantitative information.

6.2 Results compared to literature

Reasons for scope changes detected in the case company were similar to the reasons for scope change detected in the literature. In literature the most common reasons for scope changes were unclear definition of objectives, lack of communication and requirement changes (Alnuaimi et al., 2010; Mirza et al., 2013; Amoatey & Anson, 2017). Project managers of the case company emphasized the importance of starting information and told how requirements often change during a project causing the scope to be changed as well. Other common reasons for scope changes, according to project managers, were misunderstandings, lack of communication and poorly defined scope. Most of the scope change reasons detected in the case company and in the literature are related to planning phase of a project which seems to be the most important part of scope management.

Quantity trending system can be used in every part of scope management process described in PMBOK (2018, p. 130). In defining phase the quantity list describes what and how much of each item is needed for the end result. Validation of the scope can be done against reference projects where the scope is also defined with standard quantity list. Controlling of the scope is done by updating the estimate at completion for the quantities, so that a warning can be received before the scope has changed. Compared to scope management process presented in PMBOK (2018, p.130) case company’s current scope management process had similar phases. The quantity trending process has one extra phase, the saving of the scope after scope control, which is needed for archiving the data so it can be used for benchmarking purposes.

Bhutta and Huq (1999) mentioned that benchmarking requires data, and the collection of data needs to be continuous in order to offer real benefits for the company. Quantity trending is planned to be conducted as a continuous process for pulp and paper industry's projects. Measuring to support project management has come more and more common during recent years when companies have realized the amount of available data and the possible benefits of analyzing it (Vanhoucke et al. 2016). Quantity trending system is essentially a constant measuring system where the amounts of predefined elements are monitored in projects in order to detect problems in scope. Snider et al. (2018) mentioned that the automatizing possibility of quantitative measures is one of the biggest benefit of them. Same possibilities were detected based on the discussion with project managers of the case company. Project managers were keen on tracking the scope with quantitative measures, if it would not require too much work from the engineers.

In literature the quantities of similar objects than in quantity trending system are used in cost estimating purposes in a method called bill of quantities (AACE, 2004, p.384). In this method the quantities are seen as element with cost, and when summed they form the facility to be built (Lester, 2014, p.61). In bill of quantities the focus is merely in the costs and not in the scope. Quantity trending utilizes the same quantitative information, but not all the quantities used in the cost estimating are needed when defining the scope of the project. This is because not all the quantities that are used in the cost estimate are needed in the scope definition, for example having lots of special equipment might increase the cost drastically but does not affect the scope of engineering company at all.

In the scope management literature exactly similar solutions were not available but three methods had similarities to the quantity trending process created in this research. Lack of scope management methods could also be detected in the case company since all the project managers were using their own methods and techniques for managing scope. The standard quantity list idea is similar to PDRI method where the scope is defined with checklist of items (Dumont et al., 1997). In quantity trending the scope is defined with a list of quantities to be defined and with short qualitative description of the scope, which was not included in the PDRI. PDRI method enables standard way of communicating the scope which is one of the tasks of quantity trending system as well (Dumont et al., 1997). Quantitatively defined scope from quantity trending process can also be communicated towards the customer but it will require technical knowledge.

Idea of collecting quantities of items designed by engineers in quantity trending is exactly similar to quantity engineering project scope definition. In QEPSD the quantities are used to estimate the workloads of engineering disciplines. (Song & AbouRizk, 2005) In quantity trending the quantities are used for defining the scope, so utilization of the quantitative information is almost opposite to the QEPSD method. QEPSD method showed that there is clear correlation between items designed and the working hours, which could not be proven in this research. According to literature, data from completed projects can be used to accurately estimate the scope and working hours of new project (Chritamara et al., 2001; Song & AbouRizk, 2005). Some engineering disciplines of the case company were already using quantities from completed projects as the basis for their estimations of scope and working hours. This data usage was mainly handled by individual employees, and there was no standardized data utilization actions happening in the case company.

