Tampere University

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DEVELOPING PROJECT CONTROL AND PROGRESS REPORTING IN MULTI-PROJECT ENVIRONMENT

Faculty of Management and Business
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ABSTRACT

Simo Kokkola: Developing project control and progress reporting in multi-project environment
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In history, Ford and Toyota were successful in creating production system that answered the market needs in that time. In modern job shop production companies, the control problem is different as the production has elements from mass production and project production environments. This master's thesis explores the managerial challenges that emerge in a Finnish heavy machinery manufacturing company which deliveries customized products globally. The challenges are studied from a multi-project management perspective which is less covered knowledge area in the field of manufacturing.

The need for this study rises from need to get better control of labour costs in production. The symptoms of this problem are seen in exceeding work hours compared to planned workloads and poor productivity. The history data of delivery projects lacks confidence thus straightforward conclusions of the deviation reasons have been difficult to make. This managerial problem is approached by getting to know the company's competitive and operational environment and the objective is to understand how planning, monitoring and controlling of work should be organized in this multi-project environment. The study consists of literature review considering single-project and multi-project management areas and empirical part where data was collected with observation method in the case company.

The company's strategy of designing and manufacturing customized products created challenges in the planning and controlling of the production. It was seen that the environment had lot of schedule uncertainty and the projects competed for the same resources. The activity time uncertainties and conflicting resource needs were not handled with the current control system and the organization did not have homogeneous view for the production program. The situation was seen as changing priorities and confusion on the factory floor which required constant communication between different work phases.

To improve the situation, a planning and monitoring system were designed for the final assembly line. This way the communication of work packages progress and ending dates could be communicated with better detail. In order to improve the situation even more the overall production control system should be improved. The multi-project management knowledge area handles topics considering organization culture and control methods such as critical chain method which have potential for deeper research.

Keywords: multi-project management, project management, job shop production, production control, work planning and monitoring

TIIVISTELMÄ

Simo Kokkola: Projektinhallinnan ja etenemän seurannan kehittäminen moniprojektiympäristössä
Diplomityö
Tampereen yliopisto
Tuotantotalouden diplomi-insinöörin tutkinto-ohjelma
Tarkastajat: Yliopistotutkija Jari Paranko
Syyskuu 2021

Historiassa, Ford ja Toyota onnistuivat luomaan tuotannon ohjausjärjestelmät, jotka vastasivat sen hetken markkinoiden tarpeisiin. Nykyaikaisissa yksittäistuotantoyrityksissä ohjausongelma on erilainen, koska niiden tuotannossa on elementtejä massatuotannosta ja projektituotantoympäristöistä. Tämä diplomityö tutkii johtamishaasteita, mitkä esiintyvät suomalaisessa teollisuusyrityksessä mikä valmistaa ja toimittaa räätälöityjä laitteita maailmanlaajuisesti. Näitä haasteita tutkitaan moniprojektihallinan näkökulmasta mitä on valmistukseen liittyvässä kirjallisuudessa tutkittu vain vähän.

Tämän tutkimuksen tarve nousee esiin johdon tarpeesta saada tuotannon työn kustannukset parempaan hallintaan. Tämän ongelman oireet näkyvät suunniteltujen tuntien ylittymisenä ja huonona tuottavuutena. Historiadatan perusteella on vaikea tehdä suoria päätelmiä, sillä datan laatu on heikko. Johtamishaastetta lähestytään tutustumalla yrityksen kilpailutekijöihin ja toimintaympäristöön. Tavoitteena on ymmärtää miten työn suunnittelu, seuranta ja ohjaus tulisi järjestää tässä moniprojektiympäristössä. Tutkimus koostuu kirjallisuuskatsauksesta, joka käsittelee yksittäisten projektien hallintaa sekä moniprojektiympäristön hallintaa. Empiirisessä osassa data kerätään tarkkailumenetelmällä tapaustutkimuksena.

Yrityksen strategia suunnitella ja valmistaa räätälöityjä tuotteita loi haasteita tuotannon suunnittelussa ja ohjauksessa. Tutkimuksessa nähtiin, että tuotannossa on paljon epävarmuutta aikatauluissa ja samaan aikaan projektit kilpailevat samoista resursseista. Nykyinen ohjausjärjestelmä ei ottanut riittävästi huomioon tehtäväaikojen epämääräisyyttä tai resurssikonflikteja ja organisaatiolla ei ollut yhtenäistä näkymää tuotanto-ohjelman tilasta. Tehtaan lattialla tilanne näkyi prioriteettien vaihteluna ja yleisenä epäselvyytenä mikä aiheutti jatkuvan kommunikointitarpeen eri työn vaiheiden välillä.

Tilanteen parantamiseksi loppukokoonpanoon luotiin työn suunnittelu ja seuranta järjestelmä. Tämän avulla työpakettien etenemä ja valmistumispäivämääriä voidaan kommunikoida paremmalla tarkkuudella. Tilannetta voidaan parantaa entisestään jatkokehittämällä koko tuotannon ohjausjärjestelmää. Moniprojektinhallinnan kirjallisuus käsittelee organisaatiokulttuurin ja ohjaustavan, kuten kriittisen ketjun menetelmän, merkitystä, mitkä tarjoavat mahdollisuuden lisätutkimukselle yrityksessä.

Avainsanat: moniprojektihallinta, projektinhallinta, yksittäistuotanto, tuotannonohjaus, työn suunnittelu ja seuranta

PREFACE

Past times have been extraordinary in many ways and the world seems really different compared to what it was when this project started. However, these times have changed me and my life for much better. I'm grateful that I'm in this situation, finalizing this thesis and putting it behind with permanent job and strong confidence of my own competence.

For this, I want to sincerely thank all my friends and teammates, coworkers, superiors and relatives who showed interest towards this project. Those persons who remembered to stress me with questions of how the thesis is going really gave me the irritation to go forward. Special thanks go to my girlfriend who shared the stress with me and pushed me to go beyond my own comfort zone.

And for all the doubters, as the date below proves, I kept my promise and graduated before Christmas.

In Tampere, September 23, 2021

Simo Kokkola

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LIST OF SYMBOLS AND ABBREVIATIONS

ERP	Enterprise Resource Planning system
MES	Manufacturing Execution System
PBS	Product Breakdown Structure
WBS	Work Breakdown Structure

1. INTRODUCTION

1.1 Background of the research

In 1909 Henry Ford stated “Any customer can have a car painted any color that he wants so long as it is black” as he decided that his factory would only produce the T-Model. His belief was that the one model could be manufactured cost efficiently while it still would satisfy every need of a customer. (Ford & Crowther, 1922, p.72) Since Fords famous quote, modern manufacturing industry has gone through several changes. Ford was a pioneer in developing mass production systems where the main competitive factor is low price. Later, Toyota developed Lean manufacturing system that could provide the mass productions cost efficiency together with good quality and speed to market. These factors together with increased global competition have led many companies to create competitive advantage by offering customers more personalized products.

The personalization, quality, speed to market, and competitive market price create a formula that is difficult to meet with success. Especially in job shop production, where low production volumes and wide product mix do not offer the same opportunities for continual improvement as in mass production systems. In this kind of environment, the competitive factors force a company to deliver customized products with tight schedules and limited resources. This can easily cause intentional and unintentional changes to product structures and production processes from delivery to delivery. These constant changes again lead to inefficient working methods, weak control and insufficient documentation and utilization of information. The final outcome can be

seen as long lead times and poor productivity. Figure 1. shows the connection between competitive factors, the challenges that they create and poor productivity.

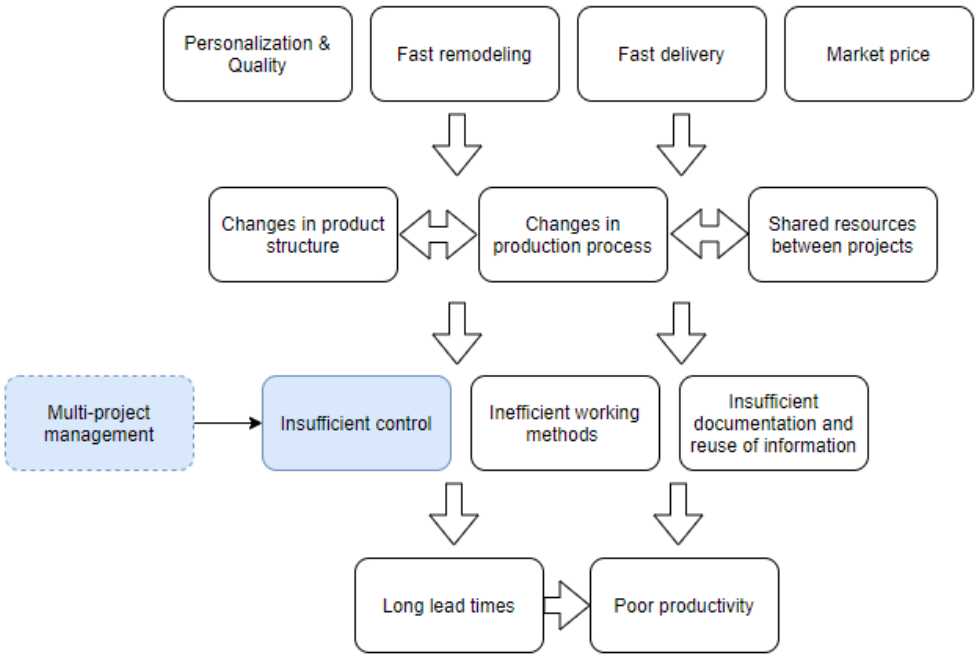

Figure 1. *Illustration of challenges caused by the competitive factors and their relation to this thesis*

At first glance, products manufactured in a job shop production do not resemble traditional idea of projects. The products can be similar to each other by the means of product structure and work stages. Still, seemingly small changes in product structures and production processes create rather unique products. This indicates that these products could be handled as projects and better productivity could be pursued with project management practices.

Major challenge arises as tens or even hundreds of projects are simultaneously under production. Traditional project management literature addresses mainly so called single-project environment where a project can last several years and all the resources are allocated to this single project. Planning and control of the individual project becomes more difficult as the number of projects increase and they start to compete for the same resources. Multi-project management is less covered project management area which tries to address this challenge. Also, there has not been many researches that cover the multi-project mangament in a manufacturing context.

This thesis studies project planning and control process in multi-project environment. The main goal is to define system and procedures that improve the control of several concurrent manufacturing projects. The reader of this thesis will learn how the basic project management tools and practices can be applied in multi-project context and

what are the main challenges and success factors of the multi-project management system.

1.2 Research problem, objectives and scope

The research problem derives from the case company's need for knowing why actualized labor hours exceed planned hours in some delivery projects. In many cases the difference is difficult to explain as even similar, consecutively manufactured products have large deviation between the actualized hours. It is generally known that several factors in the production process cause the deviation and poor productivity. Also, history data in the systems lacks of confidence and therefore solid conclusions of the hour overruns are difficult to make after the production of a project is completed.

To get better understanding of the labor hours, the case organization hopes to get more visibility to the production. The visibility could enable better control of the production and thus improve the productivity. This way possible deviations in labor hours could be noticed and reacted accordingly in the early phase. The biggest issue in this case is that how this can be done efficiently in manufacturing environment where there can be over 80 projects in different phases of their life cycle, executed at the same time. This issue leads to the main research question:

> *How planning, monitoring and controlling of the work should be organized in multi-project environment?*

The main research question can be divided in sub-questions to better understand the issue. First, to control single project it is necessary to understand and implement single-project management processes for planning, monitoring and controlling. Second, to apply these processes efficiently to multi-project environment, it is necessary to understand characteristics and success factors of the multi-project environment. This way four sub-questions can be formed:

> *What are the characteristics of multi-project environment?*
>
> *How planning of work should be organized in single-project management?*
>
> *How monitoring of work should be organized in single-project management?*
>
> *How controlling of work should be organized in single-project management?*

The aim of this study is to improve the organizations control system so that the planned and actualized hours would be closer to each other in post project review. In practice the organization would need to have control system that enables it to monitor planned and actualized hours and also the progress of each manufacturing project.

Literature review of this study aims to clarify methods and tools for managing work of individual projects and also point out how multi-project environment affects the control process and organizational requirements. The research of current state includes defining the processes of planning and controlling work in the case organization. Thus, the research objectives of this thesis are:

1. To understand factors that affect the simultaneous control of multiple projects
2. To examine how the planning process of individual projects should be organized in the case organization
3. To examine how to get real time progress information from the case organizations production

The scope of this study includes parts from single-project and multi-project management and they are highlighted in the figure 2. Single-project management area is limited to those parts that are necessary to control the organizations own manufacturing work. That is integration, scope, schedule and resource management knowledge areas. From the project life cycle perspective, the scope is limited to planning, implementation and control phase of the project. The planning phase is again limited to time after the order placement. The data collection is limited to one Finnish manufacturing organization.

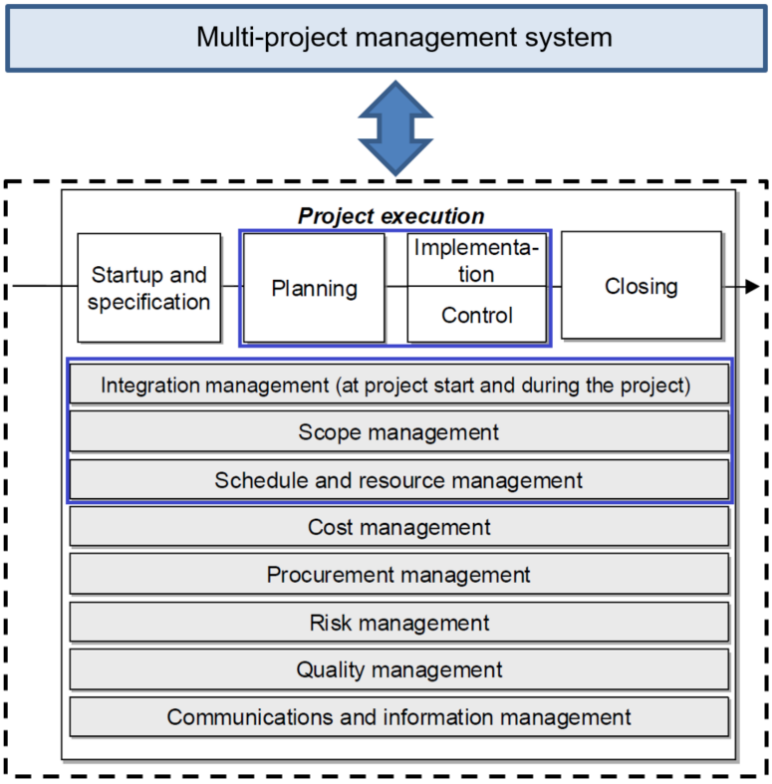

Figure 2. *Scope of the study in the area of project management (Modified from Artto et. al. 2011, p.80)*

From the research methodological perspective, a case study methodology is used. It is important to understand the case company's operation environment thus getting best business results requires combining data from different sources and processing it to information. This is why the research follows abductive approach and tries to meet research objectives by connecting information from literature and practice as the study is taking place. This limits the use of predefined interviews and thus the data is collected mainly by observations and collecting the data to a research diary. Company's information systems and documents are used as a secondary data sources to complete data from the observations.

1.3 Structure of the report

The structure of this research can be divided into six sections. The sections follow the basic research structure. The different sections of the study are presented in figure 3.