In quantity trending the aim is also to track the scope during the project and notice possible changes. ESM method presented by Valdes-Souto (2017) showed how the scope could be visualized if it is defined in quantitative way. Variance and possible scope changes are easily detectable from scope defined with quantitative information. The variance analysis and visualization of the scope are also in use in quantity trending process, even though the variety of items tracked is much wider than in ESM where only the use cases are tracked.

6.3 Practical implications

In order to utilize quantity trending, the case company needs to modify its scope management process and add some phases to it. Previously scope management was handled mainly by the project manager with three steps during a project. Quantity trending requires one more step to be added and includes engineers to the scope management process through the estimation of quantities. Project manager and proposal manager are in charge of the implementation of quantity trending, and managing the process will require working hours during the implementation. Quantity trending will save working hours in scope communication, monitoring and estimation tasks with the possibility to utilize information from previous projects.

Scope communication will especially benefit from the chance of visualizing the scope and changes to it for the stakeholders with technical knowledge. Therefore, the communication should be handled with both the combination of qualitative and quantitative scope definition in the future. When both definitions are presented to the customer already in the beginning of the project, understanding them will be easier and communication more efficient during the implementation.

Quantity trending will be handled with Excel tool where the estimations for the quantities are inserted and from where the outputs of the scope are communicated. Excel work will be an addition to the work of project team during the project life-cycle and will require work for filling the quantities during all the seven gates of quantity trending process. The importance of accurate estimates is high in detecting the scope changes, so the engineers doing the estimation need to be taught to conduct the estimates accurately. Possibility to conduct the data collection automatically from the engineering tools should be further analyzed in the case company after implementing the quantity trending process.

Scope estimated in quantitative way during planning phase based on data from previous projects can lead to more accurate estimates about the scope, and therefore also the needed working hours can be estimated more accurately. In future the quantities from previous projects could already be utilized in the estimation tasks during the proposal phase. In order to benefit from the quantity collection in the benchmarking, quantity collection should be done in multiple projects, so roll-out of the system should be done for all the parts of the company. Quantities should be collected from different kinds of projects in the same industry, for example from paper mills built with different machinery suppliers or in different climate conditions. If the data collection is done for large amount of projects, there should be sufficient amount of data to back up the estimates made for new projects.

After a while of using the quantity trending system and data collection the case company could, by analyzing the collected quantities, deduct which quantities have the most impact on project scope and needed working hours. This information would be very valuable for case company since working hours are the main source costs and, if estimated inaccurately in the planning phase of a project, it might lead to decrease in profits. The reliability of estimates could also be assessed again in, for example, a year in order to see if the estimates have become more accurate when quantities from completed projects are utilized. In future the quantity trending system could also be further developed for other industries of the case company’s offering as well, which would require defining the quantity lists, validating the process suitable for needed industries and good results from the pulp and paper industry’s implementation.

6.4 Criticism and limitations

This sub chapter describes the limitations of the research's findings. Biggest limitations of this research and its findings are the nature of project work, data quality and dependency on expertise of the engineers. Projects are always unique scope wise, so defining common ways for defining the scope is always a limitation. Data availability and quality made the quantitative validation of the quantity list impossible, which means that the list is based on engineers' expertise. Third limitation of this research is that the created system depends on the expertise and knowledge of engineers doing the data collection and estimation. There were also some assumptions made during the research and some aspects left out of the scope of this research, for example the area split used in the system and complexity differences between quantities were not analyzed at all.

Projects are always unique so trying to model them has always limitations. Quantity list of the process simplifies projects and does not consider the differences between country specific aspects like regulation or site environment. There are huge differences between countries, for example in project success factors, labor productivity and regulation. All these differences can have impact on the scope, for example adding few permits because of regulations, can lead to hours of more work per building.