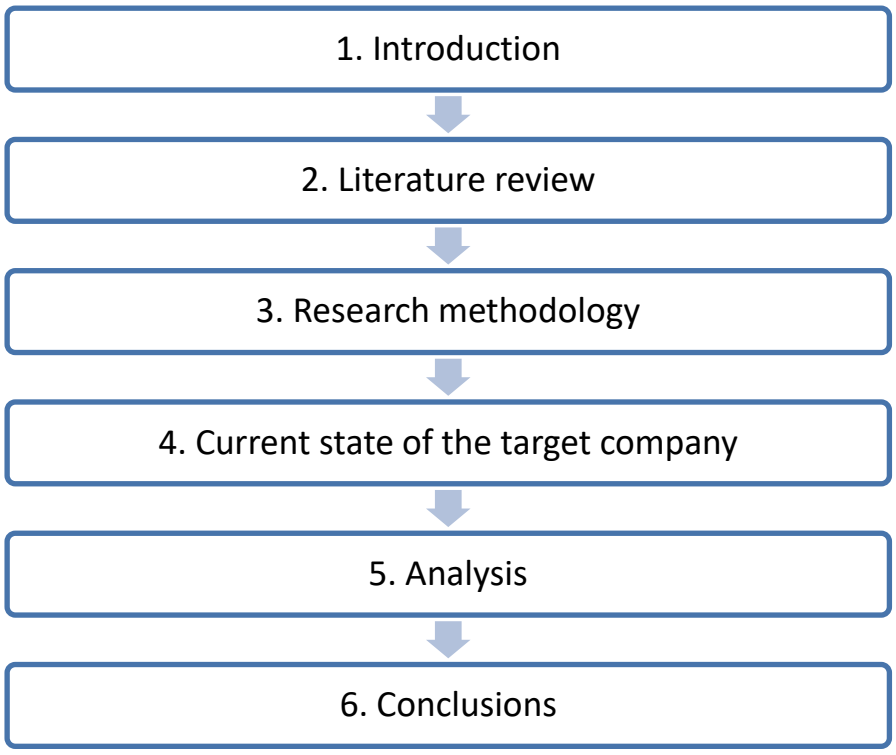

Figure 3. *Structure of the study*

After this introduction, the chapters 2 and 3 present the literature review of this thesis. The objective is to present most relevant subject areas that give better understanding of the environment and research problem. As project management theory is relatively large area, the main focus in chapter 2 is put to defining project business and project management areas of planning, monitoring and controlling scope, schedules and re-

sources. Introduction to these areas is selected because the case company's production environment is not clearly repetitive or follow basic project management practices. This way the literature review gives better base to apply these elements into a practice. Chapter 3 continues the literature review by investigating the basic principles of multi-project management. Multi-project management is less covered topic in research but the chapter defines the multi-project concept and presents some of the main phenomena that present in this kind of environments. These phenomena are for example multitasking, Parkinson's Law, Student Syndrome, resource allocation challenge and organization culture.

In third section, the chapter 4 presents the research methodology in closer detail. The chapter presents the research design, data collection and research process of this thesis. The purpose is to define and present the methodological choices and purpose considering research philosophy, approach, strategy, methodological choices and data collection techniques and procedures.

Fourth and fifth sections represent the empirical part of this study. The chapter 5 presents current state of the case company. In that chapter the case company, its products and the operational environment is presented. This is important so that the problem can be defined properly and potential directions for improvement can then be established. In this chapter in addition to presenting the overview of the case company, project management areas considering project planning, monitoring and controlling in the case company are also introduced. Purpose of the chapter 6 is to analyze the empirical data is and answer the research questions. The analysis chapter presents general challenges in current organization and production control system and introduces some potential solutions to improve information flow in the Tampere factory. The main focus of the analysis is put to designing work planning and monitoring procedure for the final assembly.

The seventh chapter concludes this thesis. In the final chapter the results are summarized and it is evaluated how well the research question could be answered and research objectives are met. The conclusion presents the overview of this research in a compact way for better managerial use.

2. PROJECT MANAGEMENT

2.1 Characteristics of project business

According to Artto et al. (2011, p.10), companies' businesses can be based on many different areas. For example, the company can operate in manufacturing or customer service business. The business form can also be mixture of different industries. Project business relates to company's business, or just a part of it, that aims for a specific change. Artto & Wikström (2005) defines project business in a following way:

> *"Project business is the part of business that relates directly or indirectly to projects, with a purpose to achieve objectives of a firm or several firms."*

This means that project business is compilation of project related activities that are managed in a goal-oriented way. These activities help to achieve company's objectives that are usually somehow related to survival and success of the company. In practice, these objectives mean answering expectations of company's stakeholders such as owners and customers by generating growth, profitability or some non-commercial values. Artto et al. (2011, p.10) state that in general, any activity may serve these purposes but in project business, the related activities are somehow goal-oriented, part-time and unique.

Artto et al. (2011, p. 11-12) continues that project business can be understood with two different meanings based on its outputs: project business as solutions delivery for customers or project business as solutions development for own business. Delivering solutions as a project means that company creates value through customer specific solutions. This kind of solution can be consultative project to change customer's procedures or a manufacturing project to deliver customized product. Developing projects are "tools" for creating value inside the company by making different functions more efficient or creating something new. For example, developing project can lead to new product offering that creates more sales or it can be an investment for new machinery that makes manufacturing more efficient.

Artto et al., (2011, p. 12-13) state that projects are common way to drive change in every industry but their role and purpose can vary case by case. Project business is most commonly known in companies that deliver projects as investment. There are many this kind of companies in constructing, energy, forest, telecommunication and

manufacturing industries. These investment projects have two perspectives depending on the stakeholder. Customer considers the project as an investment while the supplier considers the project as a delivery. This leads to a fact that even though there might be one desired output or outcome, there are two different projects. Customer manages the project as investment, meaning it is investing to the project and the product it gets as a result. It will put effort on defining business objectives, investment calculations and feasibility studies. Customer then expects it will get enough value from the investment and is willing to manage and monitor the delivery project. Supplier or subcontractor handles the delivery project that aims to create the deliver solution for the customer. This kind of project deliveries are part of supplier's business model and they require different resources and have certain expectation for return. Supplier also aims for cost efficiency as it improves margin of the project. To achieve this, several project management areas needs to be handled.

2.2 Project definition, objectives and success factors

Project can have different kinds of definitions depending on the context. Artto et al. (2011, p. 16) describe how project can presented as three parallel structures: as a part time organization, as a specific product or work structure, or as a collection of tasks or phased processes. It is important to notice that these perspectives can simultaneously be part of a project and they do not exclude each other.

According to Artto et al. (2011, p. 16), part time organization perspective means that there is specific project organization. This organization is appointed for the project and dismantled as soon as the project has been completed. This perspective is based on view that the best available group of people is working on the project. The perspective also points out that each group member has its own responsible area and the organization itself can be reason for project success or failure.

In Artto et al. (2011, p. 16) definition product or work structure perspective means that project is seen through the result of the project. This result can mean a product or work that has been done. The final product can be divided into smaller components and presented in hierarchical order. This presentation is called product structure. Work of the project can also be divided in parts and presented in hierarchical order. This way the project is easier to manage. The presentation of the work package is called work breakdown structure (WBS). This concept is closely related to scope management of a project and it is addressed more closely in chapter 2.4.

Project or parts of project can be considered as collection of tasks or phased processes. This perspective means that project schedule is managed through tasks and processes that are defined beforehand. This perspective is related mostly on schedule and resource management areas which are addressed in chapter 2.5.

Despite which of these three perspectives are used, project has always predefined objective or goal that one tries to achieve. There are also several other aspects that are typical for a project. Lester (2017) presents project definition according to British standard as following:

> *"Project is a unique process, consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve objectives conforming to specific requirements, including constraints of time, cost and resources."*

According to Artto et al. (2011, p. 17) uniqueness is the main quality that separates project from other processes. Project always differs from projects that have been done before. The differentiation may be result of different objectives, final product, working methods, organization, environment or subcontractors.

Artto et al. (2011, p. 17-18) explain that set of coordinated and controlled activities with start and finish dates means that a project needs to be divided into different tasks that need to be completed in certain time and in certain order. As stated in the project task perspective, these tasks can be linked to each other and organized into logical packages. In many cases, the linking makes the project a complex entirety because the activities are usually unpredictable in terms of duration and costs. The unpredictability is typical in project setting where tasks are performed first time by certain people meaning that special skills, creativity, constant monitoring and decision making are required to properly meet the project objectives.

Lock (2007, p. 20-21) finds that project is seen with three constraints that also act as main objectives of a project: time, cost and scope. The time constraint means that each project has its own schedule with starting and ending points. The end point defines when results of the project should be available to use for the projects customer. Artto et al. (2011, p. 22) present that the time constraint also refers to the fact that time is linear and one cannot affect to the time itself. The amount of time for individual tasks can be reduced but this usually increases costs of the project.

According to Artto et al. (2011, p. 22) and Lock (2007, p. 20) the scope constraint means that a project aims for a product or a change that is defined beforehand. The product needs to fulfill technical, functional and quality requirements that are defined by the organization that invests to the project. Technical requirements might concern

e.g. components, materials and structures used in the solution. Functional requirements might concern e.g. performance and usability of the solution. Quality requirements refer to factors related to appearance or image of the product. These factors cannot be measured in money but they create value to the customer. Quality factors are also subjective, meaning that the amount of value they create depends on the person who evaluates them.

Artto et al. (2011, p. 23) and Lock (2007, p. 19) state that the cost constraint means that project has certain amount of resources it can use. These resources can be for example cash, person-hours or materials. Total cost of the project is defined beforehand in the project budget. It is important to notice that project needs certain amount of costs in order to achieve the scope objectives. This way costs should be considered as much as objective as constraint. Cost objective is also related to expected revenue as project should create value to its customer. Figure 4 presents the linkage between scope, revenue and profit. In the end customer will pay according to the scope of the project. The scope again defines the expected costs of the project and project supplier should price the project based on these costs. Usually project supplier aims for certain profit margin and that is why project should reach its cost and revenue objectives.

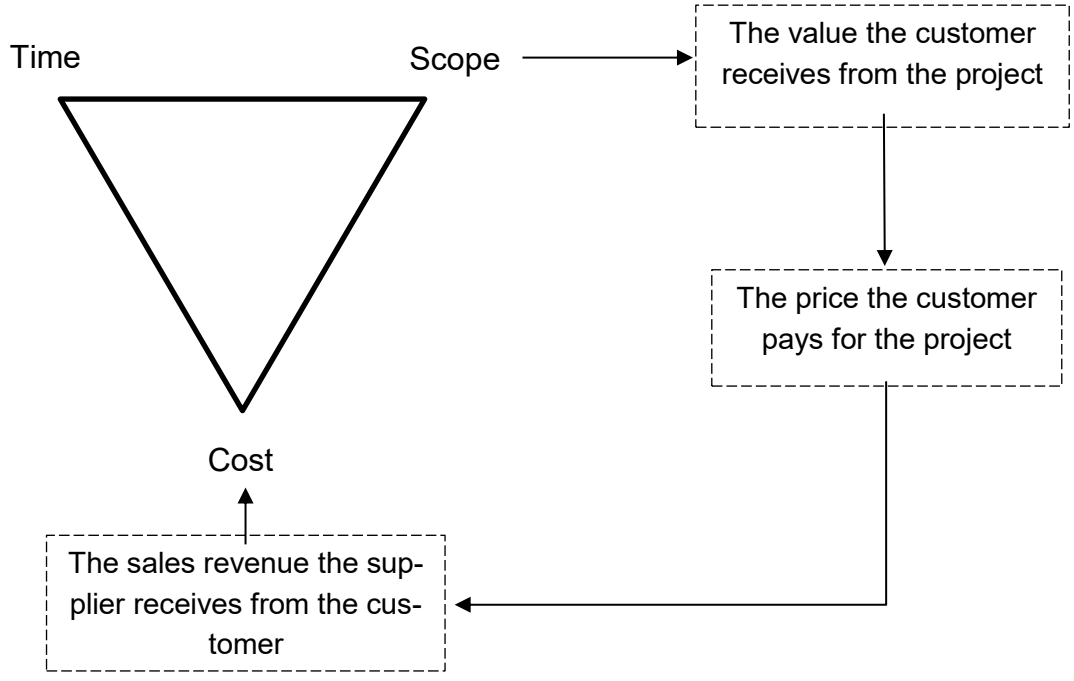

Figure 4. *Project objectives and their relation to revenue and profit (Artto et. al., 2011, p. 23)*

The three constraints of the project also act as main objectives of the project. Artto et al. (2011, p. 22) Lock (2007, p. 21-23) explain that the objectives are traditionally represented with a triangle shape where each objective has its own corner of the triangle. The objective triangle can be seen in figure 4. The triangle illustrates how

each objective is linked to each other and together they form the result of the project. For example, if time objective is tightened, scope needs to be mitigated or costs need to be increased. Alternatively, if scope objective is increased, time and cost objectives also need to be increased.

2.3 Project planning and control

Project planning and control can be seen as activities that aim to ensure achieving the project goals. According to Tonchia (2008, p. 57), project management can be divided into two different stages: planning, and control and reporting. Artto et. al. (2011, p. 80) presents the project management stages and the related knowledge areas in a framework that is presented in figure 5. Artto et. al. (2011, p.84) points out that the planning stage defines all operational variables needed in the project management. This means defining objectives for quality, time, costs and use of resources. These objectives and use of resources should be agreed with the customer and other project stakeholders to find a common understanding of the project execution. Tonchia (2008, p. 57) states that in practice the objectives can be described as different breakdown structures such as Product Breakdown Structure (PBS), Work Break-

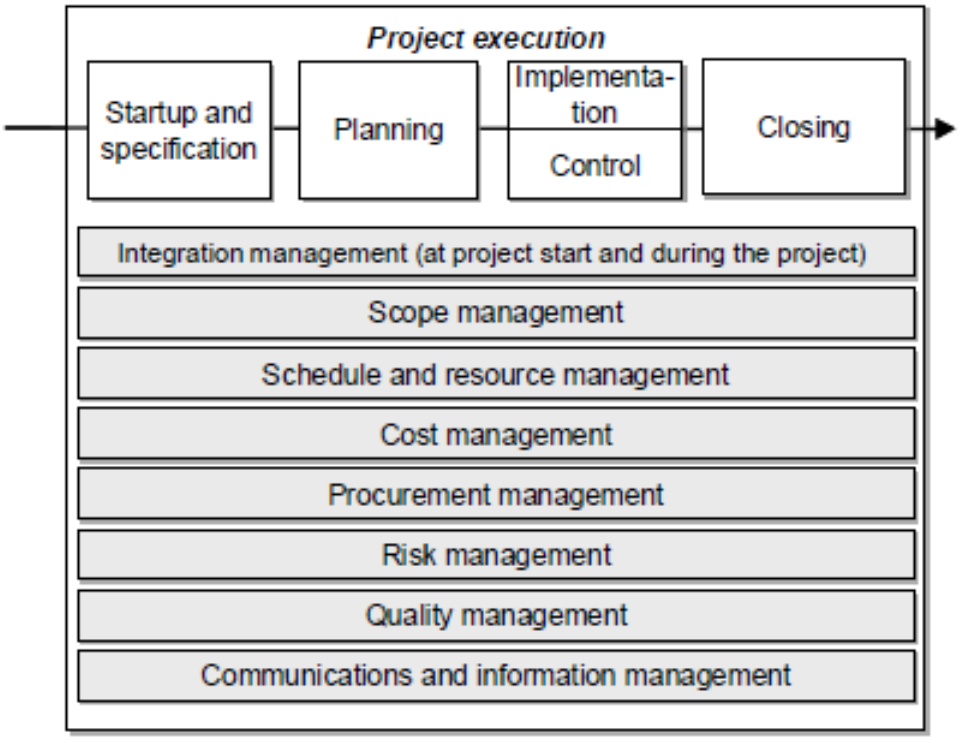

Figure 5. *Phases of project life cycle and related project management areas (Artto et. al., 2011, p. 80)*

down Structure (WBS), Organization Breakdown Structure (OBS) and Budget Breakdown Structure (BBS). In addition, activities of budgeting, scheduling and resource allocation can be done by utilizing these breakdown structures.

Artto et. al. (2011, p. 84-87) describes how planning stage should lead to a project plan where main aspects of the project are defined. The project plan is updated during the project execution and it can be used as management tool during the implementation and control phase. The purpose of the project plan is to keep the project work and different project management knowledge areas as a balanced entity. The project plan can include descriptions of project background, benefits, objectives, risk management, organization and responsibilities, scope management, work breakdown structure, schedule management, resource management, procurement management, budget and cost management, reporting and communications plan. However, size of the project should be considered when a project plan is constructed. If the project is small, only project rationale, scope, schedule, responsibilities and risk descriptions can be enough for the project plan.

Artto et. al. (2011, p. 80) illustrate project management areas that can be seen in figure 5 and explain that project management can be divided into different knowledge areas that are present during the project execution. Each of these areas are needed but their importance can differ depending on the project size and the project business environment. The management areas are also more or less connected to each other and they are relevant during the whole project execution.

In this thesis the main focus is put to scope, schedule and resource management during the project implementation and control phase of the project execution. The scope, schedule and resource management knowledge areas are directly connected to the cost objective as presented in the project triangle in previous chapter. On the cost objective perspective, this thesis addresses only the labor hours and their control with progress reporting.

2.4 Scope management

According to Artto et. al. (2011, p. 87) and Project Management Institute (2017, p. 23) scope is one of the main objectives of the project. Scope can be seen as the product that results from the project or as the work needed deliver the project. Scope consists of specification of requirements, features, functionalities and performance of the product. Project Management Institute (2017, p. 23) defines scope management as

> *"The processes required to ensure the project includes all the work required, and only the work required, to complete the project successfully."*

Artto et. al. (2011, p. 87) specifies that scope management aims to ensure that the product requirements according to customer and other stakeholder needs are considered in the project plan and satisfied efficiently without unnecessary work in the implementation phase. Still, it is normal that the scope and technical plans are clarified or changed during the project life cycle. The management of change is crucial part of scope management as changes can easily cause cost deviations. Usually the later in a project life cycle certain change is needed, the more expensive the change is to implement.

As mentioned earlier, different breakdown structures can be used as a tool to plan and control the project. Artto et. al. (2011, p. 112) states that different breakdown structures offer rational approach to managing projects and help human mind to understand and analyze a project in a greater level of detail. For example, Product Breakdown Structure (PBS) can define the scope and illustrate all the needed materials and components of the project. However, it does not describe all the work that is needed to complete the project. To improve project control, it is necessary to divide the project into phases. Work breakdown structure is common way to represent the project work.

2.4.1 Work breakdown structure

According to Lock (2007, p. 165) work breakdown structure (WBS) is one of the main tools in project management. In many cases, unclear WBS can even be the biggest reason for inefficiency and cost overruns in materials and labor. In practice, WBS is a hierarchical tree of tasks needed to complete the whole project. This means that WBS divides the whole project in to manageable and measurable areas. The top level in the hierarchy is the complete project. The next level down consists of the main parts or *work packages*. From there going down the tree, the structure goes on more and more detailed level. The bottom level shows the most precise and concrete description of the tasks that are needed to do. Often this means day-to-day tasks or project components. Figure 6 shows simplified example of WBS of a car.

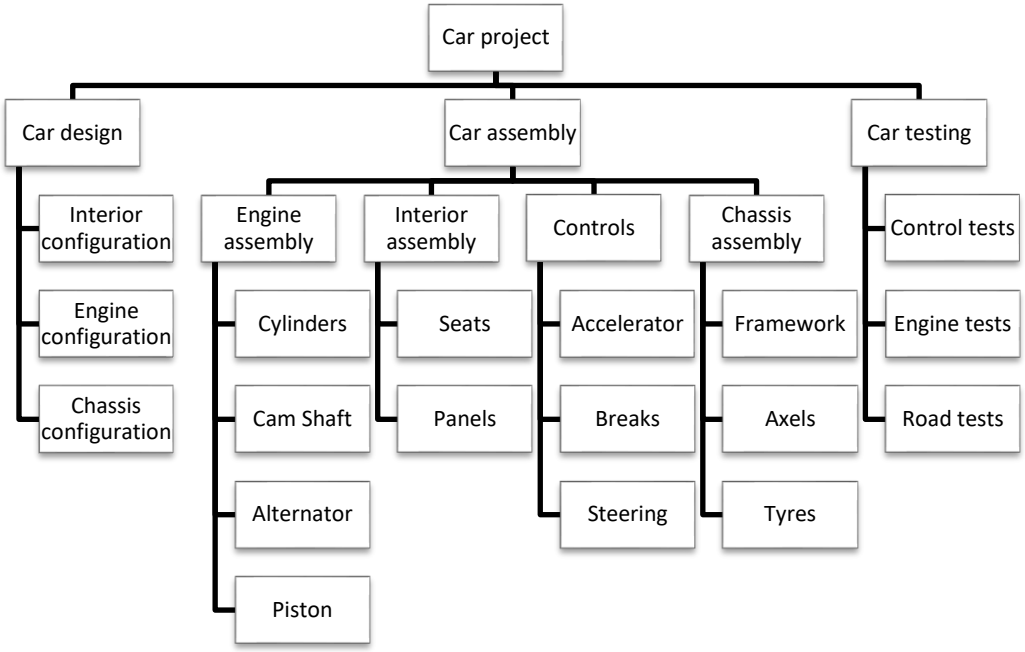

Figure 6. *Work breakdown structure example of a car project*

Atkinson et. al. (2006) state that each of the listed tasks should then have a description of the inputs, outputs, materials and other resources that are needed to complete the task. In addition, the required time for the task should be included in the task description. Based on this information, project manager knows how much effort is needed to complete the task. Artto et. al. (2011, p. 89) state that when sub-structures, work packages or task are defined, it is important they are:

- Manageable so that responsibilities and ownerships can be accounted to the tasks
- Independent enough form each other so that there are minimum number of interfaces with other tasks
- Relevant to the whole project so that the project forms as a combination of its sub-structures
- Measurable so that the progress of the tasks can be monitored

Work breakdown structure is used as a tool for planning and controlling the project. According to Artto et. al. (2011, p. 113), WBS can be used as a basis for other areas of planning and control such as:

- Ensuring scope
- Planning and control of whole project and sub-projects
- Creating and reporting costs and budget
- Specifying and monitoring time and resource needs
- Matching objectives and resources

- Monitoring project and creating network of stakeholders
- Accounting responsibilities
- Planning project contracts and financing, if needed

2.4.2 Specifying tasks and ensuring project scope

Artto et. al. (2011, p. 93) explain that tasks in the lowest level of WBS describe the concrete work that is needed to be done. They are typically used in planning costs and resource requirements. Tasks are also used in controlling and monitoring the project progress. Structure of a generic task is presented in Figure 7.

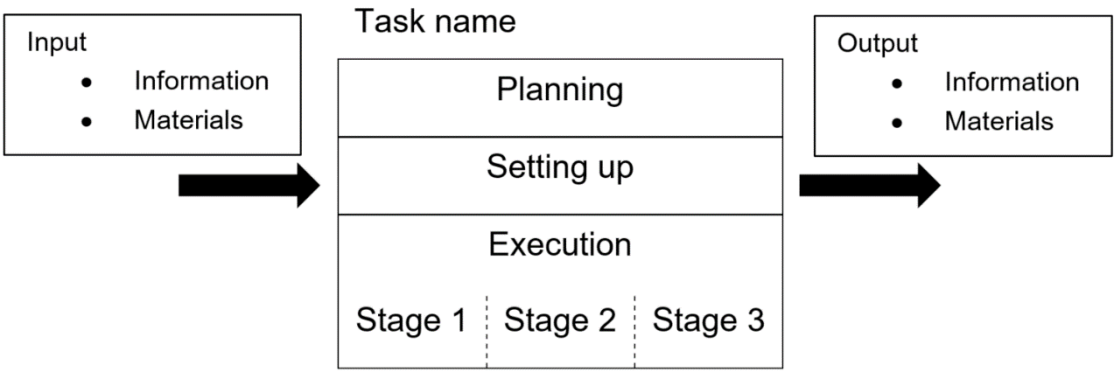

Figure 7. *Structure of a task (Simons & Hyötyläinen 1995, p. 51)*

Simons and Hyötyläinen (1995, p. 51) explain that completing a task requires planning, setting up and executing. Planning means analysing the task, breaking it down to sub-tasks and evaluating the task time. Setting up the task ensures that information, materials and tools are available when executing the task. Executing is the part where value is added through the task.

According to Artto et. al. (2011, p. 93), each task is part of *work package* that belongs to higher level in the WBS hierarchy. A work package should be designed so that it can be assigned for responsible executing party such as team, department or subcontractor. This means that the work package should include description of the expected outputs and related instructions. Outputs of each task should be also clear when defining the WBS as it helps to estimate level of completeness of the work package and the whole project.

Artto et. al. (2011, p. 93-94) explain that sufficient level of detail with work packages helps reporting and evaluation of the project status. The level of detail in work packages should depend on the amount of trust between project manager and other people working with the project. Also, project management skills of the employees should be considered. For example, when people are unexperienced and there is a lack of

trust, it could be tempting to define and instruct each task with a great level of detail. However, too detailed planning increases the amount of work in the administrative and control functions. On the other hand, too wide or complex work packages makes controlling them more difficult as it is harder to measure the progress and thus identify possible schedule and cost deviations. Simons & Hyötyläinen (1995, p. 51). points out that this also effects negatively on efficiency and quality of the work.

According to Artto et. al. (2011, p. 96), checking and defining the product structure and features together with different specialists ensures that the product structure matches the scope objectives. As product structure is connected with the work break-down structure, checking the WBS ensures that planed work is sufficient for ensuring the project scope. At the same time, it is ensured that the scope excludes parts and features that customer doesn't need and thus unnecessary work and over quality is avoided. Each task and work package of the WBS are well defined if:

- Status and progress of the work package is measurable e.g. "Work package is 50% complete"
- Start and ending events can be identified
- Each task leads to concrete results such as product, document or decision
- Time and costs can be easily estimated
- Duration of each task is within allowed limits and the whole project schedule is considered
- Tasks are undependable from other activities in a way that after start the task can be completed without disturbance and it does not require information on resources from other tasks.

2.5 Schedule and resource management

Time and schedule forms one of the main objectives in the project. Purpose of the schedule management is to ensure that the project scope is fulfilled within planned time. Therefore, schedule management is closely related to scope management and work breakdown structure of the project. Project Management Institute (2017, p. 24) defines schedule management as:

"The processes required to manage the timely completion of the project."

Schedule management includes procedures for defining dependencies and lengths of the activities, controlling the schedule and managing changes. The more critical the schedule objective is for project value; the more emphasis should be given for the schedule planning and monitoring process.

Resource management aims to ensure that right amount of resources are available at the right time and they are used efficiently. Resource management is closely related to schedule management as scheduled activities require the resources for being on time. Project Management Institute (2017, p. 24) defines resource management as:

> *"The processes to identify, acquire, and manage the resources needed for the successful completion of the project."*

Next chapters address different tools and procedures for planning and controlling schedule and resources.

2.5.1 Schedule planning

Artto et. al. (2011, p. 97) describe that schedule planning includes creating general schedule, scheduling individual tasks and defining length and order of the tasks. Scheduling is always based on estimates and the estimates are updated during the project controlling phase. Tools such as Gantt-chart, milestones and gates can be used to plan the project schedule.

Artto et. al. (2011, p. 97) continue that schedule planning can be done with top-down and bottom-up approaches. In top-down approach milestones and gates are first recognized from the overall project time objective such as delivery date. Then work packages and tasks can be scheduled and timed according to the main schedule. In bottom-up approach durations of tasks and work packages are evaluated first. The overall schedule is then formed based on this information. The two approaches do not exclude each other. On the contrary the best estimates are formed when the schedule is evaluated with both of these approaches.

According to Artto et. al. (2011, p. 98), one of the oldest scheduling tools is *Gantt chart* which visualizes the project schedule and work packages on a timeline. It shows these activities as bars drawn from starting date to finishing date. Lock (2007, p. 78) notes that Gantt chart can include links that show interdependencies between project activities thus giving more information about criticality of an activity schedule. Artto et. al. (2011, p. 98) further points out that activities defined in the WBS and their estimated durations should act as a baseline for the Gantt chart. Recommended timespan for each activity depends on the project size and determined objectives. In general, too long timeframe is more difficult to keep in control while too short time frame makes monitoring and administration heavier.

Artto et. al. (2011, p. 99) explain that project schedule can be also presented as *milestones* and *gates*. This can be more practical if activities can be performed simultaneously and the Gantt chart becomes heavier and unclear. A milestone is an event on a project timeline that is relevant for reaching project goals. It is checkpoint where some activity is or should be done. For example, a point where sub-assembly is or should be started. Setting the milestones leaves some level of freedom for planning and executing the actual work between the milestones.

Artto et. al. (2011, p. 100) describe that gates are similar to milestones. A gate is a point where some decision should be made. The decision can be ending, suspending or continuing the project. This way some requirements are connected to passing the gate. The requirement can be some preliminary result of the project such as review and approval of a bid, a contract or a product plan.

According to Artto et. al. (2011, p. 103) there is also *activity network* method that helps to determine critical path of the project by defining interdependencies between project activities. This method is excluded from the scope of this thesis as projects of the target company are similar to each other and hold the same work packages. Thus, this method does not create value for project management in this context.

2.5.2 Resource planning

Artto et. al. (2011, p. 96) points out that resource planning is closely related to WBS and schedule planning as the planned work requires available resources. In order to work to be completed on time, there needs to be right amount and certain type of resources available. Most commonly needed resources in projects can be divided into five categories: people, materials, facilities, equipment and money. For example, successful execution of an assembly task usually requires people with specific skills, certain components, some equipment and enough space for the assembly. Money is the resource that enables getting other resources and its use should also be planned and controlled accordingly.

Artto et. al. (2011, p. 96) explains that a company can have its own way of maintaining resources that are required in project. Resources can be used for a short or long period of time and they can be acquired inside or outside of the company's own organization. A common way is to have a have different resource pools, organisational units or departments where the resources can be drawn from. Despite the way that the resource pool is managed, there should be clear policies of how the resources are used. This means agreeing principles on pricing of resources, allocating costs and competing on resource usage.

According to Artto et. al. (2011, p. 114-115), resource planning should consider loading and levelling the resources. Loading resources means that resources are identified and matched with the project WBS and schedule. The loading process should evaluate the resource need for each activity. This can be done by evaluating the resource need in man-weeks, man-days or man-hours and then loading the activities according to the project schedule and WBS. Usually there is a known resource limit that the resource usage cannot exceed. During the resource planning process, one should monitor Gantt chart and resource histogram simultaneously to identify possible resource overloads. Resources that are overloaded may become bottleneck that slows down the activity completion.