The process is defined only for pulp mill and paper mill projects of the case company. The process is not directly transferable to other companies or industries since it has been modified according to case company's ways of working and existing processes. The quantity list is depended on industry, engineering tools and standards. Using the same quantity list in order to defining the scope for other than pulp and paper industry's projects would not give sufficient solution. However, quantity list for other industries could be defined with the same methods as in this research, starting from involving engineering experts and then analyzing the list again with quantitative data.

The scope of an engineering company can vary a lot between projects, some customers buy most of the engineering from one company but some customers might have different engineering company for every area of the project. This means that in some cases engineering company's scope is to design one building from the whole pulp mill and sometimes it includes all the buildings. This is why it is also very important to collect qualitative definition of the scope and correct project characteristics that match the scope of the engineering company.

Understanding quantitative scope in order to benefit from the quantity trending system requires technical knowledge from the users. Scope communication with the quantitatively defined scope requires technical knowledge and resources also from the customer. If the quantities are not defined in the contract, the quantity trending might not offer any useful information for the customer. If the customer is not willing to use its resources or does not have the technical knowledge, quantity trending does not support the scope communication. In these cases the quantity trending can still help in the internal scope management process of the case company.

In order to detect scope creeps in time, quantity trending process requires estimates about the quantities at completion. Estimates are always subjective and depended on the expertise of the estimator and available information at the time of estimation. The quantity trending process does not give right information about the scope changes if the estimates are not accurate. The gates for checking the quantities during a project implementation phase were not defined tightly to certain milestones. For individual engineering disciplines these gates could be defined but finding one set of milestones suitable for all the disciplines would require more depth analysis on the matter. So, it is project sponsor’s responsibility to detect right times for collecting quantities to detect possible scope changes.

Learning from previous is a constant process so the quantity trending process needs to continue even after this thesis in order to actually benefit from data collection. Engineers 2 and 3 mentioned that the amount of different equipment and automatization has increased a lot during the last years, which has made the facilities to be built even more complicated. This information suggests that for some disciplines the quantities increase as we move from past to more recent projects. This information indicates that the data collected from reference projects is not valid after some time if the complexity of the projects keeps on increasing.

Because there were not enough reference projects available and data could not be collected for all the quantities, reduction of the quantity list based on correlation analysis could not be conducted as a part of this research. All the quantitative data was collected from European projects and from completely new paper mills. Demolition and modification works are, according to the engineers, much harder to estimate, and creating a design for a facility that already has, for example, walls creates lots of limitations and affects the scope of the project a lot. So, before trying to use the created quantity list for brownfield projects some more validation might be needed since the limitations created by existing structures can have huge impact on the needed quantities and vary a lot between projects. Differences between countries can also impact the quantities needed for a project, for example building in South-America compared to building in Europe has lots of differences related to labor costs, freights, regulation and taxation.

Assessing the economic feasibility of the data collection during projects should be done before implementing the quantity trending system. If all the quantities are collected per each area and item in the quantity list, there would be over 3000 figures per each quantity trending step, and collecting this many numbers manually will require hours of work from the engineers. Economic feasibility could be assessed by comparing the benefits from quantity trending towards the needed working hours. If the data collection could be done automatically, it might drastically decrease the amount of needed working hours and make the quantity trending more economically feasible.

In order for quantity trending to be more automatized, the data could be read automatically from the engineering tools. This would, however, require standardized working methods between all the projects conducted by the case company. When examining the data available from the reference projects, it came clear that the way of using the tools differentiates a lot between individual engineers and projects, which makes the data quality poor and data collection time consuming.

Because there was already a preliminary quantity list in the case company, it might have affected the answers of the engineers that were interviewed in order to challenge and validate the list. Defining suitable area split for pulp and paper industry was left out of the scope of this research. Area split for the areas in typical paper mill project was assumed to be correct and therefore not analyzed. Using more detailed or more high level area split might affect the results and estimations in future projects.