Artto et. al. (2011, p. 115) describes the resource leveling as necessary process in preventing to underloading or overloading resources. Often the challenge is to find balance between schedule objective, cost due to delaying activities and cost due to adding resources. There are four different ways to level resources: Using float or buffers for starting an activity, moving the time of finish, dividing activities into parts so that resource can be relocated between the activities or using replacement resources. Resource management becomes more complicated when concurrent projects start to compete for the same resources. Chapter 3.2 addresses this challenge in more close detail.

2.6 Project control and progress reporting

Artto et. al. (2011, p. 192-193) claims that project control is needed to ensure that the project follows its plans and reaches the defined objectives and benefits. Project control is about comparing planned and actual progress of the project, identifying deviations and finding and executing corrective responses to these deviations. The corrective actions are easier to take when deviations are detected in the early phase. This is why efficient control requires constant search for information that provides picture of the project progress and gives management the opportunity to make required decisions. Reporting is formal way of providing this information. Efficient project control system requires that:

- Project work packages are carefully planned
- Time, workload and costs are well planned
- Activities required to complete the scope are clearly communicated
- Budgeting and acceptance of costs are strictly managed
- Progress and costs of the projects are reported timely

- Remaining time and costs are estimated regularly
- The level of control is fitted to the project complexity

Artto et. al. (2011, p. 194-195) claims that project reporting is important part of project control process. Efficient reporting system helps to follow the project plans and achieve project goals. The reporting forms and procedures should be agreed-upon and it is often tied to project milestones, deviations or time. However, often project managers' role is to separately ask for the information. Reporting might require gathering and processing both quantitative and qualitative information. The quantitative data is often stored to different information systems such as enterprise resource planning system. Gathering the qualitative information can be done via e-mail as part of daily procedures such as e-mail conversations.

Artto et. al. (2011, p. 193) claims that visualisation should be used to point out possible deviations and issues that require action. For example, earned-value or traffic light reports are can visualise the project situation and inform management to take actions. In this thesis focus is put to progress reporting but also other project control areas should be included in the reporting system.

3. MULTI-PROJECT MANAGEMENT

3.1 Definition of multi-project management

According to Unger et. al. (2012) researchers state that traditional project management literature focuses mainly on so-called single-project organizations and single-project management. Payne (1995) explains that This simplification is useful for educational purposes. However, in many situations, organizations operate in multi-project environment where projects scope tend to be smaller, schedule shorter and resources are more limited. In multi-project environment, several projects are operated in parallel thus creating need for multi-project management. Turner (1993) estimates that up to 90% off all project value is created in the multi-project environment. Thus, even small findings in this research area could lead considerable improvements in the multi-project management.

Dinsmore & Cabanis-Brewin (2014), Project Management Institute (2017) and Schwindt & Zimmermann (2015) state that definition of the situation where several projects are managed simultaneously is fragmented in the project management literature. Terms such as multi-project management or multiple project management (MPM), project portfolio management (PPM), program management and management of a group of multiple projects (MGMP) are used synonymously. The general idea is that a single project can be managed in three different occurrences: as an individual project, as a part of a program or as a part of a portfolio.

Project Management Institute (2017) describes *program management* as coordination of a group of related projects to obtain benefits not available from managing them individually. Artto et. al. (2011, p. 306) continues that a program can be seen as temporary entity with a set of objectives and start and end points. *Project portfolio management* again is described as a collection of projects or programs managed as a group to reach company's strategic objectives. As project and a program are temporary organizations, a portfolio is a continual entity with changing projects and programs. Project Management Institute (2017) explain that program and project management aim to do the programs and projects in a right way while portfolio management aims to do the right programs and projects.

Defining these occurrences is important in order to understand the *multi-project management* (MPM) scenario. Schwindt and Zimmermann (2015) explains that MPM re-

fers to organizational-level environment where multiple projects are managed simultaneously. In this environment, the projects can differ in size and importance, they can be in different point of project life cycle and they may or may not be interdependent. Dinsmore and Cabanis-Brewin (2014) state that MPM term is used to describe day-to-day operational management and resource allocation within the project portfolio. Thus, the main differences to portfolio management are in the strategic and operative perspectives: Portfolio management aims to reach company's strategic objectives by selecting the right projects while MPM aims to reach operational objectives by grouping projects for better managerial control and operational efficiency.

3.2 Main issues in multi-project environment

Payne (1995) state that together with the problems that emerge in single-project management, multi-project management has to cope with several other problems. One major issue is that projects are independent from each other with their own goals and challenges but still they require at least some resources from the same resource pool. For the resource pool owner this means that the projects should be integrated into same management control and reporting systems.

Patanakul and Milosevic (2009) state that factors impacting to the effectiveness of multi-project management can be categorized in to organizational factors and operational level factors. Organizational level factors include project manager assignment, resource allocation and organizational culture. Operational level includes project management processes and competencies of multi-project managers. These factors are introduced and completed with other references in the following chapters.

3.2.1 Roles and responsibilities

Dinsmore and Cabanis-Brewin (2014) state that all company's key internal stakeholders such as project, functional or resource pool managers, should understand their roles and responsibilities and be committed to corporate, project portfolio and project objectives. In a matrix organization, project managers have the responsibility to coordinate resources between the project while functional managers have responsibility to ensure the needed resources are available. If the roles are not clearly defined, individual objectives may interfere decisions and negatively impact on project success. Unclear responsibilities may create authority issue as different stakeholders can argue over resource allocation, decision making, reporting requirements and corrective actions.

Artto et. al. (2011, p. 291-292) describes that defining roles and responsibilities is one of the main issues in matrix organizations where projects are not the only form of business. In this kind of organization, the functions have also their own objectives and they try to optimize their own work. For example, sales and marketing are usually evaluated by using sales volume or sales margin while production is evaluated through efficiency, schedules and costs. The different objectives can affect negatively on the cross functional operations such as projects. This is why project business the work should be evaluated and optimized from the perspective of the whole organization. In matrix organization the perspective can be represented by project manager who is responsible for coordinating work over functions. This way the work is organized so that it benefits the whole organization and not just a specific unit.

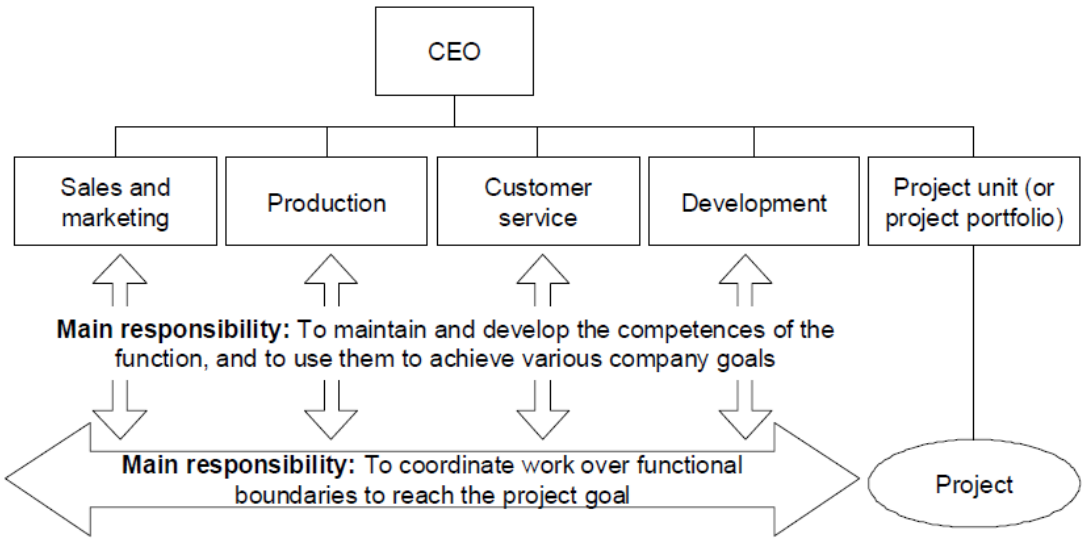

Figure 8. *Conflicting responsibilities between functions and projects in production (Artto et. al., 2011, p. 292)*

Artto et. al. (2011 p. 292) also suggests that in matrix organizations it is important to determine which of the two actors is responsible for the business: functions or projects. Responsibility of the business means responsibility on company objectives, resources, costs and strategy. Depending on the organization structure, the responsibility can be allocated to projects or functions with different weighting. Regardless of the way the responsibility is divided, it is important that objectives and metrics encourages different actors to aim for overall project success. For example, project profit could be a better metric compared to project costs or sales margin as it indicates how well the whole organization succeeded delivering the project.

In a multi-project environment, the role and responsibility of a project manager can vary depending on the company and the project. However, Patanakul and Milosevic (2009) suggests that a realistic project manager assignment is one of the most critical factors that lead to a successful multi-project management. Realistic assignment in this case means that there is a balance between project manager skills, project complexity and number of assigned projects. Managing too many projects simultaneously will cause project manager to lose time while catching up with all the problems of projects instead of actually leading the projects. According to Patanakul and Milosevic (2006), the number of projects that should be assigned to one project manager depends heavily on the company, the business environment, project size, project complexity and their phase structure.

3.2.1 Multitasking

Vanhoucke (2012) defines multitasking as performing multiple project activities at the same time. However, in reality the time is only divided between multiple activities leading to longer lead times. This way, using history data to estimate lead times in manufacturing companies is problematic as the system load and multitasking level has a certain impact on the lead times at the time.

Rubenstein et. al. (2001) studied that the time loss is typical in multitasking. The time loss results from decrease of productivity, efficiency and concentration as people switch from one task to another before the previous task is complete. When a new task is started it takes some time to orientate for it. Dinsmore and Cabanis-Brewin (2014) state that the same phenomenon occurs in multi-project environment. Multitasking issues may be seen as late projects, longer task durations, lower productivity, frustration, chaos and reduced communication. The authors also suggest that multitasking is indicator of poor planning and prioritization.

3.2.1 Parkinson’s Law and Student Syndrome

Vanhoucke (2012) notifies Parkinson’s law as a remarkable phenomenon in multi-project environment. The Parkinson’s law means that work expands to fill the given time limit. It is explained that if early finish of a task is not rewarded and late finish of a task is undesirable, the worker is unlikely to report early completion of a task. Rather he or she will start producing over quality i.e. gold plating the work. This kind of behavior can be explained as fear that planned task time is reduced in the future due an early finish, he/she will be assigned to a new task immediately as the completion is

reported and it is less stressful to remain in the current task or he/she adjust the work load to be lower for the entire task duration.

Vanhoucke (2012) introduces also the student syndrome as an undesirable phenomenon that is common in multi-project environment. The student syndrome means that people usually wait until an activity gets really urgent. An example is given where a student gets an assignment that is due in four months. If the student estimates that it will take four weeks to complete the assignment, he/she will start the work not earlier than four weeks before the deadline.

According to Vanhoucke (2012), Parkinson's law and Student syndrome is common in project environments where the uncertainty in project activity completions drives project management to embed safety buffers to the estimates. In cases where the activities could in fact be completed earlier, the buffered task time can become self-fulfilling prophecies. The author states that while there regularly occurs unforeseen delays in projects and the student syndrome has led to a situation where safety time is used, the estimates are easily overrun. This again creates a feeling that the estimates were too tight and there is a need to add even more buffer to the estimates.

3.2.2 Resource allocation challenge

It is in the nature of competitive environments that companies have to operate with scarce resources. Patanakul (2013) states that having necessary resources at the right time is essential for effective multi-project management. However, it is typical that the concurrent projects are so small that companies cannot afford to allocate dedicated resources to each of them. Dinsmore and Cabanis-Brewin (2014) claim that it is common for senior managers to feel that most projects are too small and simple to even assign a dedicated project manager or team for a project.

According to Artto et. al. (2011) the situation where concurrent projects start to compete for the same resources can result in conflict as the projects still have reach their own objectives regarding scope, costs and schedule. This is why management system needs to cover the resource allocation challenge so that there are enough resources for right projects when needed. Figure 9 illustrates the multi-project resource allocation challenge. The important questions are of which resources are allocated to which projects at when and for how long.

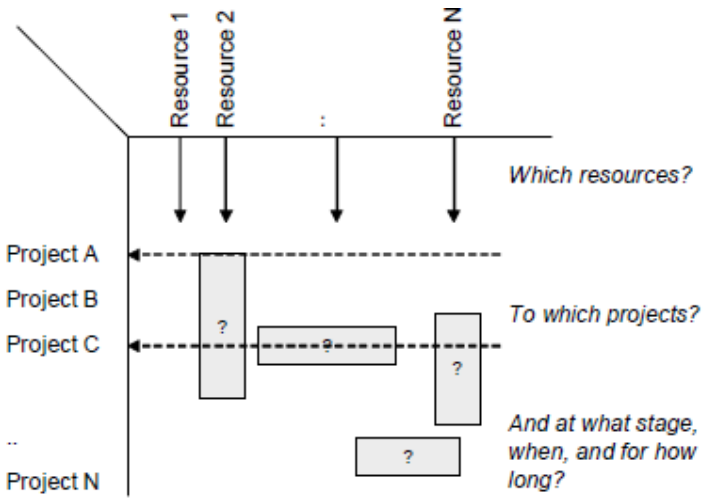

Figure 9. *Resource allocation challenge in multi-project environment (Artto et. al., 2011, p. 293)*

Artto et. al. (2011, p. 293) states that in order to ensure sufficient resources, the resource need must be planned and forecasted. The planning is important because usually resources are difficult to increase or decrease in a short term. Especially critical and rare resources may be hard to obtain quickly. A rough level resource planning should be started already at the sales phase.

Artto et. al. (2011, p. 293) explains that before any critical resources are tied to one project, there should be evaluation based on which projects serve best the company strategy. Schwindt and Zimmermann (2015) also points out that if companies have lots of project opportunities to pursue, a project portfolio concept should be implemented in order to help the decision maker to allocate resources to right projects. Artto et. al. (2011, p. 293) notifies that this kind of prioritizing might affect schedules, costs or scopes of individual projects. Yaghootkar & Gil (2012) state that schedule-driven project management policy in MPM environment will cause all the projects run late in the long term. They explain that as a first project starts to run late, often resources are reallocated to that project to catch up the schedule. This reallocation however only decreases productivity as people take time to coordinate and reorientate to the new job.

Payne (1995) states that there are multiple ways to make more resources available or increase capacity. For example, working overtime, moving staff from other departments, using temporary employment agencies, hiring fixed short-term employee or subcontracting. Payne also suggest that limiting the additional work taken by selecting best project based on the project, customer and the surrounding context can help company to allocate resources the right way.

Human resource management is important part of long-term resource management. According to Artto et. al. (2011, p. 294), a company should keep track and systematically manage its employees' competencies so that it can make sure it has sufficient amount of knowledge and skills for future projects. This is why continuous learning, flexibility of resources and dynamic resource allocation are highlighted in organizations that deliver projects. In this kind of environment, the organization-wide competency builds onto active and long-term development of individuals. The development can be done via educating, on-the-job learning, general project frameworks, job rotation and successful recruiting.

3.2.1 Organizational culture

Patanakul and Milosevic (2009) and Dinsmore and Cabanis-Brewin (2014) introduce the organizational culture as one of the main actors of successful multi-project management system. Patanakul and Milosevic (2009) and Patanakul and Aaronson (2012) state that in the multi-project project environment, it typical that functional managers try to solve resource allocating challenges across multiple projects, project managers try to juggle priorities between projects and project team works on tasks of multiple projects. This kind of setting highlights the need for effective communication, commitment, strong working relationship and rewarding system.

Patanakul and Milosevic (2009) explains that the commitment means that every level of the organization commits to the project objectives. The commitment has to come from top management level and then be supported by lower levels of the organization. The culture that supports communication is important. In practice this means that as project objectives are set, they are clearly communicated and the whole organization commits to them.

3.2.2 Management system control modes

Dahlgren and Söderlund (2010) introduce four different multi-project situations that require different approaches for the control system. The classification is created based on two dimensions: project uncertainty and dependency between projects. Analyzing the project uncertainty is important when defining the managerial control system in the multi-project organization. The project uncertainty can be defined as ability to forecast the variation of project outcome, resources and work processes.

According to Dahlgren and Söderlund (2010) the dependency between projects means that the success of a project is dependent on the results of activities in other projects. This dependency can be high or low. In high dependency cases there were

shared resources, engineering capacity or systems and products between multiple projects that created the dependency. Bathallath et. al. (2016) summarizes that resource dependency between projects can lead to situation where an individual project can either increase or decrease another projects cost.

Based on the two dimensions Dahlgren and Söderlund (2010) created a matrix that illustrates the four control situations in multi-project organizations. The matrix is presented in figure 10 In situations where project uncertainty and dependency are low, the multi-project control focuses on maintaining focus on routines and standard operating processes. This control mode is called *routine-based control.* The project management model in these situations is often based on gates and milestones. *Planning-based control* was identified in low project uncertainty and high dependency cases. In these cases, the low uncertainty enables action plans to be used as coordinating mechanism. The dependencies between projects can be solved in coordinating committees or project management offices.

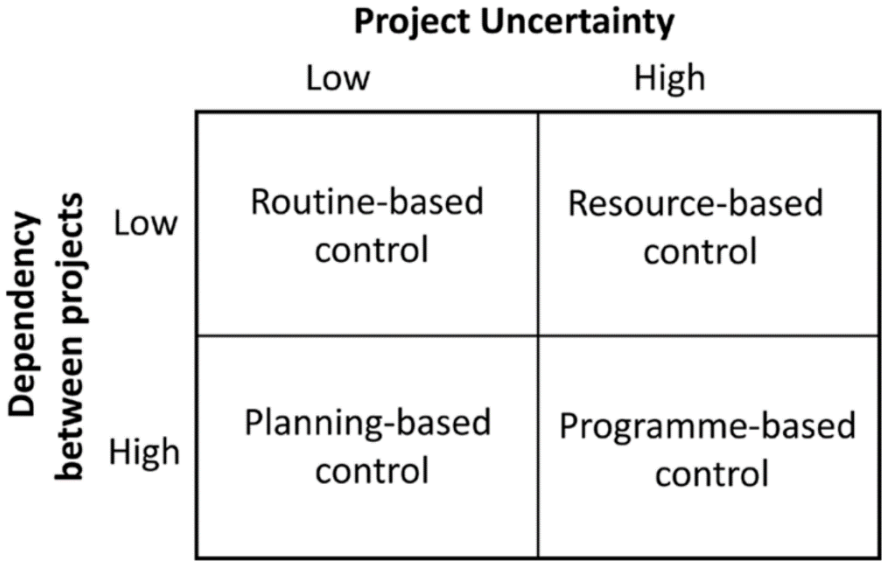

Figure 10. *Control situations in multi-project organizations (Dahlgren and Söderlund, 2010)*

According to Dahlgren and Söderlund (2010), as project uncertainty increases, plans cannot be the main control mechanism as plans require certain level of stability. Usually the uncertainty was high in cases where there were frequent changes in customer needs and requirements. *Resource-based control* can be then adopted if the dependency between projects stays low. In this kind of environment standards could be set and plans be made but their use is limited because of the uncertainty. Here, the control is focused on individual projects with project managers and other resources allocated to them. Also, much time was spent to create flexibility in each of the projects.

The final control mode is *Programme-based control*, where the projects are interconnected and the uncertainty in projects is high. Dahlgren and Söderlund (2010) emphasize that along with allocated project managers, there should be some coordinating mechanisms that consider the project dependencies. The authors analyze that the control mechanisms can be based on continuous dialogue in the steering committee and prioritizing between projects.

4. RESEARCH METHODOLOGY

4.1 Research design

The nature of this research can be identified as *applied research* in the terms of purpose and context. According to Saunders (2007, p. 8) purpose of applied research is to improve understanding of specific business or management problem, create solutions and new knowledge limited to the problem and provide findings that have value to managers in the organization. Context in the applied research means that objectives are negotiated based on the organization's needs and the time scale is limited.

For better validity and reliability, it is important to understand what are the fundamental assumptions and limitations of the study, why some choices are made and what methods were used for collecting and analyzing the data. This chapter explains the overall research design that is used in this thesis. Saunders (2007, p. 100) illustrates a basic research design in a form of a research 'onion'. The research onion is presented in figure 11.

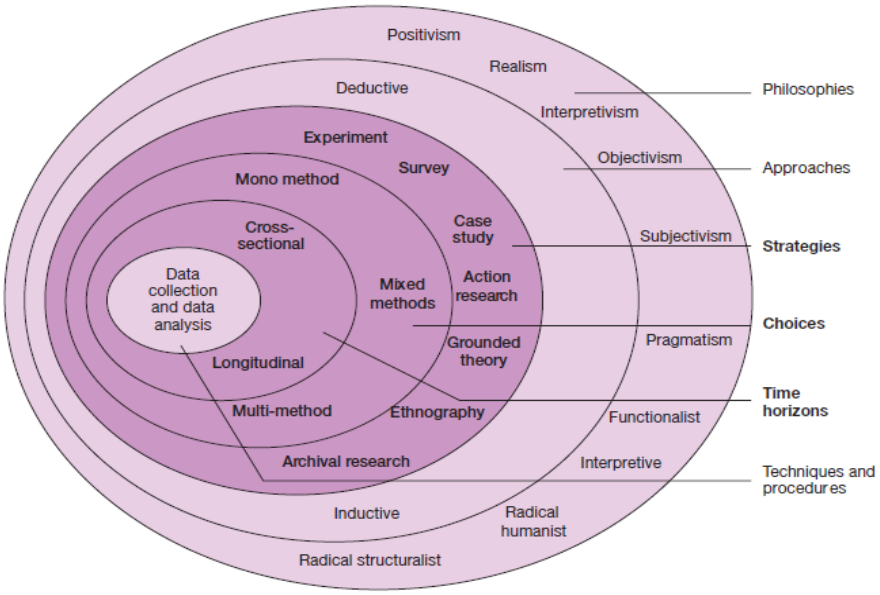

Figure 11. *Research design elements in research onion (Saunders 2007, p. 100)*

The onion has seven layers or dimensions and each of them explain different aspects of a research. These layers are

- Philosophies
- Approaches
- Strategies

- Choices
- Time horizons
- Techniques and procedures

The research philosophy in this thesis is pragmatism. Saunders (2007, p. 110) explains that in pragmatism, the research question defines the actual research philosophy that is adopted. In this meaning, the pragmatism philosophy supports thinking that knowledge and reality can be treated both objectively and subjectively and the research can't be full identified as positivism or interpretivism. For example, in this research answering research question *"How planning, monitoring and controlling of the work should be organized in multi-project environment?"* requires that the complexity of projects is defined objectively with quantitative measures and analyzing the environment requires subjective positioning.

The next layer of the onion consists of different approaches which are deductive, inductive and abductive. The approach used in this research is abductive. According to Saunders (2007, p. 117-121) deductive approach means developing theory and hypothesis and then implementing the research to test the hypothesis. As a opposite approach, inductive research approach starts by collecting data and then developing theory as a result of the data analysis. Abductive approach combines the two approaches so that both the theory and data are used to get best results to meet the research objectives. The abductive approach in this research is used so that the theory of single project management is combined with the data that is gathered in a multi-project production environment which is less covered area in the literature.

The third layer describes the research strategy. This research follows mainly the case study strategy but also an action research strategy is applied. Saunders (2007, p. 139) describes that in the case study strategy, a research is empirical and it is focused on a selected phenomenon with its real live context. The phenomenon in this thesis is planning and controlling of projects in a multi-project environment. The context of the case study is the case organization. The case study strategy is selected because the purpose of the research is to gain understanding why the case organization is in the current situation, how the problems emerge and what should be done for improving the situation.

The action research strategy is present in situations where a researcher is involved in the research. According to Saunders (2007, p. 140-142) there are four different themes present in an action research. First theme emphasizes that the purpose of the

research is to research in action rather than research about action. Second theme addresses the fact that the researcher is part of the organization and is involved in the research and the possible change process. Third theme emphasizes that the research has iterative nature where the research is done in cycles. The different cycles consist of diagnosing the situation, planning, taking action and evaluating results. The final theme suggests that the results of the research should inform other researches outside of that particular context. Schein (1999) states that a change is easier to implement when employees are involved in the research process and they feel they were part of the problem solving.

The different themes were present in this research. The objective for this research was to implement a monitoring system for the case organizations manufacturing projects so it is clear that the researcher had to be part of the research. To drive the change the researcher was involved in the process of diagnosing the situation and finding and planning different solutions for the change. For example, the researcher actively got to know to the company's information systems and tried to understand how the systems could be used to build the monitoring system. The researcher was also actively discussing with the key actors of the organization of how the project planning and controlling processes could be formed. However, the iterative nature of the action research strategy was not clearly present in this research as the researcher had difficulties obtaining resources for the solution development.

According to Saunders (2007, p. 145-146) the fourth layer of the research design considers the research choices of what kind of data, qualitative or quantitative, should be gathered and how it should be analyzed. The analyzing can be done by statistical or non-numerical procedures. For this research, a mixed model research was chosen to best answer the research question. This means that both quantitative and qualitative data were gathered and they were qualitised for the analysis. The research question is "*How planning, monitoring and controlling of the work should be organized in multi-project environment?"* which means that it is important to understand the size and complexity of the case organizations projects through quantitative measures and the different factors of the multi-project environment through qualitative measures.

The fifth layer considers the time horizon of the research. This research was cross-sectional study of the case company meaning that the phenomenon was studied at a particular and for limited time. However, it is important to notice that the researcher has been working in the case company as a part time employee for past five summers. Therefore, some aspects of the research may have the longitudinal research view as

the researcher has had the opportunity to observe the people and the environment for longer time period.

4.2 Data collection

The author of the research had worked in the production floor and engineering and sales departments of the case company in past few years. This have given a good overall view of the case company's environment and the organization but the production planning and control was unknown area for the author.

The primary data was collected through observation method. The method was chosen mainly due to practical reasons. The production environment of the case company is highly complex and the approach of the research was not clear from the beginning of the research. For example, structured interviews were not used as the "right" questions could not be asked before the approach and specific topic were clear for the researcher.

The researcher's role in the observation was "participant as observer". Delbridge and Kirkpatrick (1994) explains that in this role both the researcher and subjects of the research are aware of the researcher's purpose. This helps to gain trust in the research situation and thus some questions are easier to ask from the research subjects.

Following the categorization of Delbridge and Kirkpatrick (1994), the data was generated through primary observation, secondary observation and experimental data. This means that in different situations, the researcher could note what just happened or what was said at that time (primary observation), what had happened or had been said (secondary observation) or perceptions and feelings emerged in the situation (experiential data). The generated data from each category were recorded to a research diary.

The observation data was collected from informal discussions and meetings where the researcher could be actively or passively part of. The most discussions were held with the production manager who also was the sponsor of the research. Also, the master scheduling manager was in the close cooperation with the researcher. The researcher's work station was in the same room with these two actors so the observation data could be gotten also from meetings and discussions where the researcher only role of a bystander. Other discussions related to the research were held with the work supervisors of Tampere factory, the factory manager of the Tampere factory, ICT systems administrator and production controller.

In addition to observation data, some secondary data sources were used. The secondary data sources were mainly documentary of written materials such as presentations, project documents and the quality handbook of the case company. Also, some historical data from the company ERP system were used to better understand the production environment.

4.3 Research process

The initial need for the research was the lack of knowledge on why the manufacturing labor costs exceed the planned cost from delivery to delivery. The research started from getting to known to the case company's production planning and controlling in a general level. This diagnosing was done iteratively by discussing with the company employees and reviewing the literature. The important part of the diagnosing was to determine what is the production type of the case company because it would affect the ultimate approach for improving the planning and control of the production.

A general dilemma in the case company was that as the production could be identified as job shop production, the operations had elements from both project and repetitive manufacturing. The production was organized into general phases that were repeated from delivery to delivery which could indicate that solutions could be searched from operations management literature. However, a scope of an individual phase was usually affected by different customer requirements meaning that the schedule and cost objectives should be planned for each phase and delivery. As there were multiple this kind of phases and deliveries executed at the same time, the general topic of the research was narrowed down to a project management in a multi-project environment.

The iterative nature of the action research strategy was seen in the way that the solution proposal was built. The research process proceeded so that the multi-project management literature was mirrored to the case company's practices and vice versa. As the research process went along, the researcher tried to explain and simplify why the control of the production was so difficult, how it could be improved with project management practices and what were the criteria for building an efficient control system. From this basis, the three objectives could be formed:

1. To understand factors that affect the simultaneous control of multiple projects
2. To examine how the planning process of individual projects should be organized in the case organization
3. To examine how to get real time progress information from the case organizations production

Following these objectives, the research proceeded to gather and analyze data of the company's competitive factors and the organization model. The aim of this was to increase understanding of the initial reasons that affect control of the production. The literature review indicated that multi-project organizations struggle with resource allocation challenges and the organization culture and management system have important role in the multi-project management. The same kind of issues were seen in the case company.

The diagnosis of the general situation was followed by diagnosis of the project and production planning and control in the case organization. The aim of the diagnosis was to understand the process of the planning and control and how the information systems were used in the process. A simplified model of the production control system was made as a result of the diagnosis. This way overall criteria for the monitoring system could be built.

The monitoring system was then designed on the basis of the defined criteria. The design was created mostly by using the existing resources of the company. The monitoring system was gotten into testing but due to schedule of the thesis the final results of the monitoring system implementation where excluded from this research.

5. CURRENT STATE OF THE TARGET COMPANY

5.1 Overview of the company and the product

The case company of this thesis is a large machinery manufacturer located in Finland. The company designs, manufactures and services truck mounted, hydraulic aerial platforms. These platforms are used in firefighting, rescue, access and maintenance work. The company has annual net sales of over 100 million euros which makes it currently the global market leader. The company distribution network covers over 100 countries and 97% of its sales comes from exports. The production is organized in two factories located in Pori and Tampere and the company delivers approximately 150-170 units per year. The company employs over 400 people. The company has approximately 70 basic product types and 100 options in the active offering.

The case company has two main product groups that serve different markets. In terms of a market size, the more important product group forms of firefighting and rescue platforms. These platforms are delivered mainly for municipal fire departments and private industrial actors such as oil refineries. The second product group serves access and utility operators working in service and maintenance business. These units have various applications in sites that need aerial platform to reach objects in high places.

The product structure is generally the same in both product groups. The basic product structure is presented in figure 12. The whole unit consists of two main parts: a chassis and a superstructure. The case company designs and manufactures the superstructure mainly in-house and then installs it in top of a commercial chassis. The superstructure can be divided into several sub-assemblies. Mainframe acts as a base of the platform and it has housings for four outriggers. The outriggers stabilize the platform for operation. The lift part of the platform consists of a working cage, a cage boom, lower boom sections and a turntable. These parts are manufactured and assembled to one package which is then installed on top of the mainframe. In addition to the basic product structure, firefighting platforms also have waterway system and bodywork installed.