The complexity differences between quantities, meaning the difference between designing, for example first and second quantity, are not relevant for this research because of two reasons. First, there are no items in the quantity list that could only appear once in a project. Second, after the first quantity all the quantities, are according to interviews, equal regarding the complexity. Therefore, complexity differences were not assessed in this research even though they probably exist between the quantities at some level. Productivity differences between employees in designing work of the quantities can also affect the estimated working hour needs if there is not enough data available from completed projects for the estimation.

In quantity trending process monitoring of the scope is done three times during a project. Three times was considered to be sufficient since there are only few major steps when engineers receive more information and can make more accurate estimate of the quantities at completion. Three times was also selected, so that the data collection would not require too much work from the engineers. However, scope changes can happen any time during the project, and it is possible that scope change might be detected through other methods before quantity trending process reaches next gate. If the data collection and estimation of the quantities at the completion could be automatized, monitoring of the scope could be done even on daily basis in future.

6.5 Future research

In project management literature there were only three common methods developed for defining and controlling the scope of a project, even though the consequences of poorly executed scope management are well known. The methods presented in the literature, similarly to quantity trending presented in this research, are industry and often company specific methods, so they cannot be utilized in without modifications. Possibility to define scope of a project in high level in a simple way could be researched in the future.

When defining the deliverables and tasks needed in a project, the experience of employees can offer valuable information. One big issue that all engineering companies face at some point is transferring the knowledge of experienced engineers to next generation. This was clear during the interviews since expertise was one of the key methods for estimation and usually the person asked for expertise was someone with lots of experience from similar projects. The knowledge of experienced employee is clearly visible, for example, when estimating needed working hours or needed tasks for a new project. For future research it would interesting to find out how to collect and transfer the tacit knowledge of engineers and project management experts for future generations.

All project based companies have an issue with the scalability of work because all projects are a bit different and same solutions cannot be directly transferred to other projects. Scalability benefits can be received, for example, from the project management's planning and monitoring tasks where experience and data from completed projects could be utilized. Since projects are considered to be unique, collecting the data from completed projects seems often to be neglected. Data from completed projects could however offer, for example, basis for more accurate estimates (Nicholas & Steyn, 2017, p. 158). Nowadays projects produce massive amounts of data through the tools and systems used, this data could be utilized, for example, to support scope management as shown in this research. Gathering data directly from tools used in the projects and quantifying different project management aspects in order to make tracking of them easier and automatized could be interesting subject to research on in the future. This kind of research might also reveal correlations between unexpected variables.

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APPENDIX A: STRUCTURE FOR PROJECT MANAGEMENT INTERVIEWS

Background of the thesis:

- Solution for defining and managing scope in P&P projects
- System and standardized processes for collection and analyzing
- Benchmarking and reference project database

Project manager interview frame:

1. What are the main reasons for scope changing during a project in case company? (bad estimation, design error, resources)

2. Reference projects for estimation, how do you select?
   - How do you select?
   - What is good reference?
   - Different references for different purposes?
   - How to assess site differences etc.
   - One or multiple references

3. How do you usually define the scope of a project? (tools and techniques)
   - Is this method in common use or your own preference?
   - Have you used different methods / tools?
   - Do you use completed projects in the definition?

4. Have you ever tried defining scope using standard checklist?
   - If yes, then what and how it worked?
   - If no, why not?

5. How do you handle scope control during project? (Methods and tools)
   - What initiates the need for change?
   - How to detect?
6. How is the impact of change order estimated?
   - Scope, working hours and schedule

7. What do you think that are the most important factors behind effective scope control? (Trust, communication…)
   - How should the tool consider these factors?

8. If there was a tool for defining scope and controlling it, what kind of feature would you like it to have? (creating scope baseline etc.)
   - Would you use this tool in every project or just big?
   - Design vs. implementation needs?