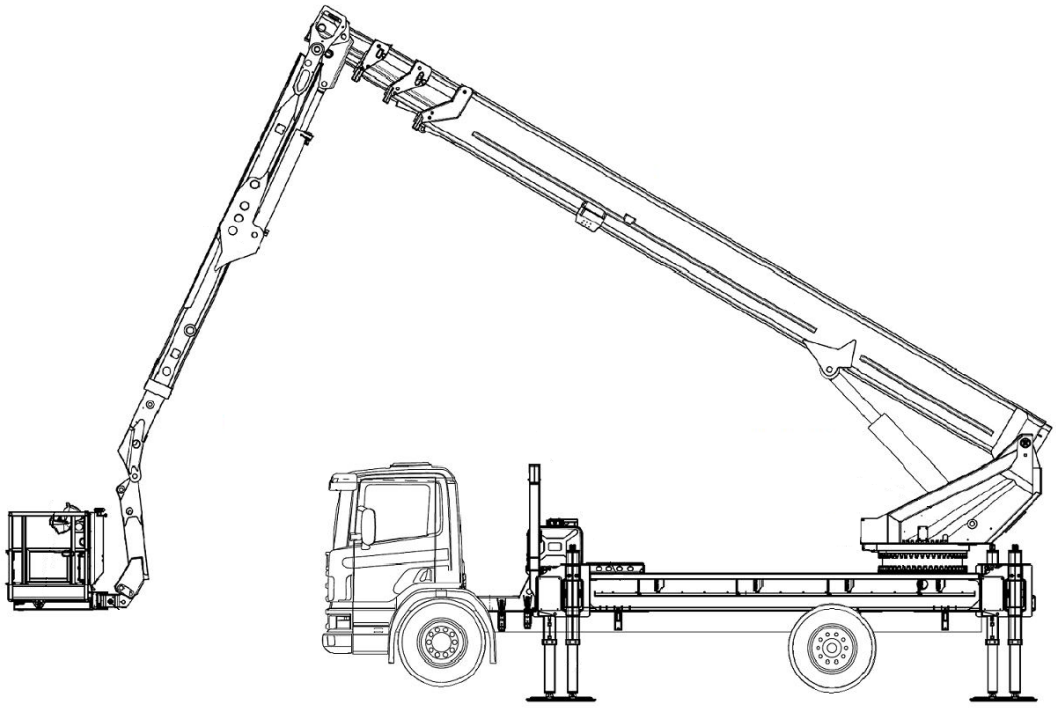

Figure 12. *General product structure of case company's offering*

5.2 Main competitive factors

It is important to understand the main competitive factors as they have significant impact on the company's processes and culture. This chapter presents the three main competition factors that are directly connected to the objectives of each project delivery and the production of each product. These competitive factors are product tailoring, fast delivery and competitive price.

One of the case company's main competitive factors is the ability to tailor the product according to various customer requirements. These requirements can functional or technical. This means that customer can require certain level of performance or certain type of design or components. It is important to understand that even though the basic product structure remains the same, customer requirements often effect different sub-assemblies of a delivery. This leads to a situation where each delivery can be different even though they are the same product type. Some of the customer requirements that can affect the product design consider

- Working cage load capacity
- Working height and outreach
- Transport dimensions
- Jacking width

- Weight of the platform
- Chassis brand and type
- Accessories and bodywork
- Control system
- Water discharge capacity (Firefighting platforms)
- Power need
- Regional regulations and laws
- Operation times and reliability
- Cost

These requirements are often connected. For example, increasing working cage load capacity decreases working outreach and increasing working height increases the weight of the platform. It is also important to notice that as the products are used to save human lives or generate income for a customer, the quality and reliability of the product have to be high.

Another important competitive factor is speed in the terms of designing the new product and delivering it to the customer. In the case company, the length of a sales cycle varies from weeks to several months depending the sales opportunity. Also, there is a lot of uncertainty whether a customer prospect will buy a platform at all or will it buy the platform from the case company. In some cases, the probability of getting a deal and the order can change within few days. Delivery time after the order placement is usually 6-12 months depending on the capacity utilization, product type, customer requirements and availability of the critical components. The speed of the process leaves the engineering department limited amount of time to design the product especially if an order requires a lot of customer specific details. Ultimately the production is responsible for reaching the delivery date on time.

Although the case company has to design the product according to many customer requirements and the promised delivery time is relatively short, the price of a product has to stay competitive. There is competition with companies providing same kind of platforms and companies providing substitutive technologies. At the same time the sales volume of the platforms is relatively small. This increases customer power in the market and forces the markets to have certain price level. The price level again underlines the importance of cost management and productivity in order to stay profitable. This means that the company has limited amount of resources available and the resource usage have to be efficient.

5.3 Company organization

The case company has a functional organization with eight departments: Sales, marketing and product management, engineering, R&D, quality, operations, finance and ICT, HR and customer service. From the production perspective, the main departments that effect the product delivery process are sales, engineering and operations department. The sales department is responsible for determining customer requirements of a delivery, engineering department is responsible for designing the product according to sales and operations department plan and control the work and schedule of the manufacturing.

Production is organized under operations department and it is responsible for organizing the in-house manufacturing of the products. The production is led by production manager. Two factory managers and master scheduling manager are responsible for rough planning and controlling of the production. Work supervisors work under the factory managers and they are responsible for managing resources in different phases of the production.

5.4 Project management

The production in the case company can be categorized as job shop production rather than project production. The repetitive nature of the production and the similarity of the products isn't generally seen as project business. However, as presented in the previous chapter the individual deliveries have special requirements regarding their design, delivery time and price. From the production perspective this means that each delivery has objectives regarding scope, schedule and costs. Thus, according to the project definition presented in chapter 2.2, case company's' customer deliveries are treated as projects.

There are constantly approximately 90-100 projects under production. These projects are grouped in the same managerial system and they share the same resources from different departments. This indicates that the company's production can be identified as multi-project environment and thus several aspects have to be considered. The main focus of this thesis is to analyse the factors affecting planning and controlling of group of projects from the perspective of the production. Other factors such as company organization and overall management system are shortly reviewed as they also have an impact on the planning and controlling processes.

5.4.1 Project planning

When an order is placed, master scheduling manager creates unique work ID number for the project. If an order has multiple platforms, each of them will be given their own work ID number. The work ID will be given a pre-defined WBS based on the sold product type. After a sales person has confirmed delivery date for the chassis and other critical components, a kick of meeting is held. In the kick-off meeting, the sales person, a responsible chief engineer and the master scheduling manager go through the order and clarify the customer requirements for the creation of bill of materials and specifying the WBS.

Each product type has a predefined work breakdown structure (WBS) (Finn. Vaihemalli). A WBS includes main manufacturing work packages or phases (Finn. Vaihe), their standard work load in hours and durations in working days. Work load and duration of each work package are estimated for a basic design of each product type. These values are based on historical data and estimates provided by product group managers and scheduling manager. The case company has also performed some work studies for examining the needed load for each work package. Based on the work studies, the company has already created tasks list with a workload estimate for each task, but they are not used in the current project-specific planning. The estimated work load is connected to a product costing of each product type and therefore it is also working as a base in the pricing of each delivery. A basic work breakdown structure of a one product type is presented in appendix A.

There can be 20-35 main work packages depending on the product type. The standard work packages are defined mainly based on the sub-assemblies or manufactured parts of the product. For example, boom welding and fabrication, mainframe welding and fabrication, turntable assembly, assembly of booms, final assembly and test drive have their own phases. In practice, each work package can include different processing tasks such as welding, painting, machining or mounting of different components but these are not currently scheduled in the company information systems. Planned workload of a standard work package varies from 8 to 800 hours and duration can vary from 1 to 25 working days. On average, one work package lasts approximately 80 hours and has a duration of seven working days.

Based on the sold options and other customer requirements, the master scheduling manager can change the pre-defined WBS. The changes can consider adding or removing phases and increasing or decreasing planned workload and durations. The needed changes are roughly estimated and they are mainly based on the scheduling

mangers experience and knowledge. After the required changes are made, each phase has expected starting and ending dates and planned workload. A basic Gantt-view of a project is presented in appendix B.

The more detailed scheduling and resource planning in each phase are done by the work supervisors. Usually, the human resources are allocated to the production cells evenly. If a work package seems to be running late, more workforce can be moved to that production cell to catch up the schedule. In history, also working overtime has been used but now it has been banned by the management. The project costs easily expand in this kind of situations.

As production takes place, schedules for each project phase are communicated and updated accordingly. The situation of each phase is covered once a week in a factory specific meeting. In the meeting each work supervisor gives best estimate for expected ending date for the responsible phases. These estimates are then updated to the company's ERP system. It is not unusual that schedules of phases are moved forward one week or more.

The main data and information of the production plan are created and stored in the company’s enterprise resource planning (ERP) system. Generally, all of the employees have access to the system and it is used daily in the production. Currently there is a project for implementing manufacturing execution system (MES) to improve the information from and into the production floor. The case company has also a business intelligence (BI) software that is used to visualize some of the historical project and production data.

5.4.2 Project monitoring and control

There are constantly approximately 90-100 projects and 250 work packages under production. Both Pori and Tampere factories run approximately 125 work packages at the same time. Each phase has 5-10 work packages under work. The production control is based on just-in-time delivery and the control system is a mixing of push and pull mechanisms.

The production workers register themselves to a one phase of a work ID at a time. This way it can be seen how many hours have been used for each work package and work ID. In the company ERP system, work packages have four statuses that are used: “Planned”, “Started”, “Stopped” and “Ready”. Some work supervisors use info column of the ERP table to clarify the status of the work package. For example, estimated progress in percentage or written description of what task is under work. The

figure 13 shows example of how the work package status, planned load, actual load, duration, starting date, expected ending date and info columns can be shown in the same table.

Työn tunnus	Vaihe	Tila	Kuorma	Tot.kuorma1	Kesto	Tot.alku	Päättyy	Info 1
[redacted]	LOK	Aloitettu	720	849,69	42	16.03.20	20.05.20	80%
	LOK	Aloitettu	560	416	29	01.04.20	15.05.20	80% , varret puuttuu,keskeytetty
	LOK	Aloitettu	560	550,49	31	06.04.20	22.05.20	70%
	LOK	Aloitettu	160	160,6	9	13.04.20	24.04.20	
	LOK	Aloitettu	320	131,11	16,88	30.04.20	26.05.20	kaappien ruostesuojaus40%
	LOK	Aloitettu	640	154,67	20	05.05.20	01.06.20	40%
	LOK	Aloitettu	80	41,15	5	07.05.20	13.05.20	m100%, s50%
	LOK	Aloitettu	160	3,57	5	08.05.20	14.05.20	m10%, s0%
	LOK	Aloitettu	560		19	13.05.20	10.06.20	

Figure 13. *Screenshot from the company's ERP system*

In order to keep the production flow smooth, some work supervisors use the phase table view in ERP to monitor their own phase and the statuses of previous and following phases. With the information in the table, they can estimate when previous or following phase gets a work package ready and manage their own resources for completing a sub-assembly at the right time.

The main focus in the project control is in managing schedule and scope. It is often seen that as a delivery date of a project is getting closer the main objective is just to get the product ready no matter of the cost. If the project is running late, it is generally accepted to work overtime or take resources from other projects so that the company would evade for paying penalties for the late delivery.

In some phases, ensuring the scope is simple because the phase has the same task list in each project. In these phases, only material or component requirements may change. In phases such as final assembly, the customer requirements effect the work package and its task list more clearly.

Production managers main focus in monitoring and controlling is to get the deliveries to customers on time. In addition to general communication about the production program status, the production manager has created a simple magnet board to keep track the status of work IDs that should be ready that month. The board has only columns for the final assembly and test drive which are the last two large phases of the production. Magnets of different colours are placed for each row to give quick information whether a phase of a work ID is ready or not.

5.5 Project background

The need for this research origins from the production management need to have better understanding of the labour costs that are allocated for a delivery project. It is common that post project review shows excess number of labour hours compared to the planned workload. The project review is usually done one month after the project delivery. This means that a phase with cost overruns could have finished 1-5 months before the project review. After that long time, examining the issues that led to the cost overruns is problematic as involved employees can only present inaccurate estimates of the reasons. The company has a process for collecting and reviewing feedback about the problems in the production. However, management thinks that the quality of the feedback is often low, and conclusions is hard to make based on that information.

The most labour cost overruns happen in the final assembly which is one of the largest phases measured in the overall load. Work packages in the final assembly also is most affected by customer requirements as many of the option solutions are implemented in this phase. The hour overruns in of the five largest phases in year 2019 are presented in figure 14.

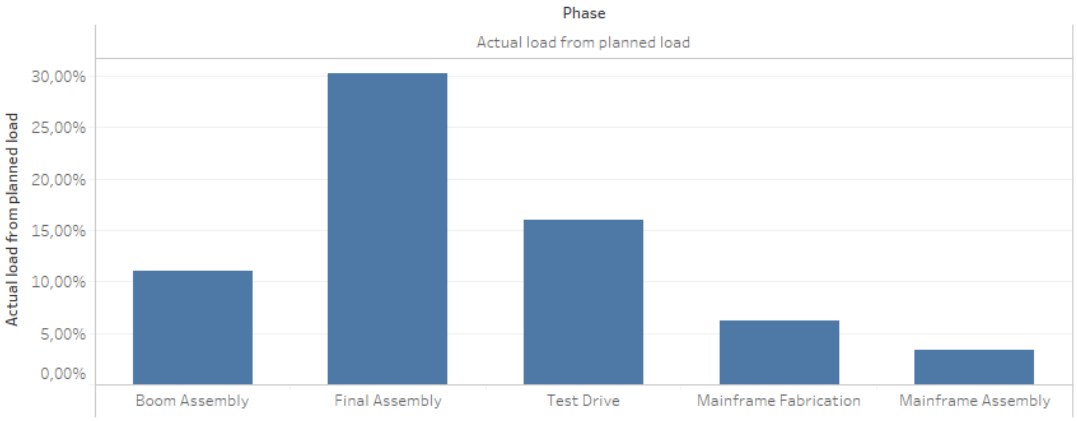

Figure 14. *Percentage of exceeded work hours in largest work phases*

6. ANALYSIS

6.1 Challenges in current state

The main competition factors of tailoring, fast delivery and competitive price drive the company's' functional organization in difficult situation. As sales department tries to maximize the amount of sales, they try to figure out ways to comply to each of the competition factors. This causes different kinds of challenges later in the supply chain as product structure and production processes change and projects start to compete for the same resources. Figure 15 shows how the competition factors ultimately lead to long lead times and poor productivity.

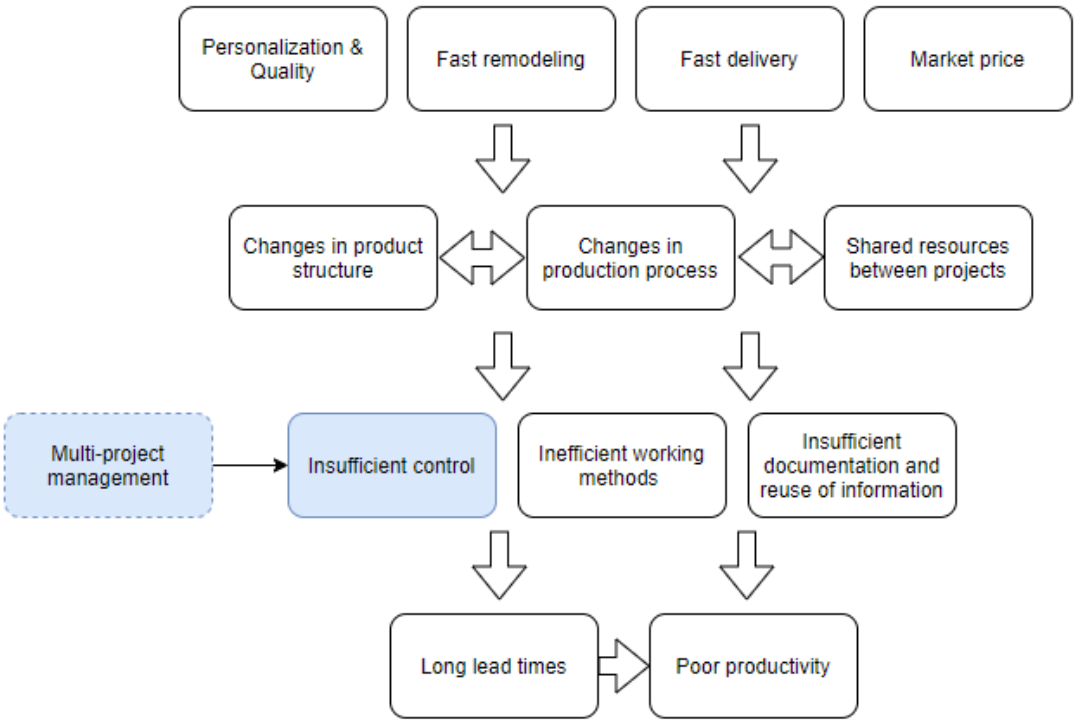

Figure 15. *Illustration of challenges caused by the competitive factors and the connection to the control problem*

The analysis chapter presents some of the challenges that emerge this kind multi-project environment and what could be done to improve the multi-project control system. Focus is put to factors that create uncertainty in the company's production and thus leads to insufficient production control. The current monitoring and control system do not provide information about the deviations on the cost, schedule and scope objectives of a project or multiple projects.

6.1.1 Organization and management system

To shorten the lead time and provide fast delivery, many of the activities are scheduled to perform simultaneously. This considers the planning and control of work between departments and planning and control of work between different work packages in the production. From a perspective of a one project this isn't a problem but as there are several projects under production the planning and control of a project becomes more difficult and company's management system should take the issue into account.

Figure 16 describes how the project execution and information flows through the functional organization. The production and project execution have different processes between different departments. Sales configuration, engineering and manufacturing process lines show how different phases of a project often require input and resources also from other departments and they are more or less overlapped to each other.

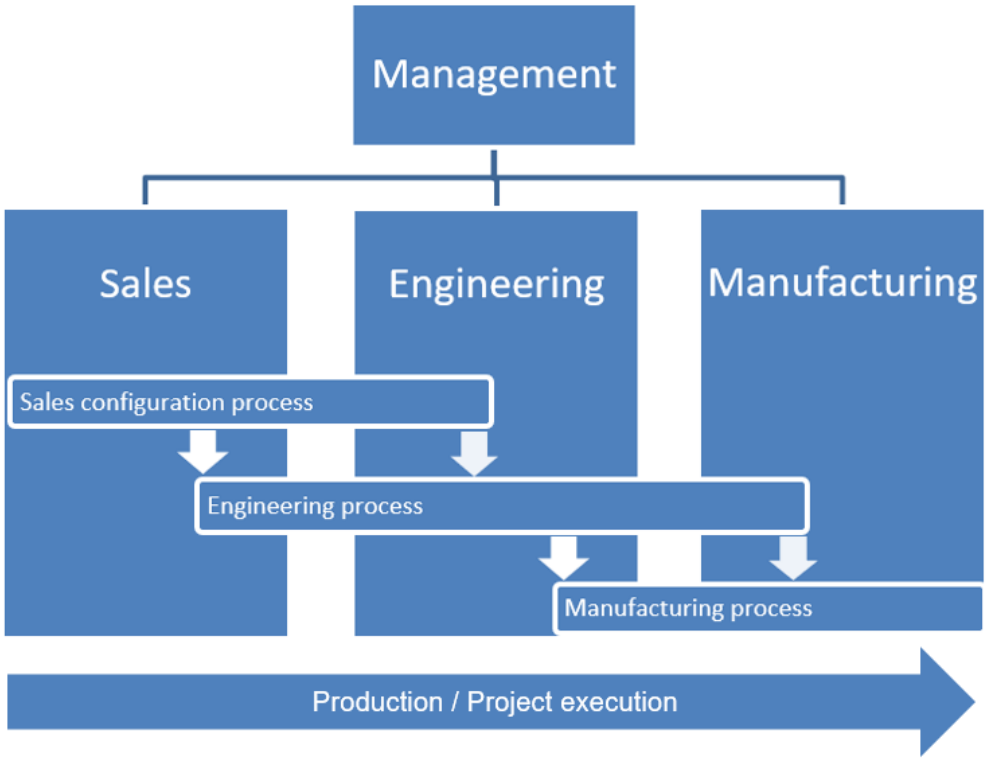

Figure 16. *Illustration of concurrent processes during the project execution*

While different processes require resources from different resource pools, situations emerge where one should decide which project or sales opportunity should be focused on. However, there isn't clear indicator what projects should be concentrated

on. Rather it is expected that people are self-guided and processes ensure that missing information is filled in and communicated to next department on time.

Overlapping processes can be seen between different departments. If a tender is won, the customer requirements might require designing the product from the beginning. This means that sales department and engineering department have to provide resources for the sales configuration process. As the delivery time is tight and also other projects and new sales opportunities require a sales persons and chief engineers' attention, the sales person and the chief engineer might only focus defining and designing the most important parts required for manufacturing the product.

For the engineering department complying to product structure changes means that they have to use large amount of time for sales support activities. For example, these activities can include providing offer drawings and reviews whether the company can comply to customer requirements presented in a tender. At the same time, the engineering department should manage their own work on projects that are already in production and support those projects in manufacturing where questions about the configuration have been emerged.

This can mean that the design and documentation of the product is not optimal from the manufacturing's perspective and some designing tasks can be left for manufacturing workers. It is known situation where a sales person says "I guess they (engineering department) will know how the sold unit can be designed" and chief engineer from the engineering department says "The people in manufacturing will figure out the way to assemble the product". It is understandable that the efficiency in manufacturing will suffer in this kind of situation.

Another example of the problems in overlapping activities is from a case where production of a project had to be started in order to meet the delivery time. However, a sales person had not yet gotten a customer's confirmation for the colour of the booms. To get the production started in time the colour was assumed and agreed to be clarified before the boom assembly. Because of the lack of control, the confirmation was gotten after the booms were assembled and it was noticed that the customer wanted a different colour for the booms. This caused excess labour cost for the project but also affected the production schedule of other projects as the booms had to be redone.

It is true that some solutions can be easier to design and implement when the physical product is in the production cell and all the dimensions can be seen and measured precisely. However, from the productions planning and controlling view this creates

challenges as it is hard to estimate how much planning is needed to finish one task. Especially production workers in the final assembly often have to use vast amount of time for planning and setting up a solution for a simple mounting task because a component did not fit the same way as in previous project. In worst cases a whole subassembly has to be dismantled and rebuilt in order to get one component to fit. This kind of environment underlines the importance of skilled and experienced workforce.

6.1.2 Information flow between work phases

The large number of concurrent projects create a large amount of data which is difficult to process in the fast-paced production environment. For example, a work supervisor can be managing eight subassemblies at the same time and each of the subassemblies have their own objectives regarding scope, schedule and costs. In ensuring the smooth production flow between different phases, a work supervisor have to also keep eye on the previous and following phase and their work packages. The difficulties can especially be seen as increased need for communication between departments and phases.

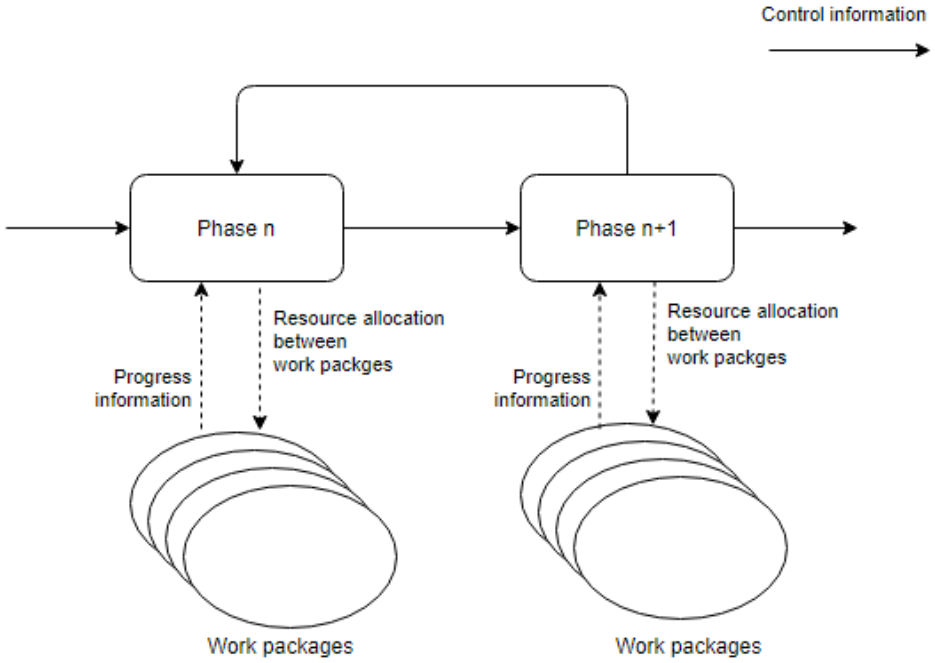

Figure 17. *Monitoring, resource allocation and control information flow within and between work phases*

Figure 17 illustrates the control situation between phases. A phase can have several work packages on progress. Each work package is affected by the uncertainty factors

caused by the competitive factors. These factors are for example unplanned engineering, missing material or insufficient documentation. Work supervisor of a phase tries to monitor progress for each work package and then allocate resources accordingly. However, the uncertainty factors make the planning and monitoring of several work packages difficult as the situation can change rapidly and the information in the ERP system can quickly become outdated.

In the production, the scheduled starting and ending dates of work packages are kept up to date on a weekly basis in different production meetings. The aim is to keep the schedule up-to-date and realistic so that work supervisors can control the flow between phases. A phase should not be finished too early or too late. This is important so that intermediate storage would not form between phases and phases would not have empty production cells and idle employees.

While a work supervisor can be working with several sub-assemblies at a time and there is a lot of data to process, mistakes can easily happen. One example of the communication need occurred when a work supervisor was informed on a Friday that a previous phase had finished their sub-assembly early and they need to send it to the work supervisors' production cell on Monday. If the work supervisor had known that two days earlier, he could have speed up his own work so that the part from previous phase could have taken in on Monday. Instead he had to put his team to work over the weekend causing excess labour cost for the project.

6.2 Proposal for improvement

The main focus of this thesis is improving the work monitoring system and the processes related to it. A comprehensive monitoring system is required to identify deviations from the original project objectives regarding scope, schedule and costs. Figure 18 shows the generic work planning and monitoring process which describes the importance of the monitoring system. Monitoring enables fast and flexible re-planning. Re-planning again enables realistic and up-to-date production plan and the plan is required for efficient execution of production. However, the complex production environment sets some criteria and limitations how the monitoring can be done.

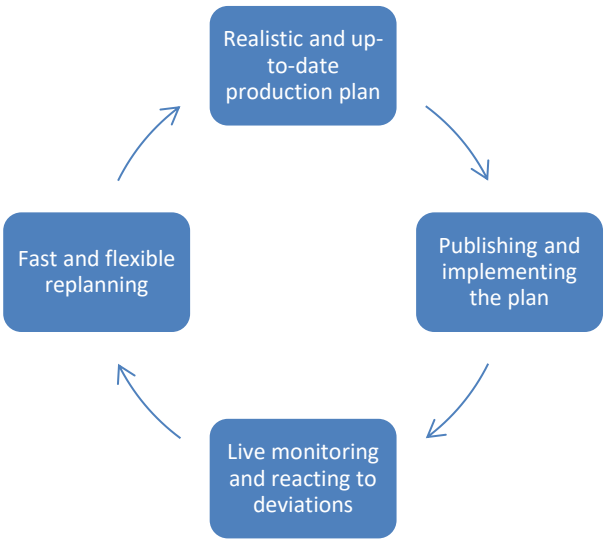

Figure 18. *Generic work planning and monitoring process*

In short, the company has 90 projects and 250 open work packages open in the production. The customization and tight schedule create a lot of uncertainty especially in larger work packages such as those in final assembly. This again leads to situation where schedules and factory load changes in a fast pace. To provide more reliable and timely information to the production a live monitoring system should be implemented. Because of the fast paced and uncertain environment with many simultaneous projects, the criteria for the monitoring system should be as following:

- The information needs to be as live as possible
- Gathering of the progress information need to be easy and simple
- The data needs to be visualized for better understanding of the situation
- The process should not cause excess amount administrative work.

The overall purpose is to improve the information flow within and between work phases and functions. This can be done only by ensuring that the data in the ERP system is up to date and the data is processed in to information by visualizing it. However, the related processes should be formed and organized so that they would not cause too much work for those operating with work planning and reporting duties.

6.2.1 More detailed work planning by using WBS

Production plan should be the base of all doing. In current situation the plan is done in rough level when the order is placed. As production processes run, the plan is updated to match with the current situation. The challenge in the more detailed planning is that it requires more resources for monitoring and administrative work such as re-

planning. However, in larger phases such as final assembly, the work package can have a planned lead time of over 30 days meaning that the actual ending date is harder to estimate.

To improve the project work planning without causing too much administrative work, another level of detail should be added to the WBS. This means adding work tasks to the work packages. With the help of the work tasks the scope of the work package can be better understood and the resources managed so that meeting the schedule becomes easier. The work tasks are used only to evaluate the work packages progress so that the expected ending date of the work package can be communicated with better precision.

The company's ERP-system has a built-in task list table for the work packages that can be used to define the WBS. The work tasks have special column where expected load can be filled in. The sum of load of all task should be matched with the rough load to ensure that the progress information matches with the official plan.

6.2.1 Communicating the plan and gathering the progress information with MES

To publish the plan and monitor the completion of tasks, there should be agreed procedure and proper tool for it. All employees have access to the company's ERP system where the tasks can be checked as started or completed. Employees accessibility to the ERP system isn't so good as there are not too many computers. Also, login in to a computer, opening right table, work ID and work package in the ERP system is not the most straight forward way to report the progress.

As this thesis was worked on, the case company planned to implement a MES system to the production. The MES system offers more easy way to communicate the plan and collect the progress information as it only shows information that is related to a specified production cell of an employee. MES system matches to the criteria as it improves timeliness of the information and the planning, reporting and monitoring doesn't require too much administrative work. This is why it is recommended that the MES system is to be implemented and used to improve the planning and monitoring system.

When the data gathering and monitoring process is developed, a thought should be given to data quality and the frequency of reporting. Too detailed and short frequency can be unmotivating for the employees as there is a lot of uncertainties and for example hourly reporting doesn't anyway tell the real situation. It can be estimated that

checking the task for few times a week should not cause too much trouble for assembly line employees and this frequency still keeps the data quality good and timely. It is also important to communicate that the monitoring is to only figure out if the current plan is still up to date and not for stalking individual workers.