9. What kind of criteria can you define for scope management tool? (Easy to use, simple, modifiable)

10. Have you used quantities or data analytics as a method for scope management?
    - If you would use such a tool, when the figures should be collected?

11. Free discussion

APPENDIX B: STRUCTURE FOR ENGINEER INTERVIEWS

Background of the thesis:

- Solution for defining and managing scope in P&P projects
- System and processes for collection and analyzing
- Discipline specific standard quantity list available, but shown only in the end from question 5.

Engineering question frame

1. How do you estimate hours you need for a project?
    a. If you want more hours how you define the amount?

2. Do you use reference projects in estimation of quantities or workload?
    a. How do you select them?
    b. One or multiple? Average or best?

3. How do you detect if change is part of project scope?
    a. Documents? Discussions?
    b. What to do when scope is exceeded?

4. If trying to tell someone how much work you have to do for a project what quantities do you use?
    a. How would you define the scope of your work?
    b. Is it affected by other disciplines, e.g. building volumes or equipment

5. What quantities and objects do you think that correlate the most with
    a. Amount of work
    b. Achieved progress
    c. Project magnitude

6. What are the quantities that are
    a. Most complex
    b. Require most time

7. How does the amount of quantities affect the time needed for designing one? (If you design one pump, is it easier to design the second?)

8. How much do the projects differ quantity wise? (E.g. pump amounts or pipe meters in pulp mills)

9. If quantities were collected during a project implementation phase
    a. What do you think would be the best times?
    b. Who in your discipline would be the best person to estimate what are the estimate at completion quantities?

10. Free word

APPENDIX C: PRELIMINARY QUANTITY LIST

Quantity	***Unit***
Flowsheets	pcs
Pumps	pcs
Standard pumps	pcs
Special pumps	pcs
Vacuum pumps	pcs
All equipment in BOP	pcs
process equipment	pcs
Tanks	pcs
Agitators	pcs
Pipe lines	pcs
Number of different flow media	pcs
Various steel structures	pcs
Piping	m
piping large pipes (DN>500)	m
piping small pipes (DN<50)	m
piping medium pipes (50≤DN≤500)	m
Elbow	pcs
CS pipes	m
piping large pipes (DN>500)	m
piping small pipes (DN<50)	m
piping medium pipes (50≤DN≤500)	m
SS Pipes	m
piping large pipes (DN>500)	m
piping small pipes (DN<50)	m
piping medium pipes (50≤DN≤500)	m
Plastic and FP pipes	m
piping large pipes (DN>500)	m
piping small pipes (DN<50)	m
piping medium pipes (50≤DN≤500)	m
Total number of stress critical lines	m
Hand valves	pcs
large (DN>500)	pcs
small (DN<50)	pcs
medium (50≤DN≤500)	pcs
Total weight of the CS piping	t
Total weight of the SS piping	t
Primary supports (split by size?)	pcs
Primary support steel weight	t
Secondary support	pcs
Secondary support steel weight	t
Distribution, HV main power transformers	MVA
Distribution, HV main power transformers	pcs
Distribution, MV cubicles/panels	pcs