6.2.2 Visual deviation reporting

Better data doesn't automatically lead to better understanding of the situation. One of the core problems is that the data in the ERP system isn't processed to information. As the situation changes and lot of new data is generated daily, the data should be processed in to a visual form that decisions could be done more easily. The case company has a data visualization software Tableau where the ERP data can be processed and different kinds of reports can be created.

The purpose of developing the planning and monitoring process is to ensure better information flow and improve production control. When individual work phases and work packages are considered, the aim is to make sure that relevant people in the organization would have the information if the current ending date of a work package is correct in the ERP system. In final assembly the ending date can only be defined more clearly if the planning and reporting done in more detail level.

Checking the task in a work package enables calculating the earned value of work package in question. When each task has the load defined, the progress can be calculated for the work package by comparing the sum of task loads and checked task loads. The calculating principle can be done for example by calculating adding 50% of started task loads and 100% of finished tasks loads. This way it is possible to get rough estimate for the progress of a work package and interpret if the estimated ending date of a work package is still valid.

Figure 19 demonstrates how the progress and estimated lead time of work packages can be put in to a matrix form. In the matrix, the progress axel goes horizontally from zero to 100%. The percentage of lead time used goes vertically. In this matrix each work package is presented as a dot in the area that goes between these two axels. If time goes by without any tasks being checked started or completed a dot moves upwards in the matrix. When tasks are being checked the dots move towards the right side of the area. The chart is supposed to give overall situation status of the final assembly and presents the opportunity to ask targeted questions such as: Is the work package going to be finished as estimated in the ERP system or why the work package is behind the schedule?

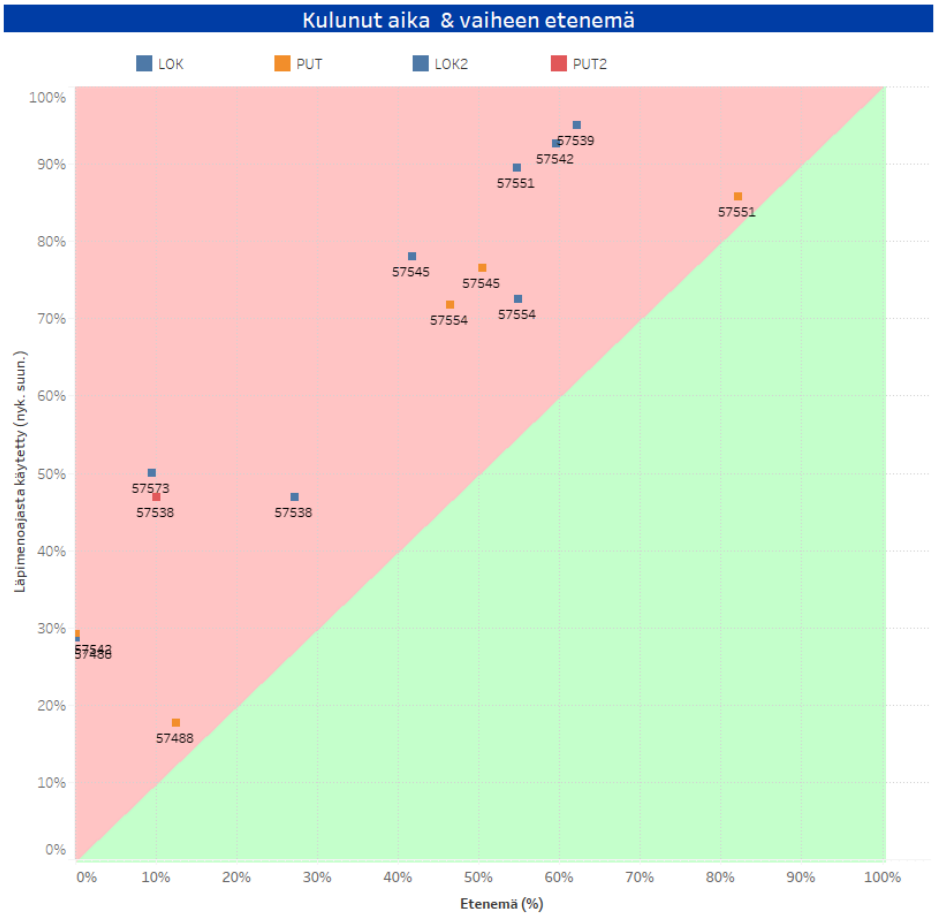

Figure 19. *Monitoring matrix – Comparing progress and used lead time of work phases work packages with visual dashboard*

6.2.3 Organizations management system

The planning and monitoring system introduced in previous chapters possibly improves the control only in single work phase in the project manufacturing process.

However, it should be noticed that the control system should consider the whole production with large amount uncertainty and handle the interdependencies between projects. In some corridor conversations it is mentioned that the main issues in production emerge because there is a “managerial problem”. By this it is meant that there should be a common understanding between different departments of which projects and their production tasks should be infused with more resources and management focus at the time.

At this point it should be sharpened that even though in the case company manufacturing department is called production, the term production means all the activities that create value to the customer and ensure that the customer gets its product or service on time, with wanted specification and with costs that keep the business profitable. This means that in the case company the production includes sales, engineering, procurement, logistics and manufacturing. This again means that production planning and control means managing all activities in and between all the departments mentioned above. As projects simultaneously flow through departments and each department manages their own resource pool, situations emerge where projects start to compete for resources. This is why there should be a management system that enables efficient resource management and solves priority conflicts between projects.

Chapter 3 presented four different control modes for multi-project environment. The modes fit different environments based on two scales: project uncertainty and dependency between projects. Case company’s production environment has both high uncertainty and high dependency between projects because of the competitive factors. Also, student syndrome and Parkinson’s law can be seen in the current production environment. The uncertainty and deviation in individual work phases is tried to dealt with extra time or “buffers”. However, due to student syndrome and Parkinson’s law it can be seen that work phases still slip behind schedules and no benefit is gained of the buffers. This is why there should be discussion of how the production program should be controlled.

One solution to the control problem could be Critical Chain method which aims to ensure that the longest production chain doesn’t stretch over the promised delivery date by reducing the impact of student syndrome and Parkinson’s law. The main idea is to give realistic but tight schedule for the longest production chain (critical chain), then remove all extra buffers between the phases and insert the buffer at the end of the project. After this the controlling can be done by monitoring work phases in the critical chain and responding accordingly. Moving a work phase in the critical chain consumes the buffer at the end which acts as a “red flag” for management to take

actions and develop part of the organization that caused the delay. The critical chain method can also solve the prioritizing problem as the buffer consumption tells which projects are in danger to miss the delivery date.

The organization culture also has emerged in some conversations. It can be reasoned that in the case company's production environment where there are lot of uncertainty and many people from different departments participate in progressing the projects forward, the organization culture should be nurtured by the management. The company already has written values that the culture should lean on. The case company's values describe the idea that people and working together to solve the problems but more concrete actions are wanted actually show that the values are meaningful. In conversations with production floor employees it was said that the management should visit more the manufacturing floor to create trust and show that the values are important also for the management team.

7. CONCLUSIONS

7.1 Summary of the results

In this thesis, case company's production environment and organization were analyzed to get better understanding of how multiple production projects should be monitored and controlled. The general problem in the case company was that actual work hours exceeded planned work hours and it was difficult to define the reasons for the poor performance. Based on the problem, the objective was to understand factors that affect the simultaneous control of multiple projects, examine how the planning process of individual projects should be organized in the case organization and examine how to get real time progress information from the case organizations production. The purpose of this study was to answer research question of *"How planning, monitoring and controlling of the work should be organized in multi-project environment?"*.

The research question was answered with literature review and empirical case study with observation method. The literature review was used to get general understanding of the factors that affect the control of individual projects and what are the characteristics of managing multi-project environment. Literature review was first used to strengthen the perspective for single-project and multi-project management as case company's production had repetitive work phases so it couldn't easily be identified as project environment. Considering the single project management, the literature review was narrowed to planning, monitoring and controlling of scope, schedule and resources. One of the key notes was that planning and reporting should be fit to the project size and resource availability. More detailed planning usually requires more reporting and increases the need of re-planning.

The multi-project management literature review addressed themes that could be identified in the case company. The multi-project management challenge could be framed in to two dimensions: project uncertainty and dependency between projects. High project uncertainty and dependency between projects indicates that there is a need for program management system where effort is put to identifying and solving priority problems between projects and allocating resources based on the information. According to the multi-project literature this is important because multitasking, Parkinson's law and student syndrome lowers the productivity of the organization. Also, the

organization model and organization culture have impact on the success of multi-project management.

The empirical part of the study focused on gaining understanding on the case company's environment and the management problem that raised from it. The empirical study addressed case company's competitive factors, organization structure and project planning, monitoring and controlling related activities. It was seen that planned work load were exceeded especially in final assembly so designing work monitoring and control system concentrated on this work phase. The study consisted mainly observations of meetings and discussions with employees that participate in work planning, monitoring and controlling. The data was also collected from company's documents and ERP system.

It was seen that the company's strategy to offer customized products with competitive lead time and price created an environment which could be identified as multi-project environment. There were a lot of uncertainties and projects competed for the same resources which led to situation where control was insufficient. In history, the lack of control was tackled with working overtime which decreased the profitability. It was analyzed that the constantly changing situation required constant information flow between work phases. In large phases such as final assembly, there was a poor visibility to the progress of each work package which made the controlling more difficult. To improve the situation, a new planning and monitoring procedure was designed. Requirements were that the system should be simple, it shouldn't create too much administrative work and the data should be put to visual form to assist decision making. This way the work supervisors could have better control of daily operations.

During the research, it could be seen that the production control system should be developed more to answer better to the problems that emerged in the manufacturing. It was seen that the current control system didn't take the uncertainty and priority problems into account, the organization culture should get more attention and measurements should promote the success of the whole organization. This way individuals in the organization could understand what projects should be worked on to prevent them to be late. Also, this could improve morale of individuals and encourage organization for better team work. The organization culture management and measurement offer opportunities for new studies in the case company.

In summary, the study provided a general answer to the research question. During the research it was noticed that the focus should be turned more to managerial issues of the multi-project management system rather than focusing on observing hourly

costs of individual projects. This study provides a good platform to investigate more of the multi-project phenomena's that are present in the case company's production and gives some guidelines to improve company's profitability.

REFERENCES

Artto K., Martinsuo M., Kujala J., 2011. Project business. Helsinki, Finland, http://pbgroup.tkk.fi/en/ , (ISBN 978-952-92-8535-8)

Artto, K. A. & Wikström, K., 2005. What is Project Business? International Journal of Project Management Vol. 23, No. 5, pp. 343-353.

Atkinson, A., Kaplan R., Young, S., Matsumura, E., 2006. Management accounting, 5th edition. Englewood Cliffs (N.J.): Prentice-Hall International.

Bathallath S., Smedberg Å., Kjellin H., 2016. Managing project interdependencies in IT/IS project portfolios: a review of managerial issues, International Journal of Information Systems and Project Management, Vol. 4, No. 1, pp. 67-82.

Dahlgren, J. and Söderlund, J. 2010. Modes and mechanisms of control in Multi-Project Organisations: the R&D case, Int. J. Technology Management, Vol. 50, No. 1, pp.1–22.

Delbridge, R., Kirkpatrick, I., 1994. Theory and practice of participant observation, in V. Wass and P. Wells (eds), Principles and Practice in Business and Management Research. Aldershot: Dartmouth, pp. 35–62.

Dinsmore, P.C., & Cabanis-Brewin J., 2014. The AMA Handbook of Project Management, 4th edition. AMACOM, Saranac Lake.

Ford, H., Crowther S.,1922. My Life and Work. Garden City Publishing Company, Inc.

Lester, A. 2017. Project Management, Planning and Control - Managing Engineering, Construction and Manufacturing Projects to PMI, APM and BSI Standards, 7th edition. Elsevier.

Lock, D., 2007. Project management, 9th edition. Hampshire, England: Gower Publishing Limited.

Payne, J., 1995. Management of multiple simultaneous projects: a state-of-the-art review, International Journal of Project Management Vol. 13, No. 3, pp. 163-168.

Patanakul P., Aaronson ZH., 2012. Managing a group of multiple projects: do culture and leader's competencies matter? Journal of the Knowledge Economy Vol 3, pp. 217-232.

Patanakul P., Milosevic D., 2009. The effectiveness in managing a group of multiple projects: factors of influence and measurement criteria. International Journal of Project Management Vol 27, No. 3, pp. 216-233.

Patanakul, P., Milosevic, D., 2006. Assigning new product projects to multiple-project managers: what market leaders do. The Journal of High Technology Management Research Vol 17, No.1 pp. 53-69.

Project Management Institute, 2017. A guide to the project management body of knowledge (PMBOK guide), 6th edition. Pennsylvania, USA: Project Management Institute, Inc.

Saunders, M., Lewis, P. & Thornhill, A., 2007. Research Methods for Business Students 4th ed., Financial Times Prentice Hall, Harlow.

Schein, E. 1999. Process Consultation Revisited: Building the Helping Relationship. Reading, MA: Addison-Wesley.

Schwindt C., Zimmermann J., 2015. Handbook on Project Management and Scheduling Vol. 2. Switzerland: Springer International Publishing.

Simons, M., Hyötyläinen, R.,1995. Mukautuva tuotanto - Toimitusprosessin kehittäminen yksittäistuotannossa. Espoo, Finland: Valtion teknillinen tutkimuskeskus.

Tonchia, S., 2008. Industrial Project Management Planning, Design, and Construction, 1st edition. Berlin, Heidelberg: Springer Berlin Heidelberg.

Turner, J.R., 1993. The Handbook of Project-Based Management. McGraw-Hill, UK.

Vanhoucke, M., 2012. Project Management with Dynamic Scheduling, 1st edition. Berlin, Heidelberg: Springer Berlin Heidelberg.

Webb, A. 2003, Using Earned Value: A Project Manager's Guide, Routledge, Abingdon.

Yaghootkar, K., Gil, N., 2012. The effects of schedule-driven project management in multi-project environments. International Journal of Project Management, Vol. 30, No. 1, pp. 127-140.

APPENDIX A: AN EXAMPLE OF WORK BREAKDOWN STRUCTURE OF A STANDARD PROJECT

Phase	Abbreviation	% of total planned load)
Chassis modification	ALM	8 %
Boom welding and fabrication 1	VAH1	3 %
Boom welding and fabrication 2	VAH2	2 %
Boom welding and fabrication 3	VAH3	2 %
Hydraulic pipe fabrication, booms	HPV	0 %
Turntable control centre assembly	JOH	1 %
Turntable assembly	JAK	4 %
Working cage assembly	TYK	3 %
Cage boom assembly	KVK	4 %
Cage boom module assembly	KVM	3 %
Energy line assembly	ENK	1 %
Boom assembly	VAK	9 %
Audit Pori	AUDP	0 %
Mounting booms	VAS	2 %
Hydraulic pipe fabrication, mainframe	HPK	0 %
Mainframe hydraulics assembly	HYD	1 %
Outrigger control centre assembly	TJK	0 %
Outrigger assembly	TUK	2 %
Decking and locker fabrication	LAV	3 %
Outrigger case welding and fabrication	TKOT	3 %
Mainframe welding and fabrication	KOH	6 %
Mainframe assembly	KOK	9 %
Mounting mainframe	KRA	1 %
Final assembly	LOK	13 %
Pump locker fabrication	PUT_K	3 %
Waterline fabrication	PUT	7 %
Test drive	KOE	8 %
Audit Tampere	AUDR	0 %
Finishing and packing	FIK	2 %

APPENDIX B: GANTT VIEW OF A PROJECT