Quantity	***Unit***
Distribution, Diesel generator	MVA
Distribution transformers	MVA
Distribution transformers	pcs
Process Motors, MV	pcs
Process Motors, LV total	kW
Process Motors, LV total	pcs
Process Motor, LV DOL	kW
Process Motor, LV VFD	kW
Process Low Voltage sectional drives	pcs
HVAC Motor, LV DOL	kW
HVAC Motor, LV VFD	kW
E-loop, Process Motor, LV DOL circuits	kW
E-loop, Process Motor, LV VFD circuits	kW
E-loop, Process Motor, LV sectional drives circuits	kW
E-loop, HVAC Motor, LV DOL circuits	pcs
E-loop, HVAC Motor, LV VFD circuits	pcs
E-loop, Electrical heat tracing switchgear/centers	pcs
E-loop, Power-, UPS- and Control voltage feeders	pcs
Cable trays - main routes (excl. droppers)	pcs
Building electrification, office	pcs
Building electrification, process area	pcs
Lighting fixtures, office	pcs
Cable trays	m
Fire alarm field devices	pcs
Maintenance power centers	pcs
Building HPAC (LVI) motor circuits	pcs
Lighting fixtures, process area	pcs
Lightning protection	m^2
Lightning protection	m
Pipe bridge lighting	m
Street or Area lighting	pcs
HW+SW DCS+SRS I-Loops	pcs
HW+SW DCS+SRS E-Circuits	pcs
SRS Loops	pcs
ATEX Loops	pcs
I/O's	pcs
Hookups Junction Box (70%)	pcs
Hookups Instruments	pcs
Switches	pcs
Flow Meters	pcs
Standard Instruments	pcs
Automatic Valves	pcs
Functional Description and Sequences	pcs

Quantity	***Unit***
Network cabinet	pcs
Cameras Production	pcs
Cameras Security	pcs
Networked application links	pcs
Fiber optic trunk cables	pcs
Fiber optic trunk cables	m
Horizontal twisted pair cables	pcs
Flowsheets/PIDs	pcs
HVAC design criteria and system description	pcs
Process areas where is HVAC systems	m^2
Electrical, cable and automation rooms	m^2
Office	m^2
HVAC Equipment	pcs
-Air handling units	pcs
- exhaust air fans	pcs
- heat exchangers	pcs
- pumps	pcs
- tanks	pcs
-other components	pcs
Pipes	m
Ducts	m
HVAC Control	
HVAC HW+SW E-Circuits	pcs
HVAC HW+SW I-Loops	pcs
Junction Box (70%)	pcs
HVAC Instruments	pcs
HVAC Switches	pcs
HVAC - Flowmeters	pcs
HVAC - Standard Instruments	pcs
HVAC - Hand Valves	pcs
HVAC - Automatic Valves	pcs
Building	m^2
Very demanding building	m^2
Demanding building	m^2
Normal building (Warehouse etc.)	m^2
Building volumes	m^3
Pre cast concrete elements	pcs
Beams	pcs
Wall elements	pcs
Columns	pcs
Slabs	pcs
Cast in situ concrete	m^3
Building foundations concrete	m^3
Building foundations reinforcement	kg

Quantity	***Unit***
Building frame, columns, beams, walls, concrete	m^3
Building frame, columns, beams, walls, reinforcement	kg
Floors, concrete	m^3
Floors, reinforcement	kg
Large machine and tank foundations, concrete	m^3
Large machine and tank foundations, reinforcement	kg
Small machine and tank foundations, concrete	m^3
Small machine and tank foundations, reinforcement	kg
Piles	pcs
Pile capacity <3000kN	m
Pile capacity 1500 - 3000kN	m
Pile capacity 700 - 1500kN	m
Pile capacity >700kN	m
Roofing and cladding	m^2
Roofing, insulated	m^2
Roofing, simple	m^2
Walls, light weight sandwich wall	m^2
Walls, light weight insulated, complex structure	m^2
Walls, simple - non insulated	m^2
Steel structures	kg
Primary steel	kg
Secondary steel	kg
Pipebridge steel	m
Weight: <3000 kg/m	m
Weight: 2000 - 3000 kg/m	m
Weight: 2000 - 1000 kg/m	m
Weight: 1000 - 500 kg/m	m
Weight: >500 kg/m	m
Building Volumes	m^3
Process area	m^3
HVAC/EL. Room	m^3
Building Areas	m^3
Process area	m^2
Electrical and Automation Room	m^2
Control Room	m^2
Cable rooms	m^2
Trafos	m^2
Office	m^2
small rooms	m^2
El./HV rooms	m^2
Other Areas	m^2
Roads/Streets	m^2
Mill area	m^